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STI 2018 Conference Proceedings

Proceedings of the 23rd International Conference on Science and Technology Indicators

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ISBN: 978-90-9031204-0

23rd International Conference on Science and Technology Indicators (STI 2018)
"Science, Technology and Innovation indicators in transition"
12 - 14 September 2018 | Leiden, The Netherlands
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Using Grant Competition Finalists to Estimate the Effect of Large Research Grants on Early Career Scientists: Evidence from Singapore

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Introduction

What is the impact of early-career scientific research funding programs? Early-career researchers often face challenges securing sufficient funding to advance their research agenda. As a result, young researchers may spend significant time pursuing research grants, instead of advancing the research frontier. The natural question then is whether being awarded a large sum of research funding early in one's career results in a significant improvement in research outcomes and scientific impact.

The challenge in identifying whether research funding causes scientific impact is that only the best projects get funded. Comparing awarded scientists to non-awarded applicants confounds the effect of funding with that of underlying research ability (Jaffe 2002). We address this by using evidence from Singapore's National Research Foundation (NRF) Fellowship Program. The NRF Fellowship (NRFF), launched in 2007, awards competitive grants worth up to S$3 million (about €1.9 million or US$2.2 million[1]) over 5 years. It is open to international applicants without restrictions on nationality. As of the NRFF Class of 2018, the NRFF has attracted over a thousand applicants and awarded eighty-eight fellowships.

The NRFF application process allows us to restrict the analysis to a comparable set of young researchers of high quality, instead of simply comparing awarded scientists to all other (presumably lower-quality) applicants. During each grant call, over a hundred early-career scientists worldwide apply. Less than 20% are shortlisted and invited to Singapore for the final selection process. All finalists are interviewed, and the interview panel typically awards about half of the finalists the Fellowship. We show that awarded and non-awarded finalists are of comparable high quality on objective scientific criteria. This will allow us to estimate

[1] Based on the exchange rate of SG$1.5944/€ and SG$1.3619/US$ listed by the Monetary Authority of Singapore on 31st July 2018.

the causal impact of winning a large grant at the early career stage using the difference in research productivity and outcomes between awardees and non-awarded finalists, four years into the grant.

Literature Review

Early career scientists face significant challenges obtaining funding and securing permanent academic positions, due to the difficulty of competing for grants against senior scientists, and the scarcity of tenure-track positions (Austin and Rice, 1998; Laudel and Gläser, 2008; Friesenhahn and Beaudry, 2014). Winning even a single early-career grant can significantly improve a young scientist's prospects of career advancement and eventual tenure (Powell, 2015). While early-career success is known to beget later success – the "Matthew Effect" (Merton, 1968) – less is known about the quantitative impact that winning early-career funding plays in boosting productivity.

There are relatively few rigorous evaluations of the causal impact of research funding programs that control for bias from the selection of better research projects (Jaffe 2002; Li and Agha 2015). Gush et al. (2018) find that winning a New Zealand Marsden Fund grant leads to more publications and citations. However, the Marsden Fund is a general research fund, unlike the NRFF which is aimed at high-caliber early-career scientists. Bol et al. (2018) find that winning a Netherlands Organization of Scientific Research early-career grant leads to more future funding and brighter career prospects. Bol et al. (2018) argue these effects are due to non-awardees dropping out from future grant competitions, rather than improved scientific productivity among early-career grant winners. Our study complements this literature by examining whether winning a high-value early-career grant results in productivity differences even among an elite group of shortlisted scientists.

The NRF Fellowship Program

The NRF Research Fellowship Scheme was started in 2007 to build up Singapore's stock of talented young researchers in science and technology. Fellowship grant calls occur annually (with a hiatus in 2013), are publicized worldwide, and are open to applicants from any nationality. The applicant must accept a full-time position in a Singapore-based research institution, if awarded. Applicants undergo a two-stage selection process. In the first stage, a "Local Evaluation Panel" (LEP) performs the initial cut, and a "Fellowship Evaluation Panel" (FEP) then determines the shortlist of finalists. The LEPs consist of scientists from the major Singapore research universities, while the FEPs consist of internationally renowned scientists. The final stage consists of a site visit to Singapore research institutions and an interview with the FEP. The FEP eschews quantitative criteria for choosing amongst the finalists, instead seeking candidates with a vision for achieving high-impact, independent research.

Data

Our data contains the individual characteristics and bibliometric records of 113 NRFF finalists[2] for the grant years 2007 to 2012 (inclusive), split between 67 awardees and 46 non-awardees[3]. Individual characteristics include the PhD year of award, PhD awarding

[2] There are 118 finalists from 2007 to 2012. We exclude 2 finalists whose Scopus records exhibit inconsistencies we could not resolve using other data. We also exclude 3 finalists because they withdrew from consideration after being shortlisted but before award announcement, and we have no data on the reasons for withdrawal.

[3] "Awarded" refers to all finalists who were made an offer of award, not finalists who eventually accepted the Fellowship. To determine whether applicant characteristics affect the probability of award, all awarded finalists

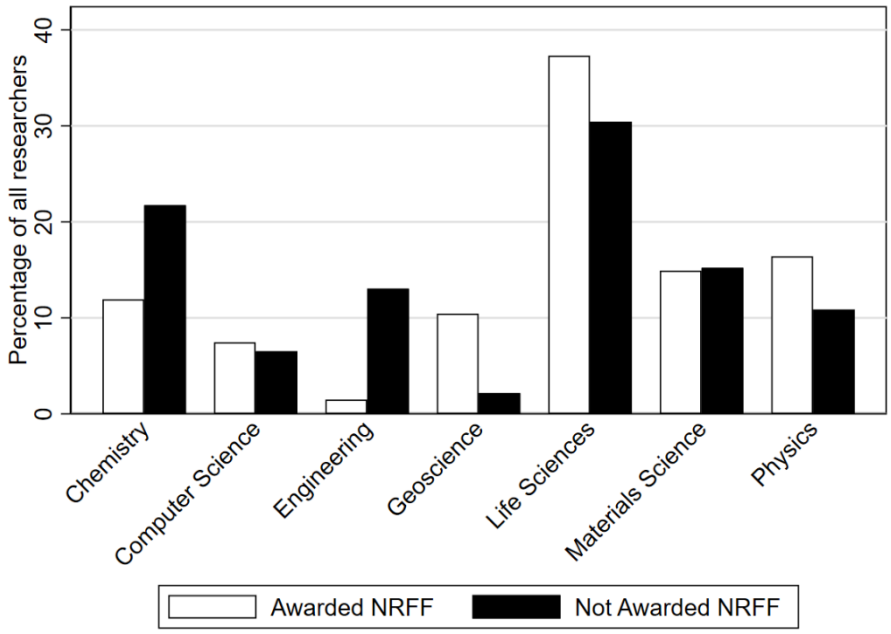
institution, PhD supervisor(s) and institutional affiliation at the time of application. From bibliometric records, we construct an annual panel dataset of cumulative publications, cumulative citations, H-index, and average citations per publication. Bibliometric records are retrieved from Scopus, while individual characteristics are obtained from personal websites, university profiles and curriculum vitae published online.

Because measurable research output and citation practices vary widely between scientific disciplines, we standardize the bibliometric measures when analyzing whether the finalist's scientific background affects the probability of award. The baseline standardization assumes the NRFF evaluation panel benchmarks finalists within the same discipline against each other, and standards have not changed over time. A standard value of 0 indicates the finalist's scientific record is exactly the mean for that discipline, across all grant call years. The alternate standardization assumes the NRFF evaluation panel instead benchmarks finalists against all others for that grant call year. In this alternate case, a standard value of 0 indicates the finalist's record is exactly the mean across all finalists, for that grant call year.

Results

Summary Statistics

Figure 1: Distribution of disciplines among NRFF finalists by award status



As Figure 1 illustrates, the NRF Fellowship is focused on science and technology disciplines, with the largest group of finalists and awardees coming from the Life Sciences. While finalists in Geoscience, Life Sciences and Physics are over-represented in the award group, finalists in Chemistry and Engineering are under-represented. These differences in discipline representation highlight the importance of controlling for differences between scientific disciplines when estimating whether a finalist's scientific record affects award of the NRFF.

(rather than actual Fellows) should be compared to all non-awarded finalists. From the 2007 to 2012 grant call years, seven awarded finalists declined the Fellowship.

Table 1: Characteristics of NRFF finalists in the year of application

Variable	Awarded (N=67) Mean	Awarded (N=67) Min – Max	Non-Awarded (N=46) Mean	Non-Awarded (N=46) Min – Max	Difference (Awarded – Non-Awarded)
Average Citations	22.06 (1.99)	3.14 – 66.00	18.47 (2.59)	2.59 – 89.83	3.59 (3.26)
Cumulative Citations	525.88 (63.02)	42 – 2305	479.93 (67.89)	57 – 2605	45.95 (92.63)
Cumulative Publications	26.73 (3.04)	6 – 170	29.26 (2.88)	6 – 90	-2.53 (4.19)
H-Index	9.85 (0.57)	4 – 25	10.02 (0.68)	4 – 22	-0.17 (0.89)
Proportion of Males	0.75 (0.05)		0.89 (0.05)		-0.15** (0.07)
Years since PhD Graduation	4.16 (0.26)	0 – 10	3.24 (0.20)	1 – 7	0.93*** (0.32)
Rank, PhD Institution: Top 20	0.42 (0.06)		0.28 (0.07)		0.14 (0.09)
Rank, PhD Institution: 21-50	0.07 (0.03)		0.13 (0.05)		-0.06 (0.06)
Rank, PhD Institution: 51-100	0.18 (0.05)		0.22 (0.06)		-0.04 (0.08)
Rank, PhD Institution: 101+	0.33 (0.06)		0.37 (0.07)		-0.04 (0.09)
Rank, Current Institution: Top 20	0.43 (0.06)		0.35 (0.07)		0.09 (0.09)
Rank, Current Institution: 21-50	0.12 (0.04)		0.13 (0.05)		-0.01 (0.06)
Rank, Current Institution: 51-100	0.06 (0.03)		0.20 (0.06)		-0.14** (0.07)
Rank, Current Institution: 101+	0.39 (0.06)		0.33 (0.07)		0.06 (0.09)

Standard Errors in parentheses; * p < 0.10; ** p < 0.05; *** p < 0.01

Table 1 shows that at the time of application, awardees have comparable scientific records to non-awarded finalists. Although awardees have more citations, they have fewer publications and slightly smaller H-Index values than non-awarded finalists; none of the difference-in-means tests for scientific records are significant. However, some individual characteristics matter: Fewer awardees are men, and awardees have almost one more year of post-PhD

experience on average. Awardees were less likely to be in an institution ranked between 51-200 at the time of application.[4]

Determinants of the Probability of Award

Table 2 reports probit regression estimates of whether the finalist's scientific record at the time of application significantly affects the probability of being awarded the NRF Fellowship. These regressions also control for individual characteristics: gender, discipline, PhD awarding institution, current institution of employment, and years since PhD completion. To control for differences across disciplines in scientific output, bibliometric measures of the finalist's scientific record are standardized following the procedure outlined earlier. Columns (1) to (3) use measures standardized within discipline, across all grant call years, while (4) to (6) use measures standardized within each grant call year, across all disciplines.

Across all regressions, there is no significant effect of the finalist's scientific record on the probability of award. The point estimates are negative, suggesting that finalists with above-average scientific records at the point of application are weakly less likely to be awarded. Of the individual characteristics, no discipline indicators are consistently significant across models even at the 10% level, although there is some differential selection for engineering, and to a lesser extent geoscience. The coefficients on academic institution rank – where top 20 institutions are the baseline – are generally insignificant for all rank groups, although finalists currently at institutions ranked 51 to 100 are less likely to be awarded. Where demographics are concerned, males are weakly less likely to be awarded, while experience in years since the PhD increases the likelihood of award. Regression models (unreported) that include all three standardized bibliometric measures at the same time provide similar results.

The results support our argument that the NRF Fellowship finalist pool is of high and comparable quality between awardees and non-awarded finalists. The final evaluation stage does not appear to discriminate on the basis of finalists' scientific research records, but does favor post-PhD experience and academic prestige to some extent. This raises concerns if either characteristic is strongly associated with future scientific productivity. However, the effect of post-PhD experience can potentially be addressed (in future work) by flexibly controlling for the researcher's scientific output trajectory, that is, their discipline-specific research growth trend. As for academic prestige, the concern is the "Matthew effect" (Merton, 1968) where scientists in more notable institutions attract more resources and are hence more productive. However, the "Matthew Effect", if any, should be muted in our study because the current institution at the point of application is typically the finalist's post-doctoral institution, and the researchers in our study generally leave their post-doctoral institution soon after the year of application for an independent research appointment elsewhere. The vast majority of NRF awardees were located in post-doctoral institutions outside Singapore and had to move to Singapore to accept the Fellowship.

[4] Institution ranks are from the field- and year-specific lists of the Academic Ranking of World Universities (Shanghai Ranking).

Table 2: Probit regression results for the probability of NRF award

	Standardization within Discipline			Standardization within Year of Application		
Pr(Award = 1)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Std. Cumulative Citations	-0.074			-0.027		
	(0.165)			(0.138)		
Std. Cumulative Publications		-0.166			-0.120	
		(0.169)			(0.169)	
Std. H-Index			-0.184			-0.155
			(0.156)			(0.146)
Chemistry	-0.188	-0.171	-0.160	-0.194	-0.113	-0.116
	(0.438)	(0.441)	(0.440)	(0.441)	(0.461)	(0.452)
Computer Science	0.478	0.458	0.457	0.477	0.584	0.455
	(0.575)	(0.590)	(0.589)	(0.580)	(0.602)	(0.582)
Engineering	-1.103*	-1.087	-1.096*	-1.100*	-0.864	-1.049
	(0.631)	(0.656)	(0.657)	(0.628)	(0.672)	(0.657)
Geoscience	0.848	0.828	0.879	0.805	0.786	0.752
	(0.640)	(0.653)	(0.633)	(0.643)	(0.645)	(0.646)
Materials Science	0.206	0.236	0.233	0.201	0.381	0.303
	(0.408)	(0.415)	(0.407)	(0.411)	(0.479)	(0.412)
Physics	0.279	0.247	0.241	0.286	0.397	0.315
	(0.424)	(0.424)	(0.427)	(0.421)	(0.450)	(0.424)
PhD Institution Rank 21-50	-0.482	-0.543	-0.493	-0.491	-0.545	-0.481
	(0.499)	(0.500)	(0.504)	(0.495)	(0.497)	(0.502)
PhD Institution Rank 51-100	-0.192	-0.220	-0.154	-0.212	-0.244	-0.190
	(0.373)	(0.370)	(0.373)	(0.370)	(0.368)	(0.368)
PhD Institution Rank 101+	-0.306	-0.349	-0.306	-0.308	-0.336	-0.305
	(0.324)	(0.323)	(0.326)	(0.324)	(0.324)	(0.326)
Current Institution Rank 21-50	-0.110	-0.103	-0.132	-0.106	-0.080	-0.105
	(0.451)	(0.459)	(0.461)	(0.453)	(0.458)	(0.458)
Current Institution Rank 51-100	-0.876**	-0.911**	-0.898**	-0.867*	-0.891**	-0.896**
	(0.442)	(0.451)	(0.443)	(0.441)	(0.447)	(0.440)
Current Institution Rank 101+	-0.452	-0.445	-0.433	-0.460	-0.446	-0.412
	(0.324)	(0.329)	(0.327)	(0.331)	(0.330)	(0.332)
Male	-0.605*	-0.568	-0.584	-0.609*	-0.616*	-0.585
	(0.356)	(0.363)	(0.353)	(0.360)	(0.358)	(0.357)
Years since PhD Graduation	0.213**	0.240***	0.239***	0.209**	0.227***	0.234***
	(0.082)	(0.086)	(0.084)	(0.081)	(0.084)	(0.084)
Obs	113	113	113	113	113	113
Pseudo-R^2	0.163	0.169	0.169	0.162	0.166	0.168

Standard Errors in parentheses; * p < 0.10; ** p < 0.05; *** p < 0.01

Table 3: Characteristics of NRFF finalists four years after award announcement

	Awarded (N=67)		Non-Awarded (N=46)		Difference (Awarded – Non-Awarded)
Variable	**Mean**	**Min – Max**	**Mean**	**Min – Max**	
Average Citations	44.99 (6.09)	7.07 – 374.96	33.26 (3.17)	6.39 – 102.65	11.73* (6.87)
Cumulative Citations	2368.25 (318.33)	237 – 11504	2047.61 (311.21)	341 – 12107	320.65 (445.18)
Cumulative Publications	64.90 (8.34)	9 – 427	68.70 (7.63)	12 – 229	-3.80 (11.30)
H-Index	19.31 (1.14)	6 – 50	19.22 (1.23)	8 – 38	0.10 (1.68)

Standard Errors in parentheses; * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table 3 reports difference-in-means tests of the scientific record of finalists four years into their Fellowship grant or post-application careers. The evidence suggests NRF Fellows have more citations to their work, but are not publishing more work overall. There is also no significant difference in the H-index between the two groups. These preliminary findings suggest that winning large grants could help early-career scientists produce more impactful research; the margin of response appears to be in quality of research, rather than quantity.

Conclusion

Early career researchers often struggle to obtain large grants because they are insufficiently established, and hence, present high risks to funding agencies. Yet large grants can be vital for making significant research breakthroughs. Our results suggest NRF Fellows produce significantly more impactful research than their quantitatively similar peers who were shortlisted but did not receive the Fellowship. Our evidence contrasts with Bol et al. (2018), who find no effect of early-career grants on the scientific output of winners. One possible explanation is that we study very large early-career grants compared to Bol et al. (2018). The NRF Fellowship is designed to fund major research breakthroughs. Winning such a grant not only funds an ambitious research agenda, but also frees winners from having to apply for additional research grants during the crucial early phase of their career.

The results support public policy initiatives by many emerging economies to jump-start scientific research and development through grant funding programs. This is important for developing nations seeking to catch up to the technological frontier, as frontier academic scientific research is positively associated with industrial innovation (Mansfield, 1999; Beise and Stahl, 1999; Cohen, et al., 2002). However, if the contrast with Bol et al. (2018) holds more generally, achieving significant growth in scientific productivity may require large and ambitious grant programs such as the NRFF.

A natural criticism is that our evidence is limited and based purely on a test of differences between NRF Fellows and non-awarded finalists, at four years after grant award. The

evidence, further, does not fully control for differences in scientific output between disciplines. Future work will extend and develop these results to study the scientific output trajectory of awardees and non-awarded finalists, controlling for the effect of differences between scientific disciplines in their bibliometric output measures and in scientific growth over time.

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