CPB Netherlands Bureau for Economic Policy Analysis

CPB Discussion Paper | 248

The effects of research grants on scientific productivity and utilisation

Debby Lanser
Ryanne van Dalen

The Effects of Research Grants on Scientific Productivity and Utilisation*

Debby Lanser† and Ryanne van Dalen‡

July 1, 2013

Abstract

This paper investigates the effect of receiving a grant from the Dutch Technology Foundation STW on the research output of an individual researcher. STW roughly distinguishes two types of funding instruments, i.e. the Open Technology Programme in which research proposals from different disciplines compete against each other and the thematic programmes on specific research themes with more prominent industrial involvement. Overall, STW funds application-oriented research by equally weighting academic quality and utilisation of submitted research proposals. Research output is therefore measured along these two criteria, that is, publications and citations for scientific productivity and publications with industry and patent applications for utilisation. We are able to identify causal effects of such a grant on research output by exploiting the discontinuity in the relationship between the priority scores assigned to each proposal and receiving an STW grant. We find no evidence that an STW grant has a positive effect on scientific productivity or utilisation for the Open Technology Programme. However, we do find significantly positive effects of an STW grant on publication rates within the thematic programmes. Grant receipt in thematic programmes leads to six additional publications including one co-authored by industry professionals over the next four years.

Keywords: Scientific productivity, research grants, regression discontinuity.

JEL codes: I23, J24, O38

*Part of this research is funded by the Dutch Ministry of Education, Culture and Science. We would like to thank STW (Eppo Bruins and Chris Mombers) for generously providing data on STW grant applications and CWTS (Ed Noyons) for supplying bibliometric data. We also thank Roel van Elk, Sander Gerritsen, Erzo Luttmer, Michiel van Leuvensteijn, Bas Straathof, Dinand Webbink, Bas ter Weel, Karen van der Wiel and several seminar participants in The Hague and Aarhus for many helpful discussions and their useful comments.

†CPB Netherlands Bureau for Economic Policy Analysis. Contact: D.Lanser@cpb.nl.

‡CPB Netherlands Bureau for Economic Policy Analysis. Corresponding Author. Contact: R.M.van.Dalen@cpb.nl.

1 Introduction

Scientific research and technology development can be characterised as public goods because research findings are non-excludable as well as non-rivalrous. Economic theory predicts that there will be under-investment in science if left to the market (Nelson, 1971; Arrow, 1971). Therefore governments devote considerable resources to scientific research and its intertwinement with technology development and useful applications.

An important instrument for subsidising and stimulating research is the provision of competitive grants. For example, the National Institute of Health (NIH) yearly allocates 0.2% of GDP on medical research of which almost 80% of its budget is awarded through almost 50,000 competitive grants. The Netherlands Organisation for Scientific Research (NWO) is the national research council in the Netherlands and has a budget of 0.1% of GDP covering all research fields. The competitive grants of NWO fund the research of more than 5,000 scientists.

In Dutch science policy, the Technology Foundation STW has a prominent role as a research council awarding competitive grants for development and utilisation of scientific knowledge. Its objective is to promote knowledge transfers between application-oriented science and technical users. STW was founded in 1981 and yearly spends approximately 80 million euros on application-oriented scientific research. For that purpose, they distinguish two broad categories of research grants, viz. the Open Technology Programme (OTP) and the thematic programmes or calls. OTP is characterized as an open programme in which research proposals from different technological research fields compete which one another. Research proposals are granted in a jury process equally weighting scientific quality and utilisation of the proposal. The thematic programmes are established when particular fields seem upcoming or are considered to be extremely relevant for a particular industry or firm. In these fields a more extensive and directed research call seems appropriate providing additional research funds or more involvement from particular industries or companies.

In this paper we are interested in the consequences of government spending on scientific research with a potential for utilisation. We focus on one particular investment channel: the impact of research grants on subsequent (research) productivity and knowledge transfers. We examine whether STW research grants submitted in the period between 1997 and 2005 improve research output of individual researchers in terms of academic productivity and utilisation.

Our empirical research strategy allows us to identify a causal relation between grants and research output, which is similar to Jacob and Lefgren (2011). We use a regression discontinuity (RD) design, because the STW funding mechanism ranks research proposals on the basis of jury scores. We are therefore able to compare individual researchers on the margin, that is, those researcher who received an STW grant with a score just below the cutoff and those researcher that did not receive an STW grant with a score just above the cutoff.

Our outcome measures are objective and quantifiable matching the two evaluation criteria of STW which are scientific quality and utilisation. Scientific quality is represented by publications and citations and utilisaton is measured by publications co-authored with industry and patent applications. The publication and citation data are provided by the Centre of Science and Technology Studies (CWTS), which is the national institute for bibliometric analyses. The patent data stems from PATSTAT, or the European Patent Office (EPO) Worldwide Patent Statistical Database, which is a database with detailed information on the application and examination process of individual patents for almost 80 patent offices. STW evaluates granted proposals after five and ten years on three other criteria, which are involvement, generated products and income, see for instance Deuten, Kieft, van der Veen, and Vermeulen (2011). A disadvantage of these criteria is that they are only available for granted proposals.

The effect of a grant might differ among OTP and specific calls. Therefore, we do not only evaluate the effect of STW grants in general, but also distinguish between OTP and thematic calls. We expect an increase in research output for researchers that receive an STW grant as opposed to researchers that do not. For thematic calls we expect a larger effect of grant receipt on utilisation because of more direct industry involvement.

In our data we do not find any evidence that OTP grant receipt increases the productivity of an individual researcher both in terms of scientific output as well as utilisation. In case of specific calls, however, we find statistically significant, relatively large positive effects of the STW grant on publications and on publications with the industry. Grant receipt increases research output by six publications of which one publication is co-authored by the industry. These results are in line with appointing one PhD student in terms of awarded budget and research output. We find no robust results for citations and patent applications.

Our paper contributes to the existing literature, because little is known on the effectiveness of research grants on scientific productivity and utilisation. The literature suggests that there is a small positive effect, which is also confirmed by our findings. For example, Gaughan and Bozeman (2002) find that researchers who obtain a research grant from the National Science Foundation (NSF) are more likely to obtain other industry grants but do not find a positive effect on the number of publications. On the other hand, Arora and Gambardella (2005) find a modest increase in subsequent publication rates and citations for NSF granted research projects especially among young researchers. Chudnovsky, López, Rossi, and Ubfal (2008)) reach a similar conclusion using data on research funding in Argentina. However, a major drawback of these studies is that they do not address potential endogeneity issues as a result of self-selection. A notable exception is the paper by Jacob and Lefgren (2011) who are able to estimate causal effects of research grants on academic productivity by using a RD design. They find limited effects of NIH research grants on productivity. Their estimates represent a 7% increase in the publication rate in the subsequent five years.

An important difference between NIH and STW research grants is the size of the awarded budget which are on average 1.7 million dollar and 400,000 euros, respectively. Furthermore, the evaluation criteria differ. NIH applications are subject to five criteria which are significance, approach, innovation, investigator, and environment whereas STW applications are subject to two criteria which are scientific quality and utilisation. We extend the analysis of Jacob and Lefgren (2011) by including utilisation as a measure of research output. This measure is also relevant for policy. Insight into appropriate channels of knowledge transfer and utilisation is very important as the government tends to direct its spending on scientific research more towards industrial applications. Furthermore, a recurring discussion involves whether research should be directed at specific topics or at the invention of the researcher. Our outcomes suggest that specific calls are more effective in achieving higher publication rates compared to grants in OTP. Although we are not able to identify the mechanism for this finding, a possible explanation is that the research areas identified as upcoming and extremely relevant have been successful choices. This is not to say that all government spending on grants should be directed towards specifical calls with more industry involvement because the number of relevant fields can be limited and the government decision might be one under assymetric information.

The remainder of this paper is organised as follows. Section 2 elaborates on the grant allocation procedure of STW. Section 3 describes the data. Section 4 gives the empirical strategy. The results are presented in section 5. Section 6 summarizes and concludes.

2 Institutional Setting

The Technology Foundation STW was estabilished in 1981 and serves as a funding agency for application-oriented scientific research. Its budget is about 80 million euros a year. The main objective of STW is to achieve knowledge transfers between the technical and applied sciences and (potential) knowledge users. For that purpose, STW has various funding instruments that are all subject to a similar review process in which proposals are evaluated on scientific quality and utilisation. STW receives its funding from the NWO and the Ministry of Economic Affairs, respectively 60% and 40%.

The OTP is the largest and longest running subsidy program. Within OTP research proposals from different disciplines compete against each other. Other STW instruments (thematic programmes or calls) cover specific research area. These research areas are considered upcoming or extremely relevant for a particular industry or firm as reflected by a more prominent role of users in the review process or by additonal private funding. STW's instruments focus on relatively small scientific projects. OTP projects have a maximum budget of 750,000 euros mostly spent on personnel, viz. the appointment of a PhD student or postdoc. For projects where more than 250,000 euros will be invested in equipment, the maximum STW contribution is 1 million euros. If the total project costs exceed 500,000 euros, co-funding by users is compulsory which amounts to 25% of the sum in excess of 500,000 euros. Approximately, 30% of the granted research proposals in the period 1997-2005 requested a budget exceeding 500,000 which are mainly OTP proposals. In our sample, the number of OTP applications is substantially larger than applications for specific calls. Table 1 shows the number of STW applications and awarded proposals by year and program.

Table 1: Number of applications and awards by year and programme

	All		Open Technology Programme		Specific calls	
Application year	Number of applications	Number of grants	Number of applications	Number of grants	Number of applications	Number of grants
1997	154	71	127	52	27	19
1998	227	90	202	72	25	18
1999	226	76	172	57	54	19
2000	191	73	171	61	20	12
2001	112	50	108	47	4	3
2002	189	75	136	60	53	15
2003	166	61	149	53	17	8
2004	164	64	152	60	12	4
2005	143	44	136	43	7	1

STW requires that each proposal contains a utilisation section in which the applicant explains the relevance of the research for potential users. Actual and potential users endorse the proposal by a statement of intention. Representatives of these users join the User Committee appointed to each awarded project. The committee is in charge of monitoring the progress and outcome of the studies.

Applications for the OTP can be submitted on an ongoing basis. The granting process consists of three phases. First, STW submits each research proposal to three to five referees, mostly foreign, who are experts peers in the relevant research field. They assess the proposal on the basis of specific questions about scientitic quality and utilisation.[1] STW then combines these individual referees' comments and sends them to the main applicant with a request to respond to these comments. In the second phase, STW puts together a multidisciplinary jury consisting of 10 to 12 members who have different backgrounds, e.g. universities, large research institutes, industry and other societal sectors who have affinity with technology development but unlike the referees are not necessarily experts in the relevant specialist area. Jury members are generally given 20 research proposals with the accompanying referees' comments and the response from the applicant(s). Each jury member assigns two ratings of equal weight on a scale of 1 to 9 (with 1 being the highest quality) to each proposal, one for scientific quality and one for utilisation. This assessment round takes place in writing without consultations. Jury members are not familiar with the identities of the other jury members. In the third phase, STW collects the ratings and calculates the average rating for both criteria. The final priority score is the sum of both averages. The board bases its allocation decision on the priority scores of the jury. In exceptional cases, the board can deviate from the priority scores for budgetary reasons or other conditions such as co-funding or major investments.

3 Data

Our main data source consists of all STW applications for the period 1997 to 2005. The data contains information on main applicant and co-applicant(s) such as name and university. For each application we have its submission date, total budget, the priority scores from the jury both on scientific quality and utilisation, and whether the application was granted or not.

There is no predetermined cutoff that can be applied to all STW research proposals. Instead, the cutoff is different for each jury and mainly depends on the yearly budget available and the number of proposals submitted to STW. To aggregate across juries, we define the cutoff c in jury j, c_j, as the average of the score of the last funded and first non-funded application. We include all proposals regardless whether they are in our analysis sample to impute the cutoff. However, in case of out-of-order funding we define the cutoff such that the number of applications that are funded out of order are minimised. There are only 26 submissions funded out of order which is 1.7% of our total sample. Each proposal is assigned a normalised priority score which is defined as: $S_{ij} = p_{ij} - c_j$ where p_{ij} is the priority score of researcher i's proposal.

Table 2 shows that the average cutoff is equal to 6.63 ranging from 5.3 to 8.2. Moreover, the juries included in our sample each received around 18 proposals and slightly more than

[1]The questions are available on the website of STW

7 proposals were granted. The success rate is around 38%. The total amount that has been applied for by all submitted proposal within a jury is around 7.5 million euros of which 1.6 million euros has been granted. An average research proposal requests a budget of around 400,000 euros.

Table 2: Summary jury statistics

	Mean	SD	Min	Max
Number of applications	18.49	2.78	3	24
Number granted	7.1	1.71	1	11
Percentage granted	38	8	2	69
Priority score	7.35	0.49	6.05	8.52
Cutoff	6.63	0.56	5.3	8.2
Total budget[a]	7,522,426	1,9461,56	2,380,719	14,195,680
Granted budget[b]	1,668,204	1,143,390	0	5,442,380
Average budget[c]	409,296	98,986	183,132	1,011,911

[a,b,c] These amounts are in euros.

We use two types of outcome measures to examine the effect of STW research grants on scientific productivity and utilisation. To assess the impact of an STW research grant on scientific productivity we use publication and citation data from CWTS. CWTS provides the aggregate number of scientific publications of each main applicant for a pre-application period and a post-application period. The pre-application period is defined as two years before the application until one year after the year of application whereas the post-application period is defined as two years after the application until five years after the application. As an example, the number of publications for the main applicant who submitted a research proposal in 2005 is the aggregate number of publications from 2003 to 2006 for the pre-application period and from 2007 to 2010 for the post-application period. Although the pre-application period exceeds the year of application, applicants indicate that the time elapsed between application and actual start of the project is at least one year. Therefore, any output generated by an STW research project is not expected within two years after the application date. We use a period of four years because we are constrained by the final application year which is 2005 in our sample. Rather than using the absolute number of citations, we use a normalised average citation index that takes into account the differences in citation behaviour between research fields and the type of document that is cited. The number of citations are the total citations to the publications of the main applicant as described above with a time window of maximum 4 years.[2]

In order to measure the utilisation component of a research proposal we use the number of

[2]For the most recent publications that do not have a citation window of 4 years, the corresponding citation index takes the shortened citation window into account.

Table 3: Summary statistics

	All applications			Open Technology Programme			Specific calls		
	All	Granted	Non-granted	All	Granted	Non-granted	All	Granted	Non-granted
Granted	0.38			0.37			0.45		
Score	7.34	6.05	8.15	7.32	6	8.11	7.46	6.31	8.42
Cutoff	6.63			6.61			6.79		
Productivity measures prior to application[a]									
Publications	20.64	21.45	20.14	21.33	21.89	21.00	16.39	19.17	14.10
Publications industry	2.28	2.69	2.02	2.32	2.73	2.07	2.05	2.49	1.68
Patent applications	0.92	1.17	0.77	0.99	1.32	0.79	0.48	0.36	0.58
Productivity measures after application[b]									
Publications	23.28	25.28	22.02	23.90	25.52	22.93	19.45	24.08	15.63
Publications industry	2.85	3.37	2.53	2.97	3.47	2.68	2.12	2.87	1.50
Patent applications	0.95	1.08	0.86	1.01	1.20	0.89	0.58	0.48	0.66
Observations	1,572	604	968	1,353	505	848	219	99	120

[a] The productivity measures are an aggregate outcome over four years, that is, from $[t-2, t+1]$ where t is year of application.

[b] The productivity measures are an aggregate outcome over four years, that is, from $[t+2, t+5]$ where t is year of application.

scientific publications that are co-authored by professional(s) from the industry. A publication is identified as being co-authored by professional(s) from the industry if there is a private company address stated on the publication. This information is also provided by CWTS. A second measure of utilisation is the number of patent applications. We use PATSTAT, or the EPO Worldwide Patent Statistical Database as it is officially known, which is a database with detailed information on the application and examination process of individual patents for almost 80 patent offices.[3] Our basic approach is to match STW main applicants to patent applications using their last names and initials. Details of our matching procedure can be found in Appendix A.

Table 3 shows descriptive statistics for both measures of scientific productivity and utilisation. We show summary statistics for all applications and then distinguish between submitted proposals to the OTP and specific calls. The success rate in the specific calls slightly exceeds the success rate in OTP whereas the cutoff is comparable for the two types of funding instruments. The average productivity measures are higher for successful main applicants than for unsuccessful ones.[4] This outcome holds for the four year period prior to the application as well as for the four year period after the application. For example, successful main applicants have on average 1.3 more publications than unsuccesful applicants prior to the application. This difference increases if we compare the post-application publication rate of successful and unsuccesful main applicants. Applicants who received an STW grant have on average 3.2 more publications than applicants that did not receive this grant. For specific calls, this number is 8.5 publications. For OTP, the number is 2.6 publications. Although the magnitude is somewhat smaller, a similar pattern is observed for publications with the industry. Patent applications are an exception because grant recipients in a specific call apply less for patents than non-recipients.

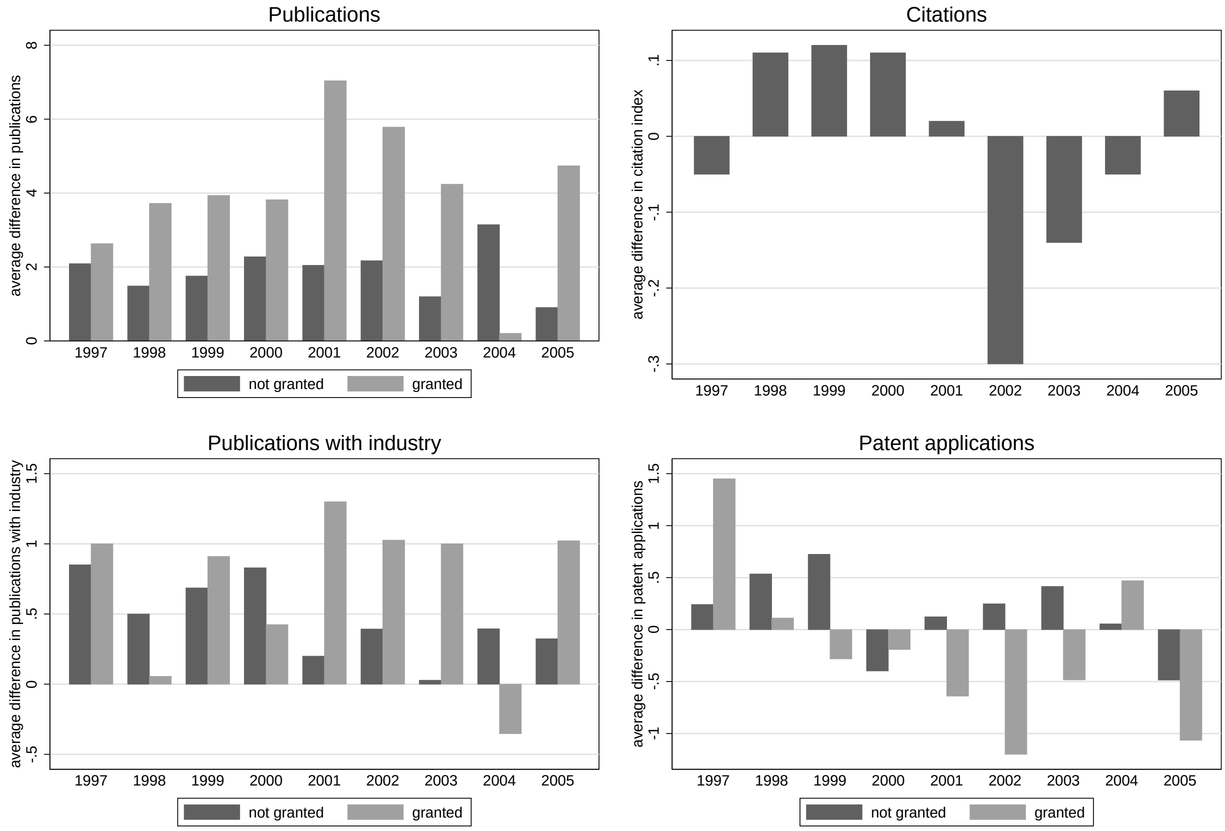
Figure 1 shows the temporal variation in our productivity and utilisation measures. Each bar represents the difference in research output between the pre-application period and post-application period averaged over all STW grant applications. We distinguish between successful and unsuccessful applications except for citations because our data only allows us to compute the difference in the average citation index. Figure 1 which represents the number of publications, publications with the industry and patent applications from 1997 to 2005, confirms our findings on a yearly base. Interestingly, publication rates appear to increase more for successul

[3] We use the version of PATSTAT from 22-12-2009 which includes 63 million patent applications and many more citations.

[4] We do not include citations because this index is an average over the number of publications per applicant and therefore cannot be averaged over granted versus non-granted applicants. Therefore, citations have to be recomputed. Figure 1 shows recomputed citations indices from CWTS yearly.

applicants than for unsuccessful applicants whereas citations and patent applications show a decreasing trend over time.

Figure 1: Differences in Scientific Productivity and Utilisation



Note: The years on the horizontal axis represent the year of application.

4 Empirical Specification

The main challenge in this paper is to obtain an estimate of the effect of grant receipt on subsequent scientific productivity and research utilisation. If STW would randomly allocate research grants to researchers then one can identify the causal effects of receiving an STW grant by simply comparing the research output of those that obtained and did not obtain an STW grant. However, STW uses a grant allocation mechanism based on priority scores of the jury. This complicates interpreting the association between grant success and research output in a causal way. Not only are more qualified and/or motivated researchers more likely to receive STW funding, they are also more likely to be more productive and/or produce higher quality academic output. Any positive association between grant receipt and academic output or utilisation could therefore reflect the existence of unobservable factors that drive both academic and entrepreneurial success (and that juries work effectively). Simple comparisons of research output and quality of successful and unsuccessful applicants will most likely yield upward biased estimates because it reflects the causal impact of grant receipt as well as differences in productivity levels.

We use the grant allocation mechanism of STW in combination with information on the priority scores of each proposal to identify the impact of an STW research grant by using a RD design. This empirical strategy is commonly used to establish causal effects.[5] The idea is that research proposals are ranked on the basis of jury scores and grants are then allocated to applicants with scores below a predetermined cutoff. If we compare applicants just above and just below the cutoff, there will be little difference in unobservable productivity factors, but observable differences in the likelihood of receiving funding. Any observed difference in output can therefore be attributed to grant receipt. More specifically, we will estimate the following equation:

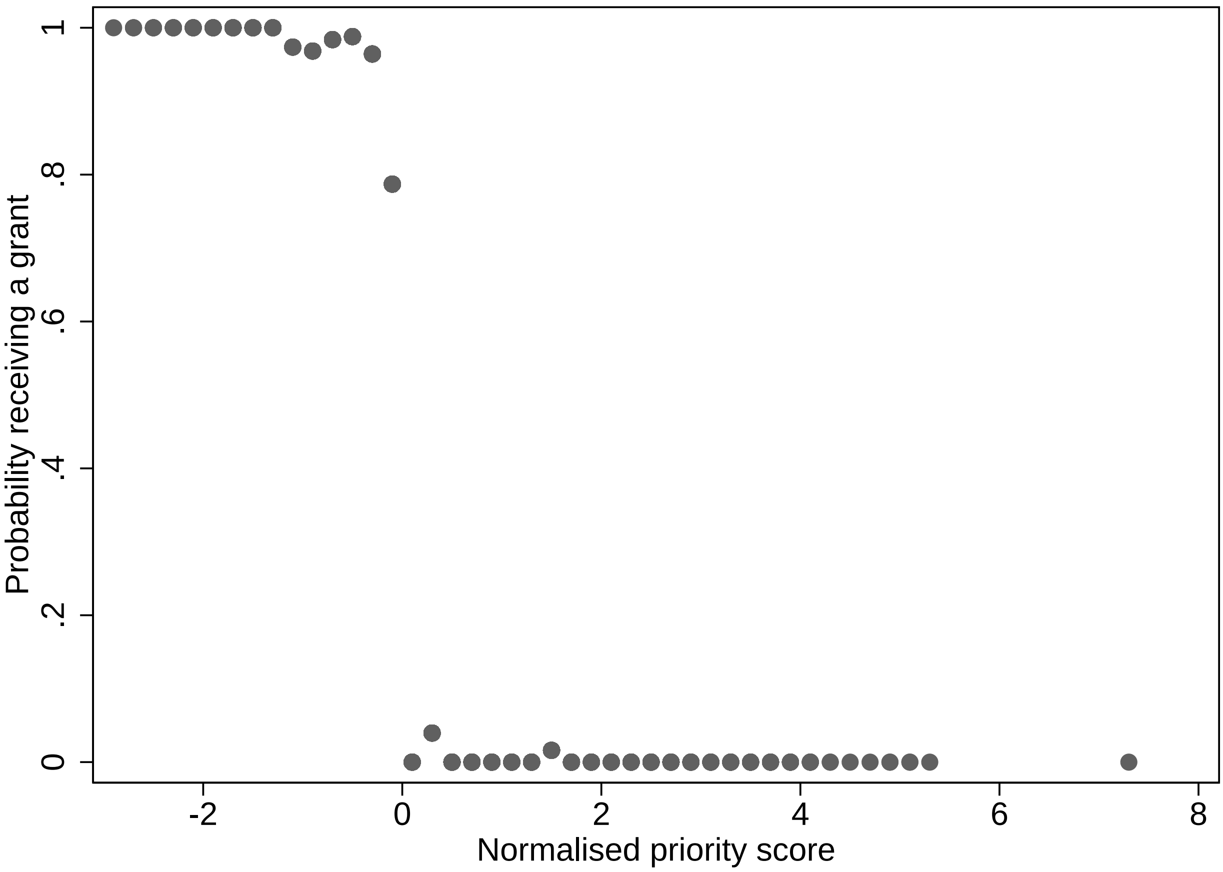
$$Y_{it\tau^+} = \alpha_0 + \alpha_1 G_{it} + \alpha_2 S_{it} + \alpha_3 G_{it} \times S_{it} + \alpha_4 X_{it\tau^-} + \epsilon_{it\tau^+} \tag{1}$$

where Y_{it} is the aggregate research output of main applicant i in period τ^+ which is $[t+2, t+5]$ where t is the year of application, G_{it} is a dummy variable indicating whether or not the research proposal was granted, S_{it} is the priority score of the research proposal normalised relative to the grant funding cutoff, and $X_{it\tau^-}$ includes prior productivity in period τ^- which is $[t-2, t+1]$ of main applicant i, year and research-field fixed effects. We include six research fields which are: 1) chemistry, physics and astronomy, 2) earth and environmental sciences, 3) engineering sciences, 4) life sciences, 5) mathematics, statistics and computer sciences, and 6) medical sciences.[6] The interaction term, $G_{it} \times S_{it}$, is included to allow the slope of the relationship between priority scores and output to differ for granted and non-granted proposals.

Figure 2 shows the probability that an STW grant application is funded as a function of the normalised priority scores with a band width equal to 0.2. The lower the priority score the better is the research proposal. So, a negative normalised score reflects proposals that the jury identifies as successful whereas a positive normalised score reflects proposals that the jury identifies as unsuccessful. The figure illustrates that the grant allocation mechanism is not completely deterministic. That is, not all submissions with a score below or equal to the cutoff receive an STW grant and not all submissions with a score above the cutoff do not receive an STW grant. The reasons are as follows. First, there are six proposals that received funding although their score was above the cutoff and there are 21 proposals that did not receive funding although their score was below the cutoff. In total, these out-of-order funded proposal

[5] Imbens and Wooldridge (2009) and Lee and Lemieux (2010) provide excellent overviews of this literature.
[6] These research fields are provided by CWTS.

Figure 2: Probability of receiving STW funding



constitute only 1.7% of our sample.

Second, our dataset tracks each research proposal separately and main applicants can appear more than once. They can either submit different proposals or they can reapply with a modified version of a previously rejected proposal. In our sample, the probability of grant receipt for those proposals that have been submitted once is 0.4 while it is 0.68 for those proposals that have been resubmitted. In total, 80 proposals, or 4.8% of our sample, are identified as being resubmissions of which two proposals have been submitted three times.[7]

To take into account both out-of-order funding and resubmissions we use the fuzzy RD design to identify the causal impact of research funding on research output. We follow the strategy of Ketel, Leuven, Oosterbeek, and van der Klaauw (2012) who estimate the returns to medical school in the Netherlands. They instrument whether a student completed medical school with

[7]We identify resubmissions as follows. First, we consider those applications that are submitted by the same main applicant and that were not granted the first time. Given these two conditions, we use the Levenshtein edit distance to determine whether two titles are a match. This metric is designed to measure the similarity of two strings and counts the number of operations that are needed to convert one string into another. The Levenshtein edit distance is normalised by dividing the number of insertions, deletions, or substitutions by the length of the shorter string. We choose the threshold to be 0.6 implying that all pairwise combinations of titles that are less than or equal to 0.6 are considered to be similar. Finally, we set the maximum number of years between the first submission and the resubmissions at three years.

the result of the first admittance lottery. In our setup this implies that we instrument eventual grant receipt with the normalised priority score being below or above the cutoff of the first application round in which the research proposal has been submitted. For resubmissions, we only include the first appearance of the proposal in our sample with the corresponding research outcomes in the period $[t+2, t+5]$ years after the first application. Our unit of observation is therefore a main applicant-proposal combination. Main applicants can thus occur more than once, in our sample on average 2.4 times, but these are different proposals with sometimes overlapping time frames. The first stage of this IV estimation is given by:

$$G_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 S_{it} + \beta_3 T_{it} \times S_{it} + \beta_4 X_{it\tau^-} + \eta_{it} \tag{2}$$

where i now refers to a main applicant-proposal combination, T is a dummy variable equal to 1 if the normalised priority score is below the cutoff and 0 otherwise, and the other variables are as described earlier. The coefficient β_1 can be interpreted as the effect of having a score below the cutoff on receiving a grant. This coefficient will not be equal to one because of out-of-order funding and resubmissions. The second stage is given by:

$$Y_{it\tau^+} = \gamma_0 + \gamma_1 \hat{G}_i + \gamma_2 S_{it} + \gamma_3 T_{it} \times S_{it} + \gamma_4 X_{it\tau^-} + \theta_{it\tau} \tag{3}$$

where γ_1 is the effect of receiving an STW grant on research output for main applicants that comply with the priority score of their first submission. We also allow for different polynomials of the normalised score and the interaction term. Moreover, we use robust standard errors clustered by main applicant to take into account multiple proposals of the same applicant, which are not considered to be resubmissions.

RD is only valid if the covariates are locally balanced on either side of the cutoff. In other words, there should be no discontinuities in covariates around the cutoff. Lee and Lemieux (2010) propose to conduct a formal estimation replacing the dependent variable with each of the covariates in X. The assumption of local random assignment is violated if the regressions show a discontinuity in the covariates. Table 4 shows that the dummy for grant receipt is not statistically significant at the 5% level for the covariates that control for research productivity prior to the application. We can conclude that there is no discontinuity in our covariates which implies that our empirical strategy is valid.

Table 4: Validity of RD results

	All	Open Technology Programme	Specific calls
Effect of grant on prior productivity			
Publications	-0.816	-1.116	-1.474
	(2.280)	(2.714)	(4.221)
Citations	0.0905	0.0171	0.549*
	(0.123)	(0.138)	(0.306)
Publications industry	-0.143	-0.0323	-1.087
	(0.434)	(0.519)	(1.063)
Patent applications	-0.0122	0.271	-1.717*
	(0.432)	(0.527)	(0.971)
Observations	1,572	1,353	219

Robust standard errors are reported in parentheses clustered by main applicant, *** p<0.01, ** p<0.05, * p<0.1

5 Results

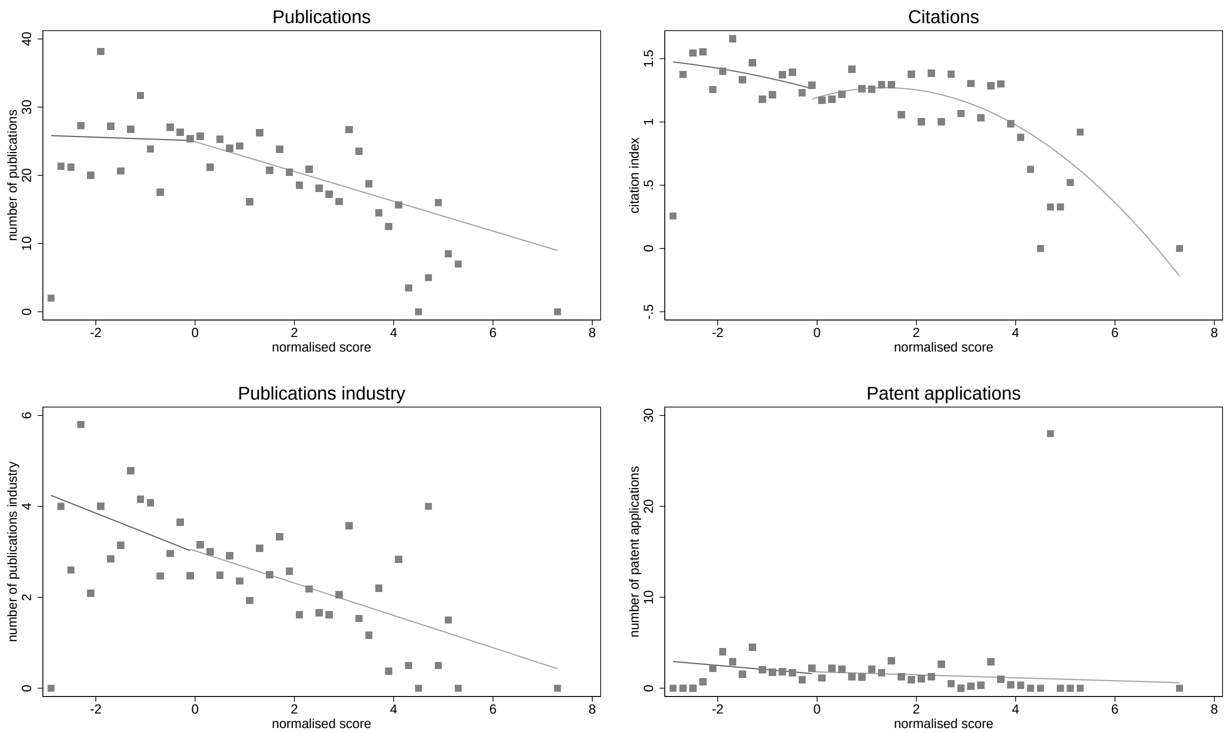
Before presenting the results of our RD design, Figure 3 shows the discontinuity we are interested in for the total number of publications, citations, number of publications with industry and patent applications. This figure shows a linear relationship between grant receipt and publications, publications with industry, and patent applications whereas a quadratic relationship is shown for citations. The order of the polynomial is chosen by the Akaike Information Criteria (AIC) for model selection.[8] These figures seem to imply that there is hardly any evidence of a discontinuity around the cutoff for any of the productivity and utilisation measures. It has to be noted that the scale differs for each subfigure.

Table 5 shows the IV estimates for receiving an STW grant, γ_1, on our productivity and utilisation measures for different specifications. The first five columns show the results for all STW applications. For all outcomes, column (1) shows the unconditional estimates for the grant and columns (2)-(5) progressively include more controls. The first-stage estimates can be found in Appendix B. The estimated coefficients in the first column suggest that STW grant recipients have a significantly higher output in terms of publications, citations, and publications with industry. Recall that this effect is without correcting for the priority score and thus without correcting for the quality of the proposal. When we correct for the ranking by including a linear or quadratic term of the normalised score and an interaction term between the normalised score and grant receipt, the estimated coefficients turn insignificant.[9] Although not reported in this

[8]The Akaike Information Criteria is given by $AIC = N \ln(\hat{\sigma}^2) + 2k$ where $\hat{\sigma}^s$ is the mean squared error of the regression and k is the number of parameters in the regression model.

[9]The linear polynomial minimizes the AIC for model selection for publications, publications with industry, and patent applications whereas the quadratic polynomial minimizes the AIC for model selection for citations.

Figure 3: Regression Discontinuity



Note: The figures show the average research output for normalised priority scores with a binwidth of 0.2. Normalised priority scores below or equal to zero are granted whereas normalised priority scores above zero are not granted. The AIC for model selection is minimised using a linear relationship for publications, publications with industry, and patent applications and using a quadratic relationship for citations as is also shown in the subfigures.

table, the priority score turns insignificant when including prior productivity. This suggests that prior productivity is a better indicator for our productivity and utilisation measures than the priority score of the research proposal. The inclusion of year and research-field fixed effects do not change the outcome but reduce the point estimates slightly. We do not include research-field fixed effects for citations because the normalised citations index already corrects for differences in publication and citation behaviour across research fields. Interestingly, our point estimate of 1.7 for the effect of an STW grant on the number of publication in the subsequent four year period is very similar in magnitude as the point estimate by Jacob and Lefgren (2011) who find that NIH grants increase the publication rate by 1.2 over the next five years.

To further investigate the effects of an STW grant on scientific productivity and utilisation, we split the sample into OTP and other applications. These other applications consist of proposals for a thematic programme or call that are considered to be upcoming or extremely relevant research areas often accompanied by a more prominent role of the industry. The involvement of the industry is mainly in terms of programme cofunding or a more dominant participation in the review process. A graphical representation of the discontinuity for both

Table 5: Results

	(1)	(2)	(3)	(4)	(5)	Open Technology Programme	Specific calls
Effect of grant on							
Publications	3.468***	-0.568	1.786	1.612	1.758	0.754	6.094**
	(1.320)	(2.054)	(1.149)	(1.153)	(1.135)	(1.195)	(2.660)
Citations	0.102*	0.0435	0.00148	-0.00117		-0.0203	0.181
	(0.0552)	(0.0888)	(0.0800)	(0.0794)		(0.0891)	(0.189)
Publications industry	0.850***	-0.146	-0.0733	-0.102	-0.0269	-0.302	1.118*
	(0.313)	(0.454)	(0.324)	(0.326)	(0.322)	(0.354)	(0.636)
Patent applications	0.448	-0.0322	-0.0490	-0.00533	-0.0171	0.0930	-1.741**
	(0.334)	(0.435)	(0.398)	(0.399)	(0.401)	(0.446)	(0.846)
Controls							
Score (linear or quadratic)[a]	NO	YES	YES	YES	YES	YES	YES
Prior productivity	NO	NO	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	YES	YES	YES	YES
Field FE	NO	NO	NO	NO	YES	YES	YES
Observations	1,572	1,572	1,572	1,572	1,572	1,353	219

[a] The score is included linearly for publications, publications with industry, and patent applications whereas a quadratic term is included for citations

Robust standard errors are reported in parentheses clustered by main applicant, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

programmes are given in Figures 4 and 5 in Appendix C. These figures suggest that there is no discontinuity around the cutoff for OTP whereas they indicate a discontinuity around the cutoff for specific calls for all four measures of research output. The discontinuity is most pronounced for both types of publications with a jump of approximately 5 publications and 1.5 publications with industry. Again note that the scale differs among the four subfigures. In contrast to our expectations, the figure shows a negative discontinuity in patent applications for specific calls. Apparently, the receipt of an STW grant seems to reduce the number of patent applications.

We do not find any significant effects of OTP grant receipt after controlling for the priority score, year, and research-field effects (except for citations) as can be seen in column 6 of Table 5. The results of the specific calls are also shown in Table 5 (see column 7). For the specific calls, we find a statistically significant effect for all our measures, except for citations. These results suggest that scientific output as measured by the number of publications increases significantly after STW grant receipt. Our two measures of utilisation show contradicting results. The number of publications with the industry increases for recipients, while the number of patents reduces. The results on citations and patent applications for specific calls should be interpreted with care because Table 4 shows that there is a discontinuity in these two prior productivity measures at the 10% significance level.

5.1 Robustness checks

As we have no administrative information on resubmissions, we first evaluate the robustness of our results when resubmissions are identified differenlty. We identified resubmissions as pairwise combinations of project titles that have a normalised Levenshtein edit distance less than or equal to 0.6. [10] Although this threshold can be considered as high, it is conditional on being a research proposal submitted by the same main applicant. Still, our results can be biased downward in case we mistakenly identify a new application as a resubmission. To ensure that our main results are not sensitive to choosing a specific threshold, we also performed the analysis assuming no resubmissions, so each research proposal is assumed to be a new submission. The results are almost identical for our measures of research output except for the number of publications for the sample including all STW applications. Receiving an STW grant results in two additional publications which is comparable to our main results but turns statistically significant at the 10% level. We also tested with other threshold levels. The results for a Levenshtein edit distance of 0 (exactly identical project titles) and a threshold of 0.25 are

[10] Recall that a Levenshtein edit distance of 0 indicates that titles are completely equal.

similar to assuming no resubmissions whereas a threshold of 0.5 is similar to our main results.

We consider several other robustness checks in which we replicate our analysis including all controls. Table 6 gives an overview of the results of these robustness analyses.[11] First, we include polynomials of a higher order in the priority score. Columns (1) and (2) of Table 6 show that the results do not change which implies that the discontinuity is not mistaken for a nonlinearity.

Second, we exclude applicants with an extraordinary high number of publications which could possibly indicate measurement error. Column (3) shows the results if we exclude applicants in the upper 5% of the publication distribution which corresponds to over 62 publications in a four year period. The results remain qualitatively similar. This also holds if we exclude those applicants who have no publications which is the bottom 3.8% of the publication distribution and/or exclude the upper 2% of the publication distribution which corresponds to more than 92 publications in a four year period. We also excluded applicants in the upper 5% of the patent application distribution to check whether the results on patents are not driven by the outliers as can be seen from Figure 3. This is not the case.

Third, we narrow our sample around the cutoff. Subsequently, intervals of the normalised scores between -2 and 2, and -1 and 1 are considered. The results are given in columns (4) and (5) and there are no changes in sign and size for all applications and OTP applications. The effects of the grant on our scientific productivity and utilisation measures remain statistically insignificant. For the specific calls, the magnitude of the estimates does not differ over the various specifications. We still find large and statistically significant effects of the grant on total publications and a somewhat smaller effect on publications with the industry. For patent applications, the size of the effect remains the same, but turns statistically insignificant due to fewer observations in specific calls.

Overall, our main results are quite robust to different specifications especially for citations, publications with industry and patent applications. The estimated effect of an STW grant on publications is stable around two additional publications and sometimes marginally signifant. However, this effect is driven by the specific calls throughout all specifications.

5.2 Discussion

The effect of an STW grant receipt on research output includes both the effect of additional resources on research output and the ability and behaviour of researcher when granted or non-

[11] The reduced-form estimates are not shown in Table 6 but give estimation results that are almost identical to our main results.

Table 6: Results - robustness

	All					Open Technology Programme					Specific calls				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Publications	1.643	1.943	1.958*	1.899	3.036	0.562	0.252	0.986	0.626	1.129	6.781**	12.57**	7.378***	8.762**	16.75***
	(1.295)	(1.606)	(1.160)	(1.511)	(2.111)	(1.408)	(1.645)	(1.284)	(1.540)	(2.116)	(3.318)	(4.998)	(2.521)	(3.898)	(6.077)
Citations	-0.0916	0.00513	-0.0126	0.0671	0.0500	-0.0919	-0.0105	-0.0366	0.0175	0.0182	-0.0506	0.300	0.243	0.572**	0.380**
	(0.0733)	(0.0917)	(0.0828)	(0.0966)	(0.0924)	(0.0808)	(0.0966)	(0.0932)	(0.102)	(0.102)	(0.172)	(0.221)	(0.186)	(0.236)	(0.192)
Publications industry	-0.0398	0.145	0.168	0.199	0.0558	-0.312	-0.151	-0.102	-0.0631	-0.264	1.450**	0.981	1.554***	0.564	1.292
	(0.369)	(0.455)	(0.291)	(0.427)	(0.586)	(0.423)	(0.507)	(0.329)	(0.465)	(0.648)	(0.720)	(0.802)	(0.565)	(0.861)	(1.154)
Patent applications	-4.52e-05	0.528	0.000481	0.00224	0.422	-0.00483	0.612	0.0978	0.0748	0.743	-1.835**	-1.516*	-1.074*	-1.882**	-2.927
	(0.438)	(0.538)	(0.385)	(0.484)	(0.715)	(0.513)	(0.577)	(0.433)	(0.523)	(0.743)	(0.899)	(0.840)	(0.577)	(0.936)	(1.827)
Observations	1,572	1,572	1,492	1,306	854	1,353	1,353	1,284	1,127	729	219	219	208	179	125

(1) includes a linear and quadratic term for the normalised score for publications, publications industry, and patent applications and only a linear term for the citation index
(2) includes a cubic and quadratic term for the normalised score for all measures of research output
(3) excludes those applications whose main applicant is in the upper 5% of the publication distribution
(4) focuses on the normalised priority scores in the interval $[-2, 2]$
(5) focuses on the normalised priority scores in the interval $[-1, 1]$

Robust standard errors are reported in parentheses clustered by main applicant, *** p<0.01, ** p<0.05, * p<0.1

granted in an STW call. The latter can influence our results in two ways. First, our results can underestimate the effect of an STW grant on scientific productivity and utilisation because STW funding can crowd out the interest of awarded research in raising additional funding. The effect of receiving a grant is identified around the cutoff for proposals of similar quality. However, if a proposal around the cutoff does not obtain STW funding this does not imply that it does not receive other funding generating addition scientific and industrial output. This can also be an explanation for the relatively small and insignificant effect of OTP funding on research output.

Second, our results can also overestimate the effect of an STW grant on scientific productivity and utilisation because STW funding can have a signaling function. Researchers who receive an STW grant may find it more easy to attract other sources of funding because being an STW grant recipient signals quality. In that case, the effect of an STW grant on scientific productivity and utilisation is an overestimation and also includes the effect of additional sources of funding.

An alternative interpretation of our results stems from interviews with applicants. Given our relatively short time frame after granting the proposal, the total effect of the grant might not be fully developed, as the publication process easily exceeds the standard PhD-period. The interviewees argue that an average granted proposal yields the same output as appointing one PhD-student. Across research fields, a PhD-student is expected to produce 3 to 6 publications. Although our results are statistically insignificant, the point estimates on the total number of publications are close to two publications. This is in line with the research output suggested by our interviewees when taking into account that the publication process exceeds the PhD-period.

A remarkable finding is that patent applications decrease with grant receipt in specific calls. As already noted this outcome should be interpreted with care because there is a discontinuity in prior productivity as measured by number of patent applications in the pre-application period. Patent behaviour and relevant outputs for utilisation also differ across research fields as can be established from interviews with STW applicants.

Another interesting result is that the point estimate of grant receipt on publications for the specific calls are relatively large compared to the point estimate for OTP. This difference cannot be explained by variation in grant size between OTP and thematic call proposals. Researchers in both calls apply for approximately 400,000 euros per proposal. Our results also show that receiving a grant in a specific call significantly increases the publication rate both with the industry and without. The increase in publications co-authored with industry professional might suggest that STW achieves its objective of promoting knowledge transfers between application-oriented science and technical users.

Our results show that funding application-oriented research through specifical calls is more effective in achieving higher publication rates than through OTP. Still we are hesitant to conclude that more government spending should be directed towards specific calls because the mechanism for this outcome are hard to unfold. A possible mechanism is that the appointed research areas turned out to be promising research fields in terms of publication opportunities. This implies that the effectiveness of grants depends on the correct appointment of research areas. Furthermore, more government spending does not automatically generate increased productivity because the number of such research areas is likely to be limited. Another explanation is that researcher characteristics differ between both programmes. The descriptives show that specific call applicants have a lower publication record compared to OTP applicants. This holds comparing pre- and post-application publication records also when conditioning on grant receipt. This might be an indication of diminising returns to scale in publication.

Moreover, our sample is restrictive in the sense that it only includes a small number of specific call applications. Ideally, we would like to perform a similar analysis on more recent data, because funding of specific calls has increased substantially after our sample period. Over the past decade, the budget for OTP funding has decreased substantially from 91% in 2001 to 33% in 2010 (Deuten, Kieft, van der Veen, and Vermeulen, 2011). So, there is trend towards funding research in more specific programmes in which the industry contributes more heavily.

Another interesting direction for future research is to examine the effect of grants on inframarginal applicants. Our results are to be interpreted as the effect of grant receipt for the marginal applicant because for observations that are close to the cutoff the assumption of "random assignment" is most credible. Angrist and Rokkanen (2012) provide an identification strategy for causual effects for applicants that are some distance away from the cutoff.

6 Conclusion

This paper examines the effect of receiving an STW grant on the subsequent research output of an individual scientific researcher. Following the paper of Jacob and Lefgren (2011) we use a RD design to identify the causal effect of a grant and control for prior quality of the researcher. Besides scientific productivity as measured by publications and citations, our paper also identifies a utilisation effect of a research grant as measured by publications with industry and patent applications. We do not find a statistically significant effect of OTP grant receipt on the publication rate and citation index of an individual researcher. In case of specific STW calls, we do find statistically significant results. We find positive effects of the STW grant on publications and publications with the industry for these thematic programmes.

These results do not call on a shift from generic towards specific funding. Our data contains a relatively small number of observations submitted in specific calls. The specific calls have been subject to change over the years. Currenlty, STW's funding scheme has shifted towards more specific calls and towards more industry involvement by relying more heavily on cofunding. Moreover, the size of specific calls in terms of budget as well as number of applications has grown substantially at STW over the last decade. It would therefore be interesting to duplicate our analysis on more recent years of STW granting.

References

ANGRIST, J., AND M. ROKKANEN (2012): "Wanna Get Away? RD Identification Away from the Cutoff," NBER Working Paper, 18662.

ARORA, A., AND A. GAMBARDELLA (2005): "The Impact of NSF Support for Basic Research in Economics," *Annals of Economics and Statistics*, 79/80, Contributions in memory of Zvi Griliches, 91–117.

ARROW, K. (1971): "Economic Welfare and the Allocation of Resources for Invention," in *The Economics of Technological Change*, ed. by N. Rosenberg, pp. 164–181. Penguin.

CHUDNOVSKY, D., A. LÓPEZ, M. A. ROSSI, AND D. UBFAL (2008): "Money for Science? The Impact of Research Grant on Academic Output," *Fiscal Studies*, 29(1), 75–87.

DEUTEN, J., M. KIEFT, G. VAN DER VEEN, AND S. VERMEULEN (2011): "Evaluatie STW 2005-2010," Technopolis Group.

GAUGHAN, M., AND B. BOZEMAN (2002): "Using Curriculum Vitae to Compare Some Impacts of NSF Research Grants with Research Center Funding," *Research Evaluation*, 11(1), 17–26.

IMBENS, G. W., AND J. M. WOOLDRIDGE (2009): "Recent Developments in the Econometrics of Program Evaluation," *Journal of Economic Literature*, 47(1), 5–86.

JACOB, B. A., AND L. LEFGREN (2011): "The Impact of Research Grant Funding on Scientific Productivity," *Journal of Public Economics*, 95(9-10), 1168–1177.

KETEL, N., E. LEUVEN, H. OOSTERBEEK, AND B. VAN DER KLAAUW (2012): "The Returns to Medical School in a Regulated Labor Market: Evidence from Admission Lotteries," Working Paper.

LEE, D. S., AND T. LEMIEUX (2010): "Regression Discontinuity Designs in Economics," *Journal of Economic Literature*, 48(2), 281–355.

NELSON, R. (1971): "The Simple Economics of Basic Scientific Research," in *The Economics of Technological Change*, ed. by N. Rosenberg, pp. 148–163. Penguin.

A Patent matching procedure

Our matching procedure consists of three steps. First, we identified the relevant PATSTAT patent applications for which the last name of an STW applicant exactly matches with one of the names of the inventor(s) or applicant(s) of the patent application. We only search in the European Patent Office because it seems reasonable to assume that a patent application which is of importance will be filed to this office. This results in a substantial reduction of the PATSTAT dataset. Of course, this narrowed dataset will include false positives especially for some well-known last names that appear often in the Netherlands. There can also be a number of false positives in case of misspellings or name changes. Therefore, in the next step we use the initials of the STW applicants to improve the match. To obtain the initials of the inventor or applicant in the PATSTAT dataset we keep the first letter of the name of the inventor(s) or applicant(s) except for the matched last name. It should be noted this does not perfectly gives the initials because PATSTAT allows for more than one name of an individual and/or company. However, this is the best approximation of applicants' initials and we will take this into account when we assess the quality of our match. We do this by making use of the following index:

$$\text{index}_i = \frac{\ln\left(\frac{\text{matches}_i^2}{\text{initials\_PATSTAT}_i} + 1\right)}{\ln\left(\text{initials\_STW}_i + 1\right)} \tag{4}$$

where matches_i is the number of matched initials for applicant i, $\text{initials\_PATSTAT}_i$ is the number of initials, or first letters of all non-matched terms, in PATSTAT, and initials_STW_i is the number of initials of applicant i in the STW dataset. This index ranges from 0 to 1 with 1 being a perfect match. This allows us to consider certain matches above a prespecified threshold. We weight the match by the number of initials in our STW dataset to take into account that a match is better if the index = 1 for an applicant that has seven initials than for an applicant that has one initial.

As an example, suppose that A.B.C. Grant submits a research proposal to STW. After searching for the last name Grant PATSTAT returns the four following cases: (1) A.B.C. Grant, (2) A. Grant, (3) A.A.B. Grant Holding, (4) A.B. Grant Corporation. The initials of these cases are defined by our procedure as: (1) A.B.C., (2) A., (3) A.A.B.H., (4) A.B.C., and the index can then be calculated to be (1) 1, (2) 1/2, (3) 1/2, (4) 1.

Finally, we narrow the number of patent applications to the relevant time period which is similar to the time window used for publications. So, for a research proposal submitted in 2004 the pre-grant patent application period is from 2002 to 2005 and the post-grant patent application period is from 2006 to 2009.

Although our procedure will not give a perfect match, we do believe that it eliminates the vast majority of bad matches. Visual inspection of the matches for which there is a perfect match (index = 1) shows that the outcome would not change if we would have done the matching manually. Moreover, there are quite some matches that identify a unique person.

B First-stage results

Table 7a: First-stage results

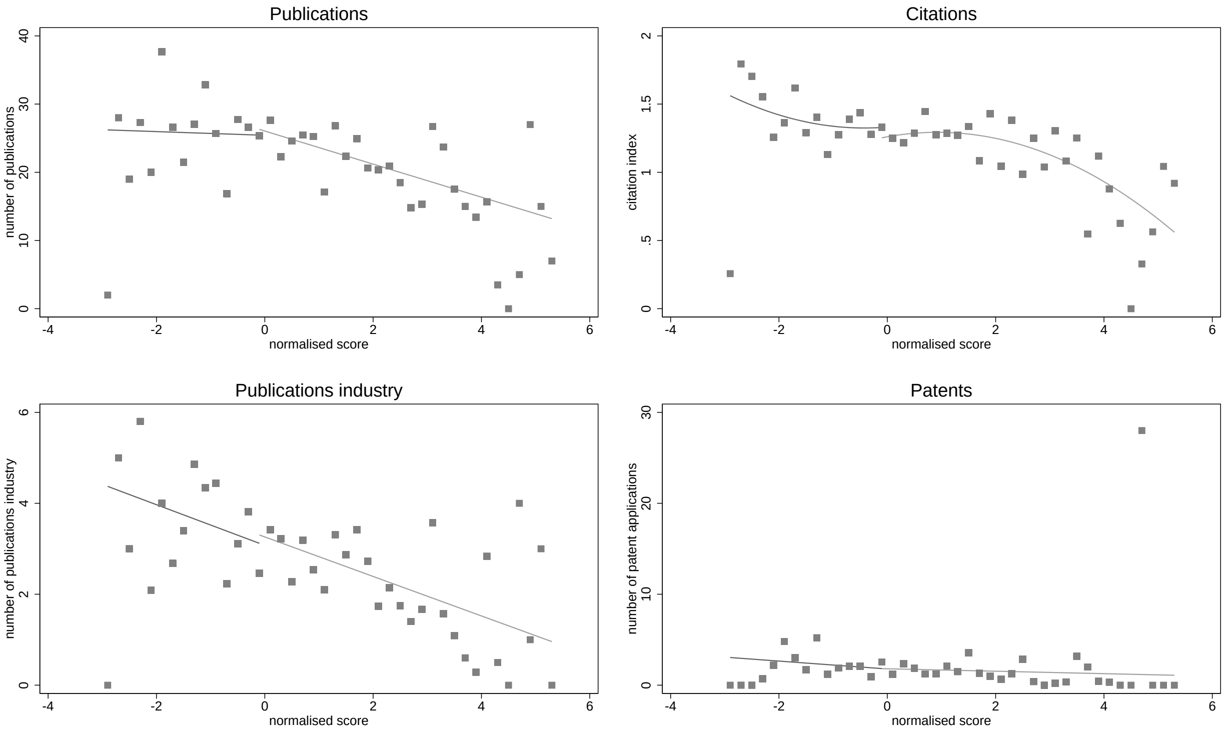
	(1)	(2)	(3)	(4)	(5)	OTP	Specific calls
Effect of a score before the cutoff on receiving a grant							
Publications	0.911***	0.882***	0.882***	0.884***	0.884***	0.888***	0.853***
	(0.00994)	(0.0213)	(0.0213)	(0.0209)	(0.0209)	(0.0231)	(0.0590)
F-statistic	8402	1714	1714	1782	1784	1471	210.1
Citations	0.911***	0.879***	0.879***	0.882***		0.868***	0.911***
	(0.00994)	(0.0289)	(0.0290)	(0.0288)		(0.0322)	(0.0587)
F-statistic	8402	922.9	920.4	938.8		724.6	253.6
Publications industry	0.911***	0.882***	0.882***	0.885***	0.884***	0.888***	0.853***
	(0.00994)	(0.0213)	(0.0213)	(0.0210)	(0.0209)	(0.0231)	(0.0590)
F-statistic	8402	1714	1713	1781	1783	1472	204.8
Patent applications	0.911***	0.882***	0.882***	0.885***	0.884***	0.888***	0.853***
	(0.00994)	(0.0213)	(0.0213)	(0.0210)	(0.0209)	(0.0231)	(0.0590)
F-statistic	8402	1714	1714	1783	1782	1465	212.4
Observations	1,572	1,572	1,572	1,572	1,572	1,353	219

Controls in each specification are similar to the main results presented in Table 5.

Robust standard errors are reported in parentheses clustered by main applicant, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

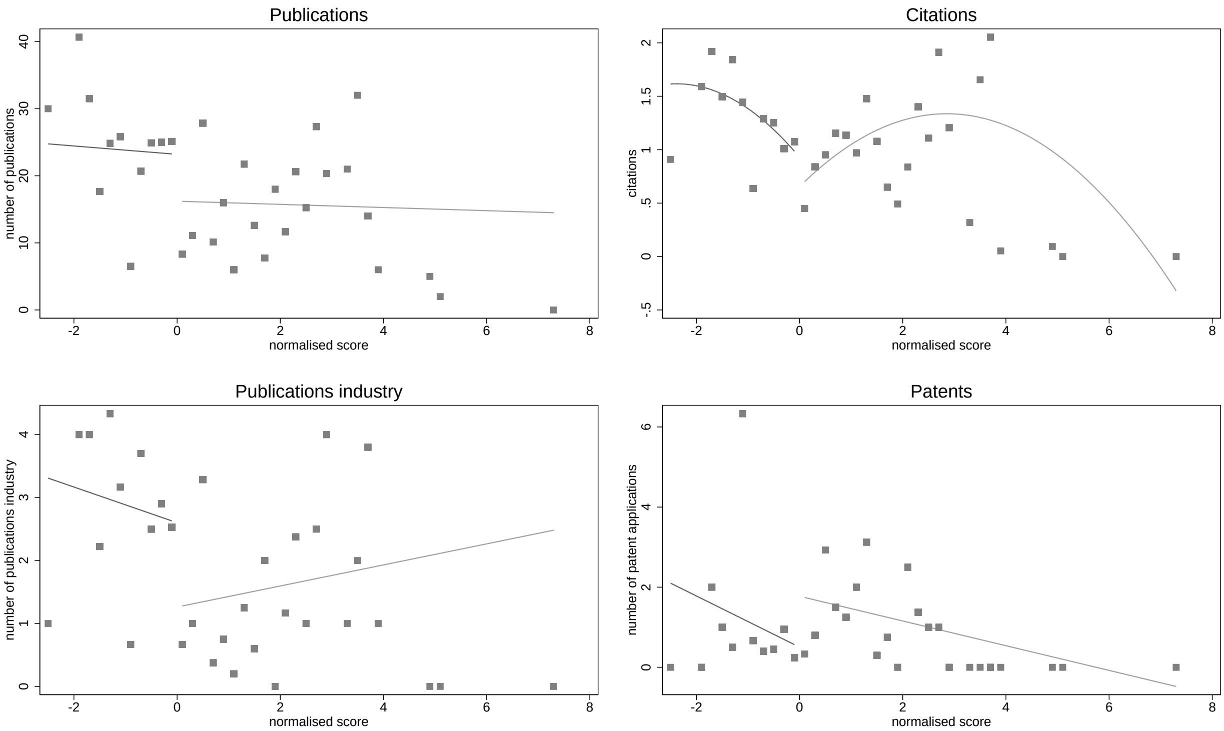
C Regression discontinuity - OTP and specific calls

Figure 4: Regression Discontinuity - Open Technology Programme



Note: The figures show the average research output for normalised priority scores with a binwidth of 0.2. Normalised priority scores below or equal to zero are granted whereas normalised priority scores above zero are not granted. The AIC for model selection is minimised using a linear relationship for publications, publications with industry, and patent applications and using a quadratic relationship for citations as is also shown in the subfigures.

Figure 5: Regression Discontinuity - Specific calls



Note: The figures show the average research output for normalised priority scores with a binwidth of 0.2. Normalised priority scores below or equal to zero are granted whereas normalised priority scores above zero are not granted. The AIC for model selection is minimised using a linear relationship for publications, publications with industry, and patent applications and using a quadratic relationship for citations as is also shown in the subfigures.

Publisher:

CPB Netherlands Bureau for Economic Policy Analysis
P.O. Box 80510 | 2508 GM The Hague
T (070) 3383 380

July 2013 | ISBN 978-90-5833-605-7