The value of insiders as mentors: Evidence from the effects of NSF rotators on early career scientists

Sebastian Hoenen†
Rotterdam School of Management, Erasmus University
hoenen@rsm.nl

Christos Kolympiris
Warwick Business School, University of Warwick
christos.kolympiris@wbs.ac.uk

We show that academics with experience in government jobs generate spillovers for their early career colleagues. Our template is the National Science Foundation rotation program in which the agency employs academics, called rotators, on loan from their university. Within two years after the rotator's return, fresh assistant professors in her department increase their research resources materially and are more likely to win small and medium size grants compared to academics in three control groups. Consistent with evidence that the mechanism is mentoring from the rotator, the results suggest that access to individuals with insights gained outside academia propels scientific careers.

Acknowledgements

The paper is dedicated to Silva and Pascal Hoenen who survive the first author, Sebastian Hoenen, who passed away far too young and he is deeply missed. NSF grant SMA-1548028 supported part of the research. We are thankful to the editor and three anonymous reviewers. We are grateful to Sandra Evans for processing the FOI request. Maryann Feldman and Jeffrey Mervis sparked our interest in developing the research stream on NSF rotators. Virgilio Failla, Christian Fons-Rosen, Patrick Gaule, Martin Goossen, Nicholas Kalaitzandonakes, Stijn Kelchtermans, Peter G. Klein, Keld Laursen, Cornelia Lawson, Alexandre Magnier, Solon Moreira, Nicos Nicolaou, Joshua Rosenbloom, Ammon Salter, Eunhee Sohn, Spiros Stefanou and Martin Watzinger provided valuable comments.

JEL codes: D83, H50, J62, I23

I. Introduction

Access to superior human capital generates improvements in productivity via knowledge spillovers (Schultz 1961, Zucker, Darby, and Brewer 1998). Indeed, in academia, one of the most knowledge intensive sectors, a major source of productivity is access to scientists with insights acquired through successful experience within it (Waldinger 2010, Azoulay, Graff Zivin, and Wang 2010, Brogaard, Engelberg, and Parsons 2014, Borjas and Doran 2015a, Colussi 2018). We report novel evidence that highlights an alternative route—positive spillovers also result from access to academics with insights gained because of their temporary experience in government jobs. An example of such academics is Steven Chu, Professor of Physics at the University of California, Berkeley, who served as the Secretary of Energy from 2009 until mid-2013 before returning to his academic home. Among other benefits, these employment spells infuse academics with insider knowledge on the allocation of resources by the government, the main funder of research endeavors. This knowledge can prove valuable when transmitted to colleagues seeking ways to boost their research capabilities and advance science.

To study the impact of temporary employment in government, we explore the link between research fund acquisition of early career scientists and exposure of these scientists to rotators—academics who are seconded to the National Science Foundation (NSF) for typically two years before they return to their respective academic institutions. During their tenure at the NSF, rotators, formally designated as Program Directors, organize and run the peer review process from the beginning until the end while often exercising decision-making power. They become insiders at the NSF as they gain insights on the process of funding decisions, possess tacit knowledge on the potential funding directions and priorities of the agency, and ultimately gain the ability to discern a promising proposal.

We ask three questions. One, do rotators influence the funding records of their early career colleagues (and if so, what is the mechanism)? Two, for how long does the effect last? Three, what type of change do rotators bring about: a “go big” (larger grants) approach or a “go-safe” approach (small and medium size grants)?

We find evidence that rotators act as mentors. They leverage their insider knowledge to communicate to their early career colleagues what to write in and how to write a proposal and where to send a proposal. As a result, rotators have a causal impact on the funding acquisition records of new hires landing their first faculty position in their department. We find that newly hired assistant professors in departments with a returning rotator raise approximately *$200,000* more, which is nearly *half* of the average first time grant acquired from the NSF, than similar academics in similar departments without a rotator (research question 1). The effect decays with time (research question 2) as we observe significant changes in resource acquisition within two years after the return of the rotator from the NSF and a decline afterwards. Rotators promote a “go-safe” approach (research question 3): the probability of winning small and medium size (but not large) grant is significantly higher for academics who interact with a rotator when compared to similar others.

Our work makes three main contributions. One, we add to the scarce literature on academic mentoring which has shown that institutionalized forms of mentorship such as postdoctoral fellowships matter (Heggeness et al. 2018, Blau et al. 2010, Jacob and Lefgren 2011). We demonstrate that informal, likely less resource demanding and more widely accessible, forms of mentoring exemplified by the relationship between rotators and early career scientists pay off too. Two, we contribute to the literature on research fund acquisition which has not zoomed in on early career scientists by switching the focus to them (Feinberg and Price 2004, Arora and Gambardella 2005, Li 2017). This is an important change because assessing how early career scientists can gain access to resources is a first order concern

(Alberts et al. 2014) and allows us to better understand the sources of individual long term productivity and scientific progress overall (Alberts et al. 2014, Rosenbloom et al. 2015, Oyer 2006, Petersen et al. 2011, Bol, de Vaan, and van de Rijt 2018, Lerchenmueller and Sorenson 2018). Three, our work pushes the emerging literature on the effects of experience outside academia using the rotation program as its template to new directions. Kolympiris, Hoenen, and Klein (2019) used a different dataset to set up a two period difference-in-differences estimation to establish that rotators can serve as effective knowledge conduits for same department peers who are similar, in terms of research topic and tenure, to the rotator. Here, we break new ground by bringing to light three novel insights.

One, by comparing our results with the findings of Kolympiris, Hoenen, and Klein (2019) we discover that spillovers from access to superior human capital gained because of experience *outside* academia are not uniform across colleagues. Rotators have an effect on junior scientists, those for whom getting grants is most important, which is considerably larger than their effect on senior scientists. This finding is relevant because it reveals that access to insights gained *inside* and *outside* academia share commonalities and have differences. The main similarity is that not everyone gains equally from access to high human capital. Aligned with (Waldinger 2016, 2010, 2012) who demonstrated that access to high human capital from experience *within* academia matters for junior scientists, has no effect for department peers and a moderate effect for attracting new hires we discover that rotators benefit their early career colleagues substantially more than they benefit their senior colleagues. The main difference is that only access to high human capital from insights *outside* academia translates to gain from same department colleagues: in contrast to Waldinger (2012) and Borjas and Doran (2012) who found no and negative effects for same department peers respectively, we document positive effects for same department peers.

Two, our novel focus on the long run or year to-to-year effects of knowledge transfer from rotators allows to unravel, for the first time, the sort of knowledge that is required in order to generate changes in resource acquisition. We find that recent insights gained via short tenure at continuously evolving funding organizations such as the NSF are more effective than general intuition about grant allocation. This finding has implications, among others, for the academic labor market as it advises candidates which job offer and *when* to accept.

Three, the focus on the types of grants that rotators push their junior colleagues to pursue offers a fresh understanding of what established knowledgeable academics recognize as the best way forward for scientists at their formative stages of their career. This finding has broad implications for the direction of science and what it means for mentoring to promote the "go safe" option.

For our identification strategy, we compare the funding records of new hires landing their first faculty post in departments with and without a rotator—the former belonging to our treatment group and the rest belonging to our control group(s). The major empirical challenge in this exercise is that superior human capital is not distributed randomly. Instead, endogenous sorting places individuals with high human capital next to each other (Kim, Morse, and Zingales 2009, Waldinger 2016). Within our framework, this would imply that the colleagues of rotators are more equipped than others in raising research funds. To circumvent this sorting issue, we exploit two features of the rotation program and carefully construct three control groups. The first feature is that the (timing of) entry into rotation is independent of the needs of the colleagues to raise funds. Academics become rotators because they want to learn more about the NSF, not because they recognize emerging colleagues who need advice. The second feature is that the return to the home institution is also exogenous to the needs of colleagues to raise funds. The rotation duties have a fixed end date. As a result, rotators do not return to their institutions because (or when) their colleagues need help. These two features of the program suggest that the allocation of early stage academics to the treatment and control group is largely exogenous to their choice of employer. However, three different sources of endogeneity may still allocate individuals to treatment and control groups non-randomly, which would constitute a threat to identification. We discuss these sources and focus on how we address them next.

First, initial job placement can be endogenous to job candidates' choice to accept an offer from a department with a rotator because of the rotator's presence in that department and the associated *ex-ante* expectation of mentoring how to raise research funds. Along the same lines, labor market conditions differ across years and can have a strong impact on which job candidate lands where. We tackle these issues by exploiting time variation: we construct our first dataset including new hires joining the same department at different points in time when labor market conditions vary, the focal colleague had or not left for the NSF and had or not the rotation experience.

Second, if the academic labor market works efficiently, then the best candidates will land in the best positions and the lesser candidates will land in lesser positions (Cole and Cole 1973). If this holds true, then success in raising funds may be explained by this matching process with rotators belonging to the better departments. Similarly, difficult to capture heterogeneity among PhD holders may also explain initial job placements. We tackle these issues by crafting a second dataset comprising PhD holders (some landing a job in a department with a rotator and others acquiring a job in a department without a rotator), who had the same PhD advisor, worked in the same science field, and graduated about in the same year (Kahn and MacGarvie 2016). Given that advisor standing and graduating institution are the prime determinants of initial job placements (Miller, Click, and Cardinal 2005, Terviö 2011), it is expected that, as shown in Tables 2 and 3 below, new hires from the same advisor land their first faculty post in departments whose main difference is the presence of a rotator as they are generally of comparable status, academic productivity and research fund acquisition records. Importantly, because the selection into advisors is not random (Waldinger 2010) and PhD training is largely standardized within doctoral programs (hence both the selection and treatment are nearly identical), these new hires are also similar to each other at the time of their first academic appointment in terms of age, gender, academic productivity and other similar qualities.

Third, university-wide policies, tenure-track incentives, grant-writing support, and other university-specific factors may boost incentives to become a rotator, shape the types of emerging scientists who decide to join a given university, and ultimately explain the increase in grant acquisition rates. This may lead to erroneous conclusions about the impact of rotators if they are disproportionally employed at institutions that for the aforementioned reasons are more successful in research funding acquisitions than in others. We tackle this issue by constructing our third dataset. This dataset holds university-wide factors constant and allows the comparison of funding records of new hires who joined the same university at approximately the same time but in different, yet comparable, departments having one main difference: some have a rotator as a faculty member and some do not.

Despite the careful construction of the datasets to match new hires in the treatment and control departments, remaining differences in training, ambitions, and career goals, among others, may still exist. We include several control variables in the analysis to account for such factors. Further, we perform a battery of exercises that reinforce the stability of our estimates and allow us to pinpoint with precision the mechanism driving the estimates.

II. The rotation program at the NSF and how rotators can induce changes in grant acquisition

The NSF has an annual budget that exceeds $7.5 billion and funds approximately 12,000 proposals out of 40,000 submissions annually in all non-medical scientific fields. These proposals support more than 360,000 scientists, teachers, and students employed at close to 2,000 institutions (NSF 2017). The agency is structured hierarchically; its seven directorates, corresponding to different scientific fields, are split into divisions that are further subdivided into programs. The program directors (PDs) are subject matter experts who run each program. They put together the review panels, communicate, *ex-ante* and *ex-post*, with submitters of funded and rejected proposals, review proposals even from programs and directorates outside their own, make grant allocation decisions, participate in panels outside their programs, and provide inputs to central strategic planning not only within their program but also across programs and directorates (Li and Marrongelle 2013). Overall, PDs are an integral part of the NSF and are key to shaping the direction of science.

Most PDs are permanent NSF employees. However, since the passage of the Intergovernmental Personnel Act in 1970, roughly 1 out of 3 PDs are academics who are posted at the NSF temporarily (Mervis 2016). These academics, called rotators, infuse the agency with new viewpoints as they move to the NSF headquarters. These rotators, on loan from their university, work full time for the NSF for up to 4 years (most commonly 2) and effectively stall their academic duties during their tenure at the NSF. From 2004 to 2014 alone, 800 rotators from around 400 academic institutions served at the NSF. Rotators are subject to strict restrictions during and even after their tenure at the NSF to avoid any conflicts of interest or favoritism (e.g., they cannot submit proposals or evaluate proposals of previous collaborators).

As revealed during a handful of discussions with former rotators, the main reason academics enter the program is a desire to acquire an in-depth understanding about the NSF and to generally contribute to the field of science.[1] These drivers explain why we do not identify specific trends among rotators; besides the fact that they were generally successful in winning grants from the agency in the past, they are employed at universities of varying size, status, and location. Additionally, they vary in terms of scholarly productivity, leadership activities, and methodological approaches in their research, among others. As mentioned above, the fact that the decision of rotators to join the rotation program is exogenous to the need of colleagues for help in raising funds alleviates concerns of endogeneity; these endogeneity concerns arise from the former's potential entry into the NSF as a deliberate response to the latter's need for mentoring to raise funds.

During their tenure at the NSF, rotators become insiders at the agency; they evaluate numerous proposals, observe others performing similar tasks, and gain hands-on knowledge of the largely unobserved factors that shape panel decision making (Bagues, Sylos-Labini, and Zinovyeva 2017); additionally, they become aware of the following: a) what the NSF prioritizes and b) the areas where the demand for promising proposals exceeds the supply. We expect these unique insights to enable rotators to recognize a competitive proposal. In turn, because knowledge sharing is stronger among individuals of the same group (department, in our application) (Hargreaves Heap and Zizzo 2009), this insider knowledge can spillover to rotators' colleagues and create an advantage for them in that they gain knowledge that their counterparts lack. In fact, evidence on the effects of rotators on later stage academics without NSF grants *ex-ante* supports this expectation (Kolympiris, Hoenen, and Klein 2019).

---

[1] The blog entry of Dan Cosley, of Cornell, illustrates why academics become rotators and the insights they gain (http://blogs.cornell.edu/danco/2016/09/09/why-im-rotating-at-nsf/)

Specifically, for early career scientists, having access to an insider can be instrumental as rotators can act as informal mentors. Evidence on formal forms of mentoring (e.g. post-doctoral fellowships) suggests that it pays off (Blau et al. 2010, Heggeness et al. 2018, Jacob and Lefgren 2011) and indeed fund raising comes up regularly in academic mentoring (Feldman et al. 2010). Specifically, rotators can mentor their early career colleagues on three main fronts in securing grants. First, rotators can direct colleagues to research areas the NSF prioritizes that are otherwise difficult to detect. In other words, they can provide suggestions on what the agency is keen to fund. Second, because grant writing is typically not the focus of doctoral training, rotators can fill the gap and assist their colleagues to present ideas effectively and, generally, craft proposals in ways that communicate the research insights in an appealing manner. The sheer number of proposals that the NSF receives makes communication and framing vital to allowing externals reviews and, subsequently, to panel members to appreciate the merits of a given proposal in a better manner. Third, rotators can address the main obstacle concerned with the initiation of the proposal—idea generation (Custer, Loepp, and Martin 2000). Since rotators possess tacit knowledge on research themes that are more likely to receive funding, they can guide their early career colleagues on research questions they can pursue. Indeed, as we explain in section VI, we find evidence that rotators influence the direction of research for their early stage colleagues.

III. Data Sources and Empirical Approach

A. The Treatment Group

To construct the datasets that trace, over time, the NSF grant acquisition record of new hires in departments with and without a rotator, we collect and merge new data from multiple sources. We accessed the list of 240 academics who ended their tenure as rotators at the NSF under the Intergovernmental Personnel Act (IPA) from between 2009 and 2011 via a

Freedom of Information (FOI) request directed to the NSF.[2] Following existing works relying on online data retrieval for academics (Terviö 2011, Amir and Knauff 2008, Kim, Morse, and Zingales 2009), we visited current and archived university websites from https://archive.org/ and combined this search with the career information retrieved from the Men and Women of Science database to identify faculty members who, as their first faculty position, were hired as assistant professors before, after, and during the year of the rotator's return to the department. We were able to build comprehensive and detailed career histories for 80 rotators. Subsequently, we examined the professional history of more than 3,200 seasoned and early stage academics belonging to these 80 departments with a rotator; of these 3,200 academics, we identified 210 academics with a comprehensive career history, who as their first faculty post joined 64 departments with a rotator between five years before and two years after the rotator returned from the NSF.[3] The 210 academics in the 64 departments with a rotator comprise the treatment group, and the indicators of a treatment effect by a rotator (discussed below) assume positive values as they all overlap with the rotator for at least one year after the rotator's return from the NSF.

We identify the following three cohorts within the 210 academics in the treatment group: a) 55 academics who joined when (or shortly after) the rotator returned from the NSF,

[2] We track grant acquisition 5 years before the departure of the rotator and 5 years after the rotator's return. As such, we focus on academics who returned from the NSF between 2009 and 2011 mainly because the start of the *ex-ante* period (2004) is recent enough to source comprehensive data from online sources and the end of the *ex-post* period (2016) allows us to observe the *ex-post* period in its entirety.

[3] The 64 sample rotators are similar to remaining rotators in terms of gender distribution, years of professional experience, success in fund raising and publication and citation records.

b) 68 academics who joined when the rotator was at the NSF, and c) 87 academics who joined within two to five years before the rotator had left for the NSF. The formulation of three cohorts helps us to surmount endogeneity and sample selection concerns. It helps us with endogeneity because from these cohorts we can eliminate nearly with absolute certainty the possibility that the new hires *chose* to join the department expecting to learn from a returning rotator for cohort (c): the academics who joined the department before the given scientist left for the NSF. With regards to sample selection, the rotation experience may correlate with an increased ability to select job candidates with higher chances of attracting research grants. If this was true, and if rotators participated in selection committees, then the treatment groups would have been populated with new hires who, *ex-ante*, were better equipped to win grants. However, the issue cannot hold for cohort (b)—academics who joined when the returning rotator was at the NSF—and it is less likely to hold for cohort (a)—academics who joined at the time of the rotator's return from the NSF. Essentially, these two cohorts allow us to address the potential for sample selection at hand.[4]

B. The First Control Group

The first control group allows us to hold department effects fixed and is composed of 25 academics belonging to 14 departments; these academics joined a department with a rotator, but their tenure at the department did not overlap with the tenure of the rotator. The absence of overlap may be either because these academics left the respective departments before the

[4] A threat to identification would be when rotation improves the selection criteria and allows rotators to give informal advice on the selection of candidates during their tenure at the NSF or during their short visits to their institutions. If this holds true, then the new hires around the time of rotation and rotator's return from the NSF would be different from other candidates. However, this is contrary to our observations.

rotator returned from the NSF or, in a few cases, because the rotator moved to a new university at the end of her tenure at the NSF.[5]

C. The Second Control Group

The second control group addresses individual heterogeneity. Using data from the ProQuest dissertations and theses database, we identified the PhD advisor of the new hires in departments with a rotator and the remaining PhD students whom she/he supervised as the main advisor and who graduated in the same year as that of, two years before, and two years after the focal new hire. We focus on same-advisor graduates because of the following reasons: a) initial job placement is largely explained by the advisor's network and standing in the profession and the graduating department (Terviö 2011), b) selection into advisors is not random (Waldinger 2010), and c) doctoral training is largely standardized among PhD candidates of the same cohort. It follows that because graduates of the same advisor are similar both in the selection (into an advisor) phase and in the PhD training/treatment phase, we expect this exercise to allow us to account for individual specific factors that can

[5] The small size of the first control group is consistent with the tenure track system in the US where (in) voluntary departures from a given department are uncommon before the end of the tenure clock. 15 of the 25 academics in the 1st control group did not overlap with the rotator because they left the department and 10 did not overlap with the rotator because once the rotator's tenure at the NSF was over she moved to a different university. If bad fit with the department prompted these 15 academics or the rotator to change institution, the control group could be less comparable to the treatment group and this could plague our estimates. We do not find evidence of such possibility: When we omit from the analysis, sequentially, academics who did not overlap with the rotator because they changed university or because the rotator changed university, we find qualitatively similar results to the baseline estimates.

influence grant acquisition. Specifically, starting with the 210 academics in the treatment group, we construct the professional history of nearly 600 PhD graduates who had the same PhD advisor and graduated within two years of the focal academic's graduation year. By eliminating academics who left academia, never landed an assistant professor position in the US, accepted an academic position outside the US, or did not have a professional history online (CV and LinkedIn, among others), we populate our second control group with 104 same-advisor academics who landed their first faculty position in 99 different US departments without a rotator.

D. The Third Control Group

The third control group accounts for university-specific initiatives that can promote entry into administrative roles outside the university, grant funding sessions and tenure track criteria that can explain differences in raising funds across different institutions. Retrieving data from university websites and the Men and Women of Science database, we populate the third control group with academics who started their first faculty position as assistant professors at the rotator's university, but in a different, yet comparable, department the same year, two years before, and two years after the rotator returned from the NSF. We find similar departments by employing the following criteria. First, the department must belong to the same larger division or school as the department with a rotator. For instance, when the department of the rotator is an Engineering department, we limit the search to other departments in the School of Engineering. Second, the control department must be in an intellectual space that is adjacent to the department with a rotator. Adhering to the previous criterion, when the treatment department is Industrial Engineering, we choose the department of Civil Engineering within the School of Engineering and not, for instance, the department of Chemical Engineering. Typically, the title of the department serves as a sufficient tool to identify similar departments. When not, we choose departments whose faculty members publish in the same journals as the faculty members of the rotator departments. Third, we select a comparable department that hired an assistant professor during the timeframe of our study. These selection criteria yielded 60 academics from 18 departments of the same university that had departments with rotators who were hired into their first position anytime between two years before and two years after the focal academic joined the focal department.[6]

Subsequent to the finalization of the list of names belonging to the treatment and the three control groups, we extracted data from the abovementioned sources, the bibliographic database SCOPUS, and the NSF grant retrieval website to build a full career history for the focal academics. Leveraging on the career history of the academics, we construct variables that describe the NSF acquisition records, tenure at the institution, research productivity, and annual academic position, among others. Online Appendix Table 1 provides an elaborate description of the sources of data and the associated variables.

E. Baseline Estimation Setup

We employ an ordinary least squares (OLS) estimator wherein the dependent variable is the inflation-adjusted amount of research funds raised from the NSF in a given year by a given new hire who belongs to either a treatment or a control group (to address our third research question we build logistic models we explain below). These amounts reflect new grant(s), with the focal academic being the principal investigator, and not continuations or extensions of existing grants.

[6] As already discussed, we pose different research questions and focus on different cohorts of scientists when compared to the only other paper on rotators (Kolympiris, Hoenen, and Klein 2019). This dictated separate research designs, different sets of methods and entirely new samples and data (e.g. no scientist is present in both datasets).

Each observation is a person-year starting from the year the focal academic joined the given department as her first faculty post in an assistant professor position and ending up to five years after the return of the rotator to the department. On average, we track the yearly grant acquisition rate for each academic in the treatment group for 8.7 years (up to five of which are after the return from rotation) and for each academic in the three control groups for 7.7 years. Therefore, in line with the importance of early career academics raising research funds early on, we follow them the years leading to the tenure clock running out. To test whether rotators induce changes in the NSF grant acquisition record of their early career colleagues, we include variables that take the value of 1 when the focal academic is in the department of the rotator in the same year that the rotator returned from the NSF (*Treatment 0*), in the first year since the rotator returned from the NSF (*Treatment 1*), and, in a similar fashion, until the fifth year since the rotator returned from the NSF (*Treatment 5*). The person-year set-up and the associated *Treatment 0 to 5* variables allow us to test the treatment effect of the rotators on their colleagues with precision (research question 1), and hence we can uncover the duration of the effect and its magnitude over time (research question 2).

We conduct the analysis on three different datasets. Each dataset includes the treatment group and the first, second, and third control group, respectively.

F. Control Variables

As demonstrated through Tables 1 to 3 below, by and large, academics in the treatment and control groups are similar to each other and they belong to similar departments. These similarities suggest that any differences in the grant acquisition records between academics in treatment and control groups *ex-post* can be attributed to the rotator. However, additional differences may exist. Accordingly, we include several control variables in the analysis to account for such differences.

Difficult to quantify or observe factors at the department level may induce changes in fund acquisition in the future. These can include visiting faculty transmitting knowledge on fund acquisition or shocks such as increased teaching load at time *t* that can limit the capacity to submit research proposals at time *t*+1,2, 3, among others. We control for such effects by adding the variables *Rotator Department -1* up to *Rotator Department-5* in the analysis. The variables take the value of 1 when the person-year observations refer to academics who joined a department from which a rotator originated from one to five years before the rotator's return from the NSF. To illustrate, if the person-year observations refer to academics who, for instance, joined the focal department two years before the return of the rotator, then the *Rotator Department 1* and *Rotator Department 2* would assume positive values, while *Rotator Departments 3, 4,* and *5* would assume the value of 0. To account for potential learning effects during post-graduate studies, we include the variable *PostDoc* that measures the number of years during which the focal new hire was employed in a post-doctoral position before assuming a faculty post. The variables *Assistant Professor* and *Associate Professor* denote experience and take the value of 1 for person-years during which the focal academic held an assistant professor and associate professor position, respectively, and 0 otherwise (the base category is Professor; this category is composed of 9 scientists who became professors within our time window). We include the dummy variable *Male* for male academics to account for gender differences in grant acquisition. The time-varying variable *H-index* (lagged by one year) measures the H-5 citation index of the academic in question and controls for the influence of an academic's existing track record on grant acquisition. The availability of research funds in previous years or from different sources may condition one's NSF funding record in a given year. As such, we include the variable *External Funding* in the analysis that measures the funding amounts from sources other than the NSF; we also include the variable *Previous NSF* that measures the sum of NSF funding raised by the focal academic during the 5 years preceding the focal person-year observation.

Further, we incorporate explanatory variables that reflect potential influences from the host institution. We include the following: a) the time-varying variable (*Ranking*) that measures the ranking quartile of the focal university to account for potential status effects afforded to academics in higher-ranked universities and b) the time-varying *Faculty NSF* variable that measures the sum of NSF funds raised by existing faculty members in the rotator's department before the rotator's return from the NSF; this variable accounts for potential learning on how to raise NSF funds from existing faculty members other than the rotator. Finally, we include the field of science and year-fixed effects to control a) for differences across the scientific fields in the propensity and need to raise funds from the NSF and b) for differences in funding cycles at the agency. In models reported in Online Appendix Table 2 we also include department and scientist fixed effects. The inclusion of these fixed effects consumes many degrees of freedom but the results are similar to the baseline estimates as presented in Table 5 below.

G. Descriptive Statistics

In this section, we provide evidence that our research design allows us to isolate the effect of the rotator; this isolation is possible because the academics who make up the treatment and control groups are similar before the return of the rotator and start their assistant professor positions in similar departments. We also provide a description of the rotators.

In Table 1, we present selected statistics for the academics in the treatment and the 3 control groups. At the start of their faculty position, between 2003 and 2015 (2012 for those in the treatment group), academics in the four groups were similar in many respects including experience, gender distribution, publication records, and, importantly, previous funding from the NSF. For instance, 71 percent of the scientists in the treatment group were male, had an

H-index of 2.34, and had raised, on average, $28,000 from the NSF as a principal investigator when they started their first faculty post. The weighted averages corresponding figures for the scientists in the 3 control groups were 70 percent, 2.60 and $18,000. Additionally, when the rotator was at the NSF, the funding records across scientists in the four groups were similar. Where we do observe a significant difference is on the total amount raised from the NSF in the 5 years following the return of the rotator (and the equivalent period for those in control groups). Academics in the treatment groups raise, on average, $831,000 while the weighted average of the total amount raised by academics in the 3 control groups is nearly half of that amount, $432,000.

But, what could explain the difference in funding records among academics in the treatment and control groups is heterogeneity in the universities and departments the sample scientists belong to. However, Tables 2 and 3 exhibit contrary findings. The departments with a rotator raised $1.2 million annually from the NSF during the period preceding the rotator's return from the NSF (Table 2). The departments without a rotator raised $1.4 million in the equivalent period. The status and research productivity indicators in Table 3 paint a similar picture—42 percent of the academics in the treatment group are employed at universities that are members of the prestigious Association of American Universities. The corresponding percentage for universities without a rotator is 40 percent. Along the same lines, 24 percent of the academics in the treatment group are employed at departments in the first quartile in the science field specific Shanghai ranking. The equivalent figure for academics in the control groups is 22 percent. Overall, we do not observe significant differences in terms of funding records and status/productivity indicators between the departments that are with and without a rotator.

Table 4 describes the rotators in the sample. They are typically mid-career academics who have been successful in raising funds from the NSF and have varied publications and citation records.

---*Tables 1 to 4 about here*---

IV. Main Results

Table 5 presents the baseline estimates. We cluster the standard errors at the department level. This choice is predicated on the finding that, as in our case, when the treatment is at the department level, but the unit of analysis is at the individual level, the estimation needs to employ a White/Huber heteroscedasticity correction for the standard errors (Bertrand, Duflo, and Mullainathan 2004). As we find in unreported results, the inference remains nearly identical when we cluster the errors at the scientist level to account for the fact that each scientist enters the analysis more than once.

In Model 1, we use the sample that includes the academics in the treatment group and the academics in the first control group. The coefficients of the *Treatment 1* and *Treatment 2* variables (also plotted in Figure 1) suggest that rotators induce positive and economically meaningful changes in the funding acquisition of their early career colleagues. The *Treatment 3* coefficient is also statistically significant. However, we interpret such evidence as suggestive because the significance does not hold across specifications, both for the baseline estimates and for selected robustness checks. Addressing our first research question, overlapping with the rotator one and two years after her return from the NSF leads to an increase in funding that exceeds $200,000. To put this in perspective, as shown in Table 1 above, academics in the treatment groups raise $831,000 during the 5 years following the return of the rotator, while in the corresponding period academics in the control groups raise $432,000. At the same time, the average first time grant from the NSF across directorates is $439,000. As such, given the *Treatment 1* and *Treatment 2* estimates, it appears that the rotator treatment effect increases the fund acquisition record of early career scientists by more than 50 percent and is responsible for close to half of an academic's first grant from the agency.

The estimates also imply that the treatment effect of rotators has an important magnitude relative to the overall NSF funding for research. Based on data from 2004 to 2017, the NSF allocates, on average, $4.5 billion every year for research grants. Forty-nine million of those (or more than 1 percent) can be attributed to the effect of rotators on their junior colleagues (using average figures: 80 (returning rotators in t-2) * $92,000 (Treatment 2 coefficient) * 80 (returning rotators in t-1) * $113,000 (Treatment 1 coefficient) * 3 (junior colleagues who interact with the rotator and raise NSF funds) = ~$49 million). The 1 percent estimate is noteworthy when considering a) that it originates only from a small number of academics when the NSF receives around 40,000 proposals yearly and b) it is likely a lower bound of the true effect of rotators as it is not accounting for the potential impact that rotators have on collaborators, senior colleagues, colleagues in different institutions rotators deliver seminars and the like.

Finally, the $200,000 figure allows us to compare the effect of rotators on early career scientists with their effects on their established colleagues with limited fund acquisition in the past as measured in Kolympiris, Hoenen, and Klein (2019) who find that within a 5 year window since interaction with a rotator, established colleagues raise $138,000 more than similar others. This gain is $62,000 *less* than what early career colleagues gain due to a rotator or nearly half of the full gains realized by established colleagues. Finally, the fact that we find that rotators impact their same department peers implies that access to high human capital gained from experience *within* academia differs from access to high human capital gained from experience *outside* academia: Waldinger (2012) and Borjas and Doran (2012) found no and negative effects for same department peers respectively.

Addressing our second research question, the gains from the rotator are stronger in the first two years of overlapping (when, roughly, the tenure track clock is about to run out) and do not extend beyond that time period. As we demonstrate in section VII, two main reasons underpin this finding. First, within the 5-year window, the increased workload following the award of a grant limits new grant application submissions in the subsequent years. Second, over a period, there is a decay in the value of the knowledge the rotator transmits to her colleagues as the agency evolves and changes priorities, among others.

In Model 2, we conduct the analysis using the academics on the treatment group and the academics in the second control group. Similar to the results in Model 1, the *Treatment 1* and *Treatment 2* estimates indicate that indeed overlap with a rotator is beneficial to research funding, even after accounting for individual-specific heterogeneity. The reduced magnitude of the *Treatment 1* and *Treatment 2* coefficients in Model 2 when compared to the Model 1 coefficients implies the significance of individual-specific factors for fund acquisition.

In Model 3, we employ the sample composed of the treatment group and the third control group. The results are qualitatively similar to the results in Model 1 and Model 2. The *Treatment 1* and *Treatment 2* estimates suggest that rotators induce an increase in the NSF funding records of their early career colleagues.

Concerning control variables, we find that academics with previous NSF funding in higher ranked universities, perhaps due to the availability of internal grant writing support or status effects, raise more funds from the NSF. We also document a suggestive positive relationship between non-NSF grants and NSF funding. Importantly, the *Rotator Department* minus 1 to 5 variables are not statistically significant indicating that the estimates are driven by the overlap with the rotator *after* her NSF experience.

---*Table 5 and Figure 1 about here*---

To address our third research question we build logit models using the same setup of person year observations, the same set of right hand side variables and the samples used for Table 5. The models measure the change in probability of securing NSF grants of different size after interacting with a rotator (the dependent variable takes the value of 1 if in a given year the focal scientist receives a grant of a given size, 0 otherwise). As shown in Table 6, the probability of winning a grant is significantly higher for academics in the treatment group when compared to academics in the first control group (similar estimates for the other two control groups). The magnitude of the effects allows us to infer the sort of change that rotators bring about (research question 3). An increase in the probability for academics to win grants in the treatment group is significant for small- to medium-sized grants (82 percent and 57 percent more likely for grants above $50,000 and $250,000, respectively); this probability diminishes for larger grants (18 percent for grants above $500,000) and becomes non-existent for grants above $1 million. This finding is consistent with the $200,000 difference in fund acquisition between academics in the treatment and control groups, as reported in the baseline estimates. Importantly, it suggests that rotators, experienced individuals with informed priors as to how academic careers unfold, promote a "go-safe" approach as the most promising way forward for their early career colleagues.

---*Table 6 about here*---

V. Robustness of the Results

To measure the potential rotator effect, we include in the analysis, as a subgroup of the 210 academics in the treatment group, 55 new hires who joined a department with a rotator after the rotator returned from the NSF. This modeling choice may plague the estimates if these 55 new hires choose to join the focal department because of the presence of the rotator among the faculty and the expected knowledge transfer from this rotator. To test whether such potential endogeneity biases our estimates in Test 1 in Table 7, we omit these new hires from the analysis (showing only the results with the first control group for ease of presentation).

The results are qualitatively similar to the baseline estimates suggesting that this source of potential endogeneity does not influence our analysis.

We reduce heterogeneity at the scientist level in the second control group based on the expectation that the same advisor and same graduation-year academics who joined departments without a rotator are similar to academics who joined departments with a rotator. In robustness checks 2 and 3 (Table 7), we reduce heterogeneity by identifying similar academics via alternative means. First, we relax the “same graduation-year” criterion and run the regression on a sample that includes the following: a) academics who joined departments with a rotator and b) academics who joined a department without a rotator, had the same advisor, and graduated 3 to 10 years before the focal academic. Second, we relax the “same advisor” criterion under the idea that several similar academics might not have the same advisor. Specifically, after we create a pool with all the academics who joined departments without a rotator, we identify similar academics from a different advisor, by using Coarsened Exact Matching,[7] and include these academics in the sample we analyze together with the treatment group academics. The results are qualitatively similar to the baseline estimates, and hence our conclusions remain intact.

---*Table 7 about here*---

Along the same lines, if unobserved factors in raising funds were not captured by our research design to compare new hires from the same university, advisor, and graduation

[7] We matched on PhD granting university ranking, H-Index at the time of joining the focal department, and having at least one first authored publication before the PhD graduation (following Kahn and MacGarvie (2016) our measure of innate ability). In a separate test, presented in the Online Appendix, we created a random sample of academics who did not match the academics in the treatment group *ex-ante* so to find that our conclusions are not tied to the way we construct the three control groups.

year—if, for instance, inherent ability of raising funds was not distributed normally among the population—then it would have been difficult to interpret our estimates as causal. Indeed, in test 4 presented in Online Appendix Table 3, we employ a difference-in-difference specification under which early career scientists from different universities, advisor, and graduation-year enter the analysis either in the treatment or the control group. Academics who joined a department with a returning rotator *before* her return from the NSF belong to the treatment group and those who joined departments without a rotator belong to the control group. The dependent variable is the average NSF funds raised by the focal individual during the three years before the return of the rotator (*ex-ante* period) or during the three years after the return of the rotator to the department (*ex-post* period). The allocation of scientists to treatment and control groups should be quasi-random as we do not expect most academics to select a department based on the presence of the rotator. Indeed, we include a variable that measures the number of years in the focal department to account for potential selection effects. The statistically significant positive interaction of the *ex-post* and *treatment group* variables is in line with the argument that we are unraveling causal effects.

VI. The Mechanism Driving the Results

In this section, we explore whether the findings we reveal are driven by mentoring from the rotator, or by other means. We present only the estimates using the first control group for brevity, whenever applicable, as we expect this control group to approximate the counterfactual as closely as possible.

In the first two tests, we scrutinize the mentoring/knowledge transfer mechanism. The first test starts with the premise that if the mechanism underpinning the results is mentoring advice from the rotator, including direction on how to frame a proposal and to which program to submit, then we would expect more helpful rotators to induce more pronounced changes in the funding acquisitions of their emerging colleagues. Similar to Laband and Tollison (2003) and Oettl (2012) and based on the intensity of the thank you notes in acknowledgements in PhD dissertations supervised by each rotator, we construct a helpfulness index using the sentiment analysis algorithm of Rinker (2013) and the weighted sentiment dictionary of Hu and Liu (2004). Higher values of the index correspond to more helpful rotators (we provide details in Online Appendix Table 1). Indeed, early career scientists in departments with rotators in the top 10th percentile of the helpfulness score raise, on average, $1,135,346 in the 5 years following the return of the rotator. The corresponding figure for early career scientists in remaining departments is $683,721.

The second test on knowledge transfer relies on the expectation that if rotators are indeed mentoring their early career colleagues, we would expect them to influence the topics these emerging scientists pursue. Specifically, prompted by work on cognitive mobility (Borjas and Doran 2015b), we form two groups of rotator colleagues each with different exposure to a returning rotator and check how similar the grants won by members of each group are to topics that the rotator's NSF directorate has funded during her tenure. The first group is composed of academics who we expect to be subject to the rotator's influence; those who won a first-time grant from the NSF within 3 years of the rotator's return. The second group is composed of academics who we expect to be less influenced by the rotator; those whose first - time grant from the NSF was awarded before the rotator's return to the department or those who won a first-time NSF grant after 3 years had elapsed from the rotator's return. If mentoring is the mechanism underpinning the results, the first group should be affected the most by the rotator. Indeed, we find preliminary evidence that this is the case.[8] Specifically, first we develop a text similarity algorithm (details in Online

[8] We interpret these findings as preliminary because we cannot rule out the case that the sets of abstracts we compare are the outcomes of a selection process. For instance, we analyze

Appendix Table 1) which yields a score ranging from 0 (no similarity) to 1 (high similarity) where scores above 0.30 indicate meaningful levels of similarity. Then, we compare the abstract of every grant awarded by the rotator's directorate when the rotator was at the NSF with the abstract of every first-time grant awarded to rotator colleagues belonging to the two groups above. 0.13 percent of first-time grants awarded to rotator colleagues in the first group had an average similarity score against the focal directorate's grants above 0.30; the equivalent figure for first-time grants awarded to junior scientists in the second group was 0.11. More importantly, while for 0.08 percent of the grants in the first group the similarity score was 0.40 and above, the corresponding percentage for the grants of the second group was half, 0.04. Consistent with mentoring driving the estimates, rotators appear to be pushing their colleagues towards areas with recent funding from the directorates they served.[9]

---

only junior scientists who interacted with a rotator. Then, within this cohort, by design, we focus only on those that won a grant. Largely based on such factors, which could introduce selection bias in the analysis, we opt to not draw statistical inferences by conducting the focal exercises using regressions.

[9] We also checked whether rotators push their junior colleagues a) towards areas they research themselves and b) away from their doctoral work. Regarding (a), we do not find such evidence as only a handful of grants and publications authored by rotators are meaningfully similar to the grants won by rotator colleagues (i.e. similarity score above 0.30). Regarding (b), when we compare dissertation abstracts to first-time grant abstracts we find that rotators steer their junior colleagues away from their doctoral work (i.e. the similarity score between dissertation and grant abstract is lower for those that interact with a rotator). But, even for junior colleagues who are not influenced by the rotator the similarity between dissertation and grants is, for the most part, below the threshold score of 0.30.

While the tests above indicate mentoring from the rotator as the mechanism, the estimates could also be driven by knowledge transfer from co-authors or co-investigators who had success in raising funds from the NSF. To test for such potential mechanisms, we conduct three tests that are presented in Online Appendix Table 4. In the first test in Online Appendix Table 4, we omit from the analysis scientists whose more recent and frequent co-authors experienced improvement in their *ex-post* NSF funding record. Specifically, we omit from the analysis academics whose at least 1 of the 3 most frequent co-authors gained more NSF funding in the previous three years than the sample average. In the second test, we omit from the analysis scientists whose co-investigator in the focal grant had recent success with the NSF. In other words, after a focal academic's co-investigator is awarded an NSF grant as a principal investigator, all subsequent person-year observations of this focal academic are omitted. In the third test, we limit the analysis to grants without co-investigators (69 percent of the grants had no co-investigators). The results from all three tests suggest that neither the co-authors nor the co-investigator account for the findings we reveal.

Besides knowledge transfer from the rotator, the results could also be driven by scientists in the treatment departments working on "hot topics" that typically attract more funds. To test for such possibility, we conducted the following exercise. First, we counted the number of articles in the SCOPUS bibliographic database that include, in their list of keywords, the 3 most occurring keywords for articles published in 2010 by all academics in the sample. Subsequently, we counted the number of articles in SCOPUS that 5 years later, in 2014, included the same keywords. The number of articles that include in their list of keywords the 284 unique keywords of the articles published by the 110 scientists in departments without a rotator who published in 2010 increased by 27.7 percent. The corresponding increase for the 470 unique keywords from articles of the 168 scientists in departments with a rotator who published in 2010 was 23.7 percent. We observe similar trends when we use articles published in 2008 and 2009 as our template. Therefore, academics in departments with and without a rotator appear to work on topics that increase in popularity in parallel.

Similarly, the fact that the NSF picks a given scientist to be a rotator may indicate that the scientist's research area is gaining traction and her department is more active in that area when compared to the other departments. The following factors lead us to discount this as a likely driver of the findings: a) as shown above, the control and treatment departments are similar to each other and their research topics grow in a similar fashion in popularity, b) the analysis includes fixed effects for science field, and c) rotators are not headhunted by the NSF very often; they are typically self-nominated and decide to apply for a rotator position mostly because they want to learn more about the NSF and contribute to the field of science.[10]

VII. Supplementary analysis

In this section, we further elucidate the driver of our findings by exploring whether the estimates are driven by an increase in the applications submitted by the rotator's colleagues upon her return, whether the applications submitted are of higher quality, or/and whether they are better targeted and hence are more likely to be successful. Because the NSF does not release rejected applications on an individual basis, we cannot address the question directly. However, empirical exercises described below suggest that, for the largest part, the estimates are not driven by an increased number of applications but an improvement in the quality of the submitted applications.

[10] The Online Appendix includes tests that dismiss favoritism towards rotator's colleagues as the mechanism and show, via a placebo test, that the effects we observe are tied to the actual timing of the return of the rotator, and not any other point in time.

First, in unreported results, we econometrically find that rotators do not have an effect on the number of awarded grants. If more applications correlated with an increase in awarded grants, then this finding would imply that the rotator effect stems from direction and feedback, among others, for better and more carefully targeted proposals. Second, as shown in Table 6 above, and discussed in section IV the probability of winning a grant is significantly higher for academics in the treatment group when compared to academics in the first control group. This is supportive of our expectation because better and more carefully targeted proposals (and not necessarily more) are more likely to be funded.

In the last set of supplementary analyses, we inform the mechanism that drives the results by shedding light on why we observe an effect in *Treatment 1* and *Treatment 2* but not in the later treatment years. We consider two main potential explanations. First, in line with the above discussion that an increase in the number of applications to the NSF does not drive the results, it is possible that once the focal academic raises a grant in, for instance, the treatment year 2, then the academic would devote time toward conducting the research of that grant instead of submitting additional grant applications. To test this proposition, we start with the premise that more grants correlate with more applications. Subsequently, in Online Appendix Table 7, we limit the analysis to the top 3 directorates in terms of the number of grants awarded from 2006 to 2016 (i.e., engineering, computer science, math and physics), and hence the need for a continuous flow of grants is larger. If the lack of applications following the award of a grant would drive the results, then among fields of this kind we would expect an effect in the later treatment years. However, this is contrary to our observation. Second, it is possible that the rotator's effect wanes over time in that the insights and knowledge gained by a rotator are not updated as the NSF progresses, likely changes focus, and priorities, among others. The figures in Table 8 do not dismiss such possibility. The longer the rotator stays away from the NSF, the lesser the gain of the new hires in their first year of overlap with the rotator. To illustrate, if the rotator returns at year *t*, hires who join the department at *t*-1 and at *t*, raise, on average, $123,855 and $130,252 at *t* and *t*+1, respectively. On the other hand, those who joined the department during *t*+1 raise $70,144 in *t*+2.

---Table 8 about here---

Overall, the tests devised to understand the reason behind the absence of an effect past *Treatment 2* imply that the following two forces are at play: a) increased workload after the award of a grant that limits the number of new applications and b) diminishing applicability of the insights that the rotator conveys as the NSF changes over time. Empirically, we cannot separate the two forces mainly because the NSF does not provide access to rejected applications and it is prohibitively difficult to measure with accuracy whether the relevance of the rotator's insights indeed diminishes over time.

VIII. Conclusions

We study knowledge spillovers from academics with a temporary experience in government jobs and reveal evidence consistent with a causal link between an increase in the NSF funding record of newly hired assistant professors and their exposure to academics in their department who return after their tenure at the NSF as PDs (rotators). We document an economically meaningful increase (approximately *$200,000* more, which is nearly *half* of the average of the first-time grant from the NSF) which arises from mentoring as rotators advise their colleagues on what to write in and how to write a proposal and where to send a proposal. Importantly, the gains from having access to a rotator diminish sharply with time which implies that *recent* insights (and not general knoweldge) gained via short tenure at continuously evolving funding organizations such as the NSF are required to induce gains in resource acquisition among early career academics. Rotator's colleagues are more likely to secure medium-sized (but not large) grants and this finding implies that informal mentoring encourages a “go-safe” and not a “go-big” approach at the formative stages of one’s career.

Overall, our research highlights that insiders, individuals with insights of an organization type that is different from the one in which they are permanently employed, can generate positive spillovers for their colleagues. These findings contribute to the literature analyzing the effects of access to high human capital in academia (Azoulay, Graff Zivin, and Wang 2010, Waldinger 2016, 2012, 2010, Borjas and Doran 2012, Borjas and Doran 2015a, Colussi 2018) by adding novel evidence on gains from high human capital with insights from experience outside academia. As well, the work speaks directly to the literatures on success in science (Kelchtermans and Veugelers 2013, Kahn and MacGarvie 2016), academic mentoring (Blau et al. 2010, Heggeness et al. 2018, Jacob and Lefgren 2011) and resource acquisition (Feinberg and Price 2004, Arora and Gambardella 2005, Li 2017). Broadly, the results are informative for the academic labor market too. Apparently, rotators with recent experience at the NSF are equipped to contribute positively toward the careers of their colleagues by inducing significant changes in early fund acquisition. Essentially, the presence of a rotator in a given department may be a decisive factor when selecting a job offer.

The work also breaks new ground in the emerging literature on the effects of experience outside academia using the rotation program as its template (Kolympiris, Hoenen, and Klein 2019). We bring to light three new findings: a) rotators benefit their early career colleagues considerably more than they benefit other colleagues, b) their effects decay with time and c) rotators have no effect on the acquisition of larger grants. Still, we have only started to scratch the surface before we understand what experience outside academia entails, the sorts of knowledge spillovers it can generate and the conditions that shape the magnitude of those spillovers. Rotators are main actors in the knowledge economy (Li and Marrongelle 2013), but have received considerably less attention in the literature when compared to inventors, entrepreneurs, patent examiners, and others (e.g. Lampe 2012, Lemley and Sampat 2012, Moser, Voena, and Waldinger 2014). As such, the research program on knowledge transfer from insights gained outside academia can be extended in a number of ways and we see at least two as immediate additions to the present work. One, what is the full extent of knowledge transmission from rotators? For instance, we do not know a) whether the recipients of the rotator's knowledge share this knowledge with others, likely outside their institution, b) whether the seminars rotators often give outside their university also generate gains in NSF funding and c) whether the collaborators of rotators also accumulate new knowledge or whether they are left behind. This is an important line of inquiry to investigate because it has implications for the organization of the distribution of research funding, among others. Two, besides mentoring their early career colleagues to win grants, do rotators have any influence in how these grants are best utilized? Addressing this question is relevant because it can inform the literature about the long-term effects rotators may have for academic careers and for scientific progress at large.

Our research is timely and has policy implications. Because scientific advancements are built on the progress of early career scientists, it is imperative to explore ways in which these early career scientists can gain access to relevant resources that can contribute toward scientific advancements. Indeed, the difficulties this cohort of academics faces in securing resources is a cause for concern (Poirazi 2017), and it may impede the scientific progress and harm the overall social welfare (Alberts et al. 2014, Nature_Editorial 2016). Policymakers have started to take initiatives mostly by altering the institutional environment to ensure that it improves the chances of early career scientists in raising research funds (Kaiser 2017). Here, we demonstrate that informal mentoring, tapping into existing knowledge held by colleagues' human capital, might also be a complementary and less resource-intensive strategy with immediate results that would address one of the main obstacles early career academics face—lack of experience and insights; this obstacle puts them at a disadvantage as they often compete for the same grants with high-status scientists who have established funding and publication records.

Along the same lines, this study speaks directly to the design of the rotation program. Under the premise that home universities gain from the rotation program, a recent policy mandates that they cover part of the rotation program bill (Mervis 2016). Here, while we do not fully measure the benefits and the costs of the program, we do find that home institutions realize gains from returning rotators.

Our analysis, albeit careful, has caveats that render it incomplete; hence, our study is subject to improvements. First, we follow previous contributions (e.g Kahn and MacGarvie 2016) to construct one of our control groups by matching on observable characteristics such as having the same PhD advisor. Success in raising funds may be driven by unobservable factors, which we cannot account for in this study. Our expectation, however, is that the unobserved factors correlate, at least to a certain extent, with the observable factors. The difference-in-difference analysis that we conducted as a robustness check supports this expectation. Second, we focus on early career scientists who land their first faculty position in the US. However, all the PhD holders do not follow such a career trajectory. Accordingly, our analysis is conditional on early career scientists having secured a faculty position in a US university. We do not see this as a major concern, *per se*, because our focus is not on who lands a US faculty post in the first place as we compare only similar emerging scientists who follow an academic career in similar institutional environments. Third, the analysis focuses on the US, and hence the results may not generalize directly to other countries as the rotation setting is unique to the NSF. This uniqueness of the rotation program at the NSF together with our estimates gives rise to the question whether other funding agencies in the US and elsewhere would benefit from a similar setting. This is because the diffusion of knowledge that we document is likely predicated on the design of the NSF that requires the inclusion of external academics in its grant review process not only as reviewers but also, and perhaps more importantly, in more central roles as decision makers.

References

Alberts, Bruce, Marc W Kirschner, Shirley Tilghman, and Harold Varmus. 2014. "Rescuing US biomedical research from its systemic flaws." *Proceedings of the National Academy of Sciences* 111 (16):5773-5777.

Amir, R., and M. Knauff. 2008. "Ranking economics departments worldwide on the basis of PHD placement." *Review of Economics and Statistics* 90 (1):185-190.

Arora, Ashish, and Alfonso Gambardella. 2005. "The impact of NSF support for basic research in economics." *Annales d'Economie et de Statistique*:91-117.

Azoulay, Pierre, Joshua S Graff Zivin, and Jialan Wang. 2010. "Superstar extinction." *The Quarterly Journal of Economics* 125 (2):549-589.

Bagues, Manuel, Mauro Sylos-Labini, and Natalia Zinovyeva. 2017. "Does the gender composition of scientific committees matter?" *American Economic Review* 107 (4):1207-1238.

Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan. 2004. "How much should we trust differences-in-differences estimates?" *The Quarterly Journal of Economics* 119 (1):249-275.

Blau, Francine D, Janet M Currie, Rachel TA Croson, and Donna K Ginther. 2010. "Can mentoring help female assistant professors? Interim results from a randomized trial." *American Economic Review: Papers & Proceedings* 100 (May):348 -352.

Bol, Thijs, Mathijs de Vaan, and Arnout van de Rijt. 2018. "The Matthew effect in science funding." *Proceedings of the National Academy of Sciences* 115 (19):4887-4890.

Borjas, G. J., and K. B. Doran. 2015a. "Which peers matter? The relative impacts of collaborators, colleagues, and competitors." *Review of Economics and Statistics* 97 (5):1104-1117.

Borjas, George J, and Kirk B Doran. 2012. "The collapse of the Soviet Union and the productivity of American mathematicians." *The Quarterly Journal of Economics* 127 (3):1143-1203.

Borjas, George J, and Kirk B Doran. 2015b. "Cognitive mobility: Labor market responses to supply shocks in the space of ideas." *Journal of Labor Economics* 33 (S1):S109-S145.

Brogaard, Jonathan, Joseph Engelberg, and Christopher A Parsons. 2014. "Networks and productivity: Causal evidence from editor rotations." *Journal of Financial Economics* 111 (1):251-270.

Cole, J.R, and S. Cole. 1973. *Social stratification in science*. Chicago: University of Chicago Press.

Colussi, Tommaso. 2018. "Social ties in academia: a friend is a treasure." *Review of Economics and Statistics* 100 (1):45-50.

Custer, Rodney L, Franzie Loepp, and G Eugene Martin. 2000. "NSF funded projects: Perspectives of project leaders." *Journal of Technology Education* 12 (1):61-74.

Feinberg, Robert M, and Gregory N Price. 2004. "The Funding of Economics Research: Does Social Capital Matter for Success at the National Science Foundation?" *Review of Economics and Statistics* 86 (1):245-252.

Feldman, Mitchell D, Patricia A Arean, Sally J Marshall, Mark Lovett, and Patricia O'Sullivan. 2010. "Does mentoring matter: results from a survey of faculty mentees at a large health sciences university." *Medical education online* 15.

Hargreaves Heap, Shaun, and Daniel John Zizzo. 2009. "The value of groups." *American Economic Review* 99 (1):295-323.

Heggeness, Misty L, Donna K Ginther, Maria I Larenas, and Frances D Carter-Johnson. 2018. The Impact of Postdoctoral Fellowships on a Future Independent Career in Federally Funded Biomedical Research. National Bureau of Economic Research.

Hu, Minqing, and Bing Liu. 2004. "Mining opinion features in customer reviews." AAAI.

Jacob, Brian A, and Lars Lefgren. 2011. "The impact of NIH postdoctoral training grants on scientific productivity." *Research Policy* 40 (6):864-874.

Kahn, S., and M. J. MacGarvie. 2016. "How important is U.S. location for research in science?" *Review of Economics and Statistics* 98 (2):397-414.

Kaiser, Jocelyn. 2017. "NIH to impose grant cap to free up funds for more investigators." *Science*.

Kelchtermans, S., and R. Veugelers. 2013. "Top research productivity and its persistence: Gender as a double-edged sword." *Review of Economics and Statistics* 95 (1):273-285.

Kim, E Han, Adair Morse, and Luigi Zingales. 2009. "Are elite universities losing their competitive edge?" *Journal of Financial Economics* 93 (3):353-381.

Kolympiris, Christos, Sebastian Hoenen, and Peter Klein. 2019. "Learning by seconding: Evidence from NSF rotators." *Organization Science* 30 (3):528-551.

Laband, D. N., and R. D. Tollison. 2003. "Good colleagues." *Journal of Economic Behavior and Organization* 52 (4):505-512.

Lampe, R. 2012. "Strategic citation." *Review of Economics and Statistics* 94 (1):320-333.

Lemley, M. A., and B. Sampat. 2012. "Examiner characteristics and patent office outcomes." *Review of Economics and Statistics* 94 (3):817-827.

Lerchenmueller, Marc J, and Olav Sorenson. 2018. "The gender gap in early career transitions in the life sciences." *Research Policy* 47 (6):1007-1017.

Li, Danielle. 2017. "Expertise versus Bias in Evaluation: Evidence from the NIH." *American Economic Journal: Applied Economics* 9 (2):60-92.

Li, Ping, and Karen Marrongelle. 2013. *Having Success with NSF: A Practical Guide*.

Mervis, Jeffrey. 2016. "To save money, NSF requires university cost-sharing for rotators." *Science*.

Miller, C. C., W. H. Click, and L. B. Cardinal. 2005. "The allocation of prestigious positions in organizational science: Accumulative advantage, sponsored mobility, and contest mobility." *Journal of Organizational Behavior* 26 (5):489-516.

Moser, P., A. Voena, and F. Waldinger. 2014. "German Jewish émigrés and US invention." *American Economic Review* 104 (10):3222-3255.

Nature_Editorial. 2016. "Early-career researchers need fewer burdens and more support." *Nature* 538 (7626):427.

NSF. 2017. FY 2017 Budget Request to Congress.

Oettl, Alexander. 2012. "Reconceptualizing stars: Scientist helpfulness and peer performance." *Management Science* 58 (6):1122-1140.

Oyer, P. 2006. "Initial labor market conditions and long-term outcomes for economists." *Journal of Economic Perspectives* 20 (3):143-160.

Petersen, Alexander M, Woo-Sung Jung, Jae-Suk Yang, and H Eugene Stanley. 2011. "Quantitative and empirical demonstration of the Matthew effect in a study of career longevity." *Proceedings of the National Academy of Sciences* 108 (1):18-23.

Poirazi, P. 2017. "The perfect grant and how to get it." *Nature* 543 (7644):151.

Rinker, T. W. 2013. "qdap: Quantitative Discourse Analysis Package." *University at Buffalo/SUNY*.

Rosenbloom, Joshua L, Donna K Ginther, Ted Juhl, and Joseph A Heppert. 2015. "The Effects of Research & Development Funding on Scientific Productivity: Academic Chemistry, 1990-2009." *PloS one* 10 (9):e0138176.

Schultz, Theodore W. 1961. "Investment in human capital." *American Economic Review* 51 (1):1-17.

Terviö, M. 2011. "Divisions within academia: Evidence from faculty hiring and placement." *Review of Economics and Statistics* 93 (3):1053-1062.

Waldinger, Fabian. 2010. "Quality matters: The expulsion of professors and the consequences for PhD student outcomes in Nazi Germany." *Journal of Political Economy* 118 (4):787-831.

Waldinger, Fabian. 2012. "Peer effects in science: Evidence from the dismissal of scientists in Nazi Germany." *The Review of Economic Studies* 79 (2):838-861.

Waldinger, Fabian. 2016. "Bombs, Brains, and Science: The Role of Human and Physical Capital for the Creation of Scientific Knowledge." *Review of Economics and Statistics* 98 (5):811-831.

Zucker, L. G., M. R. Darby, and M. B. Brewer. 1998. "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises." *American Economic Review* 88 (1):290-306.

Table 1. Selected statistics for the junior academics in the treatment and control groups.

	Treatment group	**1st control group**	**2nd control group**	**3rd control group**
	210 academics who joined a department **with a rotator** and overlapped with her.	25 academics who joined a department **with a rotator** but did not overlap with her.	104 academics who joined a department **without a rotator** and had the same advisor with those in the Treatment group	60 academics who joined a department **without a rotator** in the rotator's university in a similar department
Previous NSF funding at the start of the faculty post ($M)	0.028	0.045	0.003	0.034
	(0.115)	(0.201)	(0.019)	(0.181)
Yearly NSF funding from the start of the faculty post until the rotator's return from the NSF ($M)	0.099	0.108	0.068	0.042
	(0.315)	(0.238)	(0.261)	(0.134)
Total NSF funding in the 5 years *ex-post* rotator return ($M)	0.831	0.543	0.418	0.409
	(1.229)	(0.913)	(0.929)	(0.584)
Male	0.710	0.720	0.683	0.733
	(0.455)	(0.458)	(0.468)	(0.446)
Years as a Post-Doc	2.181	2.320	2.308	2.650
	(2.006)	(1.6)	(2.252)	(1.83)
H-index at the time of the first faculty post	2.345	3.898	1.821	3.429
	(3.204)	(4.26)	(2.643)	(3.43)
Yearly non-NSF funding until first faculty post ($M)	0.006	0.002	0.004	0.002
	(0.054)	(0.01)	(0.028)	(0.013)
Years between PhD graduation and first faculty post	3.676	2.400	3.827	4.017
	(2.045)	(2.021)	(2.545)	(2.221)
First author publication before PhD graduation	0.719	0.000	0.654	0.783
	(0.451)	(0.000)	(0.478)	(0.415)

Figures reflect average values with standard deviations in parentheses

Table 2. Departments with and without a rotator raise similar amounts from the NSF.

	Average yearly department NSF funding the five years preceding the rotator's return from the NSF.	
	Total	Per faculty member
Treatment department	$ 1,220,694	$ 33,871
Control department	$ 1,438,457	$ 39,974

Table 3. Departments with and without a rotator are of similar status and productivity.

		Treatment department	Control department
Member of the Association of American Universities		42%	40%
Department Shanghai ranking the year the rotator' return	*First quartile*	24%	22%
	Second quartile	17%	14%

Table 4. Descriptive statistics of the 64 sample rotators

	Mean	**Std. Dev.**
Years in rotation	1.625	0.951
Male	0.734	0.445
Career age at start of rotation	20.536	7.947
Publications (5 years *ex-ante*)	16.300	18.887
Citations per paper (5 years *ex-ante*)	67.556	133.203
NSF funding (5 years *ex-ante*)	$527,426	$1,664,688

Table 5. OLS Baseline Estimates. Dependent Variable is yearly NSF funding in million.

	MODEL 1 Treatment Group & 1st Control Group	MODEL 2 Treatment Group & 2nd Control Group	MODEL 3 Treatment Group & 3rd Control Group
RotatorDepartment t-5	-0.014	-0.010	-0.003
	(0.015)	(0.010)	(0.012)
RotatorDepartment t-4	0.059	0.079	0.099
	(0.040)	(0.045)	(0.055)
RotatorDepartment t-3	-0.010	0.002	0.019
	(0.018)	(0.018)	(0.017)
RotatorDepartment t-2	0.007	0.005	0.029
	(0.027)	(0.028)	(0.027)
RotatorDepartment t-1	0.007	-0.003	0.010
	(0.023)	(0.020)	(0.021)
Treatment 0	0.034	0.037	0.040
	(0.021)	(0.019)	(0.022)
Treatment 1	**0.092*** **	**0.058** **	**0.070** **
	(0.032)	**(0.026)**	**(0.027)**
Treatment 2	**0.113*** **	**0.061** **	**0.088*** **
	(0.036)	**(0.026)**	**(0.024)**
Treatment 3	0.072**	0.034	0.042**
	(0.035)	(0.018)	(0.019)
Treatment 4	0.030	0.007	0.005
	(0.037)	(0.020)	(0.024)
Treatment 5	-0.000	-0.001	-0.004
	(0.033)	(0.025)	(0.026)
PostDoc	-0.003	-0.003	-0.003
	(0.002)	(0.002)	(0.002)
Assistant Professor	0.017	0.025**	0.011
	(0.016)	(0.012)	(0.013)
Associate Professor	0.009	0.008	-0.007
	(0.015)	(0.012)	(0.013)
Male	-0.001	0.013	0.010
	(0.011)	(0.009)	(0.009)
H-index	-0.000	0.001	0.000
	(0.001)	(0.001)	(0.001)
External Funding ($M)	0.355	0.381**	0.341
	(0.186)	(0.181)	(0.187)
Previous NSF ($M)	0.113***	0.098***	0.122***
	(0.017)	(0.015)	(0.017)
Ranking	-0.007**	-0.007**	-0.007**
	(0.003)	(0.003)	(0.003)
Faculty NSF ($M)	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	0.039	0.035	-0.004

	(0.022)	(0.023)	(0.019)
Science field FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	2,152	2,642	2,319
R^2	0.170	0.156	0.179
Adjusted R^2	0.155	0.144	0.166
Number of Departments	65	158	80

Robust standard errors in parentheses clustered at the department level
*** p<0.01, ** p<0.05

Table 6. Change in probability of securing an NSF grant after the rotator returns.

	Grant larger than $50,000		Grant larger than $250,000		Grant larger than $500,000		Grant larger than $1,000,000
Treatment 0	0.160	**	0.152	**	0.036		-0.008
Treatment 1	**0.209**	*******	**0.193**	*******	**0.091**	******	**0.017**
Treatment 2	**0.231**	******	**0.222**	*******	**0.091**	******	**0.010**
Treatment 3	0.222	**	0.143		0.002		-0.005
Treatment4	0.095		0.034		0.013		-0.003
Treatment 5	0.062		0.038		0.002		-0.004

The change in probability is calculated after holding all other variables at their means
*** p<0.01, ** p<0.05

Table 7. Omit from the treatment group new hires who join the rotator department after the rotator has returned + Relax same advisor and graduation year criteria

	Test 1 Omit hires who joined the department after the rotator returned	*Test 2* Add academics with the same advisor who graduated 3 to 10 years before the focal academic who joined a department with a rotator	*Test 3* Use Coarsened Exact Matching to populate the control group
RotatorDepartment t-5	-0.010	0.008	-0.009
	(0.015)	(0.012)	(0.069)
RotatorDepartment t-4	0.067	0.081**	0.046
	(0.041)	(0.038)	(0.054)
RotatorDepartment t-3	-0.000	-0.005	0.023
	(0.020)	(0.019)	(0.047)
RotatorDepartment t-2	0.007	0.003	0.036
	(0.029)	(0.023)	(0.036)
RotatorDepartment t-1	0.007	-0.022	0.003
	(0.025)	(0.022)	(0.027)
Treatment 0	0.032	0.025	0.054**
	(0.024)	(0.018)	(0.023)
Treatment 1	**0.098*** **	**0.055** **	**0.064*** **
	(0.037)	**(0.026)**	**(0.021)**
Treatment 2	**0.119** **	**0.072*** **	**0.060*** **
	(0.045)	**(0.024)**	**(0.020)**
Treatment 3	0.084	0.039**	0.026
	(0.042)	(0.017)	(0.020)
Treatment 4	0.033	0.006	0.003
	(0.042)	(0.020)	(0.019)
Treatment 5	-0.010	0.004	0.001
	(0.046)	(0.024)	(0.019)
PostDoc	-0.003	-0.003	-0.004
	(0.003)	(0.002)	(0.003)
Assistant Professor	0.010	0.030***	0.013
	(0.017)	(0.010)	(0.019)
Associate Professor	0.006	0.016	-0.008
	(0.015)	(0.011)	(0.021)
Male	0.002	0.012	0.004
	(0.014)	(0.008)	(0.010)
H-index	-0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)
External Funding ($M)	0.395**	0.338	-0.038
	(0.176)	(0.186)	(0.055)
Previous NSF ($M)	0.111***	0.096***	0.104***
	(0.018)	(0.013)	(0.009)
Ranking	-0.006	-0.006**	-0.005

	(0.003)	(0.002)	(0.003)
Faculty NSF ($M)	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	0.049	-0.032	-0.022
	(0.030)	(0.022)	(0.045)
Science field FE	YES	YES	YES
Year FE	YES	YES	YES
Observations	1,800	3,181	2,654
R^2	0.197	0.138	0.094
Adjusted R^2	0.179	0.127	0.0813
Number of Departments	180	193	66

Robust standard errors in parentheses clustered at the department level
*** p<0.01, ** p<0.05

Table 8. The longer the rotator has been away from the NSF, the less new hires in their first year of overlap with the rotator gain.

	Average NSF funding acquired during first three years of overlap with rotator after return from NSF				
Variable	**Tr0**	**Tr1**	**Tr2**	**Tr3**	**Tr4**
Joined 1 year before the rotator returned	$123,855	$239,955	$198,553		
Joined the same year the rotator returned	$10,654	$130,252	$130,834		
Joined 1 year after the rotator returned		$26,840	$70,144	$61,849	
Joined 2 years after the rotator returned			$76,057	$24,383	$78,931

Figure 1: Dynamics of the rotator effect