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Heterogenous Impacts of National Research Grants on Academic Productivity*

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Abstracts

Measuring the impact of research grants on academic productivity is essential for determining optimal funding allocation, selection processes, and evaluation criteria. This study evaluates the effect of Japan's primary national research grant (*KAKENHI*) on academic productivity in economics using novel administrative data from the Japan Society for the Promotion of Science (JSPS). To control for potential endogeneity and omitted variable bias, we employ a regression discontinuity (RD) design based on the peer-review scores used by the JSPS to select the applications to be funded. The results show that research grants increase the number of papers and citations in economics by 10–15% and 20–26%, respectively. The cost-benefit analysis indicates that the effect is three times greater for young scientists than for other recipients. Further, the results demonstrate that receiving the grant encourages junior scientists with tenure to independently carry out high-impact research, while it typically leads researchers without tenure to pursue quantity over quality.

Keywords: innovation, research grants, academic productivity, peer-review system, regression discontinuity design
JEL classification: H54, O31, O38

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1. Introduction

In various countries, government policies support research and development (R&D) activities, recognizing that innovation is the engine of economic growth and development. Allocating financial resources to scientific research is essential because the production of knowledge is a public good that the market would inevitably fail to supply (Arrow 1962). However, governments face competing social needs, and how to allocate the public R&D budget has become a central question in the policy debate. In this context, understanding the relationship between the provision of a research grant and the performance of the funded projects is crucial. However, to the best of our knowledge, only a few studies have examined the causal relationship between them (exceptions are Benavente et al. 2012 and Jacob and Lefgren 2011). In particular, there is little studies on heterogeneous impacts of research funding among applicants with different fields and attributes, although such studies are useful to decide how policymakers should allocate limited funding. To address this gap in research, this paper evaluates the heterogenous impact of national research grants in Japan (the KAKENHI, in particular) on the publication productivity of grant recipient with different background in economics.

The KAKENHI is the most extensive competitive funding program for academic research in Japan, which is managed by the Japan Society for the Promotion of Science (JSPS). The overall budget provided by the government was 237 billion yen in 2019. Academic researchers in Japan have increasingly relied on this funding source since the government began shifting from a stable flow of subsidies to research funding through competitive grants for universities in 2004, when national universities became independent entities under the newly enacted National University Corporation Law (Shibayama 2011; Wang et al. 2018).

To cope with the potential selection bias arising from superior researchers or proposals being systematically funded and other confounding factors that are correlated with both applicants attributes and research outputs, we employ a regression discontinuity (RD) design using peer-review scores as the forcing variable. The JSPS allocates limited research budget to applicants based on the review scores of all applications. Hence, a cutoff exists in the review scores between awarded and non-awarded applicants. Given that the grant decision is "as good as random" at the cutoff, we can identify the local average treatment effect (LATE) of the grant. The study's source of information is the administrative records, including the scores provided by the JSPS. To measure the quality of research done by the applicants, we obtain the number of forward citations that publications received as well as the number of publications.

Further, our rich data allow us to identify heterogenous effects of the funding across applicants with different attributes. The estimated effect for each of subsamples classified by researchers' academic positions and affiliations would reflect the conditions constraining the applicants' research productivity and their incentives as well as their capability. For example, since young researchers often do not have alternative funding sources unlike senior researchers, marginal return to funding for the former group will be higher than the latter group. Researchers' affiliations would also affect the productivity of funding. In general, researchers in top-ranked university or universities in metropolitan areas have better internal fund, research environment, and network to find collaborators than others. Thus, marginal return to research funding may be higher for those in other institutions that offer less resources and limited opportunities. Therefore, we expect the impacts of funding to vary across subgroups. We also need to understand that the results using RD represent the LATE around the cutoff, and is likely to be the lower bound of the total average effect of the funding on research outputs given the general expectation that ability and resources are complementary (Jaffe 2002). Therefore, our study reveals nothing about the total effect of research grants or the LATE for top researchers.

The results show that research grants in economics increase the numbers of publications and citations by 10～15% and 20～26%, respectively. The impact on the latter is higher than that on the former for the full and most subsamples, showing that the KAKENHI led to an increase in quality as well as quantity. Our cost-benefit analysis reveals that the effect is three times greater for young scientists (the Grant-in-Aid for Young Scientists) than for the recipients of the Grant-in-Aid for Scientific Research (B) (GSR-B). Further, while the grant helps researchers with tenure produce research with more citations and fewer co-authors, it causes researchers without tenure to publish more papers with no decrease in the number of citations. This result indicates that a stable job helps researchers to undertake a challenging project, whereas those on unstable positions are also pressed to increase more publications without sacrificing their research quality. Interestingly, we find that funding for projects in top ranked universities do not increase neither publications nor citations, while that for those in second ranked universities or below significantly increase both indicators. When comparing researchers in the Tokyo metropolitan area and *Keihanshin* (an abbreviation for Kyoto, Osaka, and Kobe) with those from other areas, the impact on the former areas is found to be twice as large. Lastly, we find a significantly positive productivity effect of the grant in applied fields (applied economics, economic policy, and history), but no effect in theoretical fields (theoretical economics, economic thought, and econometrics).

The remainder of the study is organized as follows. In Section 2, we review the relevant literature, and in Section 3, we briefly explain the KAKENHI programs. In Section 4, we introduce the data, and in Section 5, we describe the estimation strategy. In Section 6, we present the results. We summarize and interpret our findings in Section 7 and conclude in the final section.

2. Related literature and background

Although governments consider subsidizing academic research socially desirable, how to allocate resources efficiently is not straightforward. Various researchers examined the relationship between the provision of research grants and academic performance. Ebadi and Schiffauerova (2016) focus on natural sciences and engineering in Canada to evaluate the overall impact of funding on research outcomes. Their data include all funding—both public and private—that researchers receive. Their results show that grants are positively associated with the quality and quantity of publications. Gush et al. (2017) investigate the funding program in New Zealand and find that receiving grants is positively associated with academic outcomes. They also find that the funding increases the number of citations more than the number of publications.[2] Chudnovsky et al. (2008) and Fedderke and Goldschmidt (2015) focus on the funding program in developing countries, and present that the funding increased both publications and citations compared to researchers with similar scholarly standing who did not receive funding. Wang et al. (2018) compare competitive project funding that is largely KAKENHI to internal block funding in Japan, and find that the former significantly improve novelty of research than the letter.

However, some studies find no significant impact of competitive funding, especially on the quality of research. Arora and Gambardella (2005) study US economists receiving the National Science Foundation (NSF) grant and find that funded researchers do not increase their publications in the five years following the reception of the grant, on average. Using Swedish databases of university researchers, Sandström (2009) shows that the total amount of the grants received is weakly associated with the number of publications but do not significantly increase the number of citations per publication. Part of the reasons behind the mixed results might be that the impacts differ across research fields. Fukuzawa (2012) studies productivity effect of the large competitive fund in Japan using the difference-in-difference approach. The treatment group—those who received the funding is compared with a matched control group of researchers from the same department in the same university. The results show a significant and positive impact on both the number of publications and citations in life sciences, but only on the number of citations in information/electrical and electronic engineering. However, no significant effect is found in social sciences.

Another issue related to the estimation of the impact of research grants is the presence of confounding factors affecting both the likelihood of receiving grants and the recipients' research outputs (Jaffe, 2002). In particular, potentially productive researchers or researchers with high quality proposals are more likely to obtain competitive grants. Therefore, the impact on research outcomes might be overestimated. Conversely, the effect of funding on research outputs might be underestimated because

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[2] They attempt to use an RD design to evaluate the impact of the funding to control for other confounding factors. Unfortunately, they do not have sufficient observations for review scores around the cutoff in review scores.

various studies do not control for the presence of substitute funding sources.

To address potential bias, especially upward one, the RD design has been employed in the literature to identify the causal effect of research funding on academic outcomes. Jacob and Lefgren (2011) focus on Grant R01 in the National Institute of Health (NIH) funding in the US (the average grant is 1.5 million) for life sciences, using the review score as the forcing variable. They find that receiving grants enhances research outputs by only 7% or 1.2 publications over the next five years on average. Two possible explanations for the small effect exist: (1) the LATE around the cutoff rather than the total average treatment effect is estimated; and (2) multiple funding sources are available for many researchers in life science. Similarly, Benavente et al. (2012) study the impact of the Chilean National Science and Technology Research Fund on research outputs. They find a significant and positive impact on the number of publications, but they do not find any effect on the number of citations. They argue that the marginal impact is attributed to the small size of the grant ($50,000-100,000 per application) and the strict requirements for the research outcomes, such as the journal submission. Those studies exploiting the RD design indicate that the estimated impact of grants on academic outcomes could be small. However, the results do not necessarily imply that public research grants are ineffective because they might have larger impacts for applicants for whom scores are far beyond the cutoff. In addition, the total effects tend to be greater than the sum of individual effects due to the existence of substitutable funding sources.

A few studies also focus on the relationship between the effect of funding and researchers' characteristics. Although most research projects in economics do not require as large amount of funding as is needed by those in other disciplines like life science or experimental physics, some financial support is necessary for most economists to buy high-performance computers, employ research assistants, or travel to attend conferences. Young scientists are generally in poor research conditions and financial resources available to them are especially limited. Therefore, funding their projects should improve their research outcome more substantially than senior researchers. In reality, Arora and Gambardella (2005) show that younger economists who receive funding improve their academic outcomes. Chudnovsky et al. (2008) and Jacob and Lefgren (2011) also show that the impact of the funding is higher for younger grant winners, although the latter study no longer applies the RD design to this subsample. More recently, Wang et al. (2018) find that young scientists tend to undertake less explorative research when they receive competitive funding in Japan. They explain that young researchers have less chance of winning grants if they propose risky, explorative, and challenging research theme because they have little reputation and the reviewers find limited credibility in such proposal. If this is true, the productivity effect for young researchers of the funding would become modest or realize as more publications rather than more citations. Reassuringly, they find that competitive funds do not increase novelty of research for them.

To cope with their limited resources, some young researchers may rely more on senior researchers' fund. While this may increase their productivity through mentoring, peer-learning, or ready-made research agenda, they cannot pursue their own research idea. Receiving grants as principal investigators will allow them to do research more independently.

It is generally believed that researchers in metropolitan areas can more easily collaborate with other researchers and freely participate in conferences, workshops, and seminars organized by major schools, which are mostly concentrated in big cities. Since knowledge spillover often is confined by geographical distance (Jaffe et al. 1993; Lee et al. 2010). Researchers in regional cities and rural areas do not have as much opportunities to interact with other researchers as those in metropolitan areas. Further, since top-ranked universities receive greater internal block funding than lower-ranked universities, they can better promote research by hiring more researchers in similar research areas and buying more books and journals. This may imply that equally eligible researchers in local or lower ranked universities can increase their research productivity more substantially after receiving research grants than their counterparts in top ranked universities. On the other hand, the financial resources received by researchers in metropolitan areas or high ranked university may be mostly used to increase inputs such as data collection, hiring research assistants, and inviting coauthors from abroad to further build their advantage rather than investing in basic research environment (e.g. buying PCs, wifi connection and journals, traveling to attend workshops in metropolitan areas etc.).

In this study, following Jacob and Lefgren (2011) and Benavente et al. (2012), we employ RD design and estimate the LATE around the cutoff, and further, the rich information of applicant characteristics in our dataset allows us to apply this method to various subgroups to examine how heterogeneous the impact is depending on researchers' characteristics.

3. Government Funding for Academic Research in Japan

3.1 The KAKENHI system

The KAKENHI is the largest government funding program for academic research in Japan. The fund covers all disciplines, including humanities and social sciences, as well as natural sciences and engineering. The KAKENHI is managed by the JSPS, a funding agency of the Ministry of Education, Sports, Science, and Technology (MEXT, henceforth). The funding purpose is "to significantly develop all scientific research (research based on the free ideas of the researcher), from basic to applied research," and "the scope of the funding is "for creative and pioneering research projects that will become the foundation of social development."[3] Thus, the JSPS allocates the grants based on the applicants' research proposals and

[3] The goal of the funding is explained in webpage in the JSPS at: https://www.jsps.go.jp/english/e-grants/index.html

the main criteria include creativity and novelty. The majority of academic researchers in Japan rely on this grant to carry out research (Shibayama 2011; Wang et al. 2018). Overall, 94% of respondents surveyed by the MEXT declared that the KAKENHI was the primary funding source for their research (Iida, 2007).

The KAKENHI provides different grants based on the purpose and scale of the research and the applicants' age. The largest categories either in terms of the number of applicants or the budget are Grant-in-Aid for Scientific Research (S) (A) (B) (C), the Grant-in-Aid for Young Scientists (S) (A) (B), and Grant-in-Aid for Young Scientists start-up (GSR-S, A, B, C, GYS-S, A, B, and GAS, henceforth). The main difference between the GSR and the GYS is the requirement of age limitation and whether co-investigators are allowed or not. The latter only allows researchers under 39 years old to apply (37 years old before 2009) and do not allow applicants to list co-investigators who share grants, while the former does not impose any age limitation or individual researcher requirement. S, A, B, and C indicate the categories distinguished by budget ceilings. The funding ceiling for the GSR-S is 200 million yen and 50 million yen in the GSR-A, and the number of awards is far more limited than in other grant categories. The majority of applications are submitted to GSR-B, C, and GYS-B.[4] The ceiling for the GSR-C and GYS-B is 5 million yen, but the number of awards is large. The GSR-B is in the middle, and its ceiling is 20 million yen. The GAS is very similar to the GYS-B, but it has a different application period. The characteristics of each type of GSR/GYS and GAS are described in detail in Appendix 1. Since the proposed estimation strategy needs a sufficiently large number of observations in both awarded and non-awarded samples, we focus on GSR-B, C, and GYS-B,[5] which comprise over 96% of all applications and 70% of the total grant budget earmarked for economics (Table A1). The field of economics comprises seven subfields in the KAKENHI: economic theory (3601), economic doctrines and economic thought (3602), economic statistics (3603), applied economics (3604), economic policy (3605), public finance and monetary economics (3606), and economic history (3607). An applicant needs to choose a subfield in which his/her application is reviewed.

The following application rules apply to the grant categories of interest. First, an applicant, as a principal investigator, is required to choose only one category, and he/she can apply for the KAKENHI only once a year. Second, a principal investigator who is awarded the KAKENHI is not allowed to reapply for any other GSR/GYS grants as a principal investigator until the last year of the current grant period.

[4] The ceiling for GYS-S is 100 million yen and 30 million yen for GYS-A.

[5] We also include the Grant-in-Aid for Young Scientists start-up and its continuous grant, the Grant-in-Aid for Research Activity start-up because these two funding sources are similar to GYS-B in their purpose, scale, and applicant qualification. In the start-up programs, only researchers who have just become eligible for the grant (e.g., employed by Japanese research organizations or returned from parental leave) can apply, approximately half a year earlier than the regular application period for the GSR/GYS programs.

Thus, each researcher can apply for the KAKENHI as a principal investigator only once a year, except for a small number of special-purpose funds.[6] Therefore, in the case of rejection, the applicant needs to wait until the next year to apply again. However, awarded researchers can join KAKENHI-funded projects led by other principal investigators. Third, the application process takes several months; thus, applicants need to plan their submission far ahead. Proposals are submitted in October, and applicants are informed of the result of their application in April. Then, they can start their research. Unsuccessful applicants need to wait until next April to apply again. Partly due to this delay, the JSPS allows principal investigators to modify their research plans without notification, to some extent. This flexibility presumably encourages researchers to explore or pursue new research questions more freely.

3.2 Examination process

To select the successful proposals, the KAKENHI employs a single-blind peer-review: reviewers know the applicants' names, but applicants do not know who review their proposals. The review process comprises two stages. In the first stage, reviewers (typically three or four reviewers assigned to a set of 70 applications, on average) give each application a score between 1 (poor) and 5 (excellent) based on evaluation criteria established by the JSPS guidelines. In doing so, each reviewer needs to force the curve of his/her evaluations to a predetermined distribution: 5:10%, 4:20%, 3: 40%, 2: 20%, and 1: 10% of all applications that the reviewer assesses. Further, to adjust for the differences in variance of the score distribution across reviewers, the JSPS normalizes the score by using a method called "*T-score*."[7]

In the second stage, a secondary-review committee discusses the decision according to the T-score rank and finally selects the proposals to be funded. The committee members are different from the first-stage reviewers except for the GAS, where the first-stage reviewers make the final decision on the grant. Since the secondary-review committees are provided with a ranking of the proposals based on the average T-scores, they generally discuss only the appropriateness of the ranking among proposals whose review scores are around the cutoff. The number of grants funded in each category and discipline in a year is decided in advance based on the government budget, the number of applications, and the amounts required in the proposals. In reality, a formal calculation equation is used to allocate the budget. The

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[6] This rule implies that we do not need to distinguish among the award rate (application-based), success rate (project-based), and funding rate (applicant-based) used by the National Institutes of Health (https://nexus.od.nih.gov/all/2014/03/05/comparing-success-award-funding-rates/) because they coincide in the context of KAKENHI. We use the award rate throughout the study.

[7] The JSPS calculates the T-score using the following equation: $Tscore_{ij} = \frac{(score_{ij} - \overline{score}_j) \times 0.6}{\sigma_j} + 3$ j: reviewer j ; i: applicant i.

committee for economics most likely chooses the number of awards so that the award rate is similar across subfields. Thus, the award cutoff is essentially exogenous in a year. However, the committee sometimes swaps the order in the ranking on the basis of their own reviews, their interpretation of the first reviewers' comments, and possibly other information.

4. Data

To evaluate the impact of KAKENHI grants on research outcomes, we use administrative records of the KAKENHI in the field of economics between 2005 and 2012 obtained from the JSPS. The data contain all unsuccessful and successful applicants' information, such as their names and affiliation, the submitted categories, and the subfields. The peer-review scores and reviewer names for all applications in the first stage are also available.

To measure the research outcomes, we use the number of publications and forward citations obtained from the Scopus database published by Elsevier. Although Scopus covers a broader range of peer-reviewed journals than any other database, it is subject to some limitations. Some research outputs by Japanese economists are published in *Japanese*, especially in economic history, economic policy, regional studies, and Marxist economics. Since almost all these publications are not included in Scopus, our outcomes variable might underestimate the impact of the grants. Another problem is that Scopus reports several non-refereed articles, such as conference proceedings and books. Therefore, our quantity indicator may be a noisy measure of research productivity. For this reason, we prefer citation counts to measure the quality of research. We do not use the funding sources revealed in the acknowledgement of articles to detect outputs supported by each grant because the JSPS did not rigorously require authors to present it until recently.

Using the applicant's name and affiliation, we manually collected applicants' publications. In this process, we encountered several problems. First, we needed to convert names written in *Kanji* (Chinese characters) from the KAKENHI database. In many cases, we used applicants' professional bios or CVs on their personal or institutional websites to determine the accurate spelling of their names because many *Kanjis* have multiple pronunciations in Japanese. We also used the CVs to double-check whether we collected their publications correctly. Second, although same names are rarer among the Japanese than among the English, ambiguities exist in the data from Scopus. The data also include names of foreign origin. We discarded the applicants when we could not uniquely identify their publications in Scopus.[8] In this process, we also discarded applications with errors in the administrative data. The final sample

[8] Although Scopus assigns ID numbers to researchers, we found that this number is not sufficiently reliable to identify individual researchers.

comprises 7145 observations.

5. Estimation Strategy

Since the KAKENHI is not randomly assigned to applicants, the causal impact of the grants on research performance is hard to disentangle. Successful applicants are likely to have superior past research productivity and better prospects for future publications. Therefore, the estimated impact of the grant on research performance may be biased upward if one just compares the mean publications or citations between awarded and non-awarded applicants, conditional on observables.

In line with the literature, to identify the causal impact of the grant on performance, we employ the RD design. We examine the difference in research outputs between the treatment and control groups near the cutoff of the review scores as the local treatment effect. Since the cutoff varies across subfields, we centered the cutoff at zero by subtracting the cutoff score from each score. Since the second-stage reviewer committees sometimes swap the order in the ranking, the sample includes successful applications just below the cutoff and unsuccessful applications just above it. Therefore, we employ a fuzzy RD design with instrumental variables (IV). However, since some subfields in each year present a sharp discontinuity (i.e., the second-stage reviewers simply endorsed the judgment of the first stage), we also show the results estimated by a sharp RD design by restricting the sample to the interested subfields, as a robustness check. The research outcome equation is as follows:

$$Y_{it+6} = X_{it}\pi + \beta KAKENHI_{it} + f(ts_{it}) + \varepsilon_{it+6} \quad (1)$$

where Y_{it+6} is the outcome of interests—the numbers of publications and received citations, in logarithm, between t+1 and t+6 for individual i.[9] We do not account for research outputs in the starting year of the KAKENHI because publishing in the first year of the grant is very unlikely. To control for the truncation problem that arises using the number of citations, we introduce application year dummies in the estimations.

$KAKENHI_{it}$ is a dummy variable that takes a value equal to one at time t if an economist obtains a KAKENHI grant, and zero otherwise; $f(ts_{it})$ is the polynomial function of the normalized T-score that captures the effects of the quality of proposal and other applicant abilities. We use a cubic

[9] We consider six years from when researchers receive the grant because the publication delay in economics is longer than in other disciplines, and the average lag is 18 months (Björk and Solomon, 2013). Using all awarded applicants, we roughly depict the average number of publications before and after receiving the KAKENHI in Figure A1, showing that the peak of publications is in five years.

function for the score. X_{it} is a vector of other covariates describing individual characteristics, including the number of past publications (in the five years before the application), a dummy variable indicating whether the applicant received a KAKENHI grant within five years from the application, a dummy variable for whether the applicant was a member of another KAKENHI project as a co-researcher in the application year, a female dummy, a foreign applicant dummy, academic degree dummies (e.g., a master's degree dummy and a PhD degree dummy), academic title dummies (e.g., professor, associate professor, and so on), university prestige dummies, grant category dummies, and subfield dummies. We report the definition, data sources, summary statistics, and correlation matrix for all variables in Appendix B.

The first-stage equation for the IV estimation is as follows:

$$KAKENHI_{it} = D_{it} + D_{it} \cdot g(ts_{it}) + g(ts_{it}) + X_{it}\gamma + u_{it} \quad (2)$$

The variable D_{it} takes a value equal to one if the score of the proposal is above the cutoff, and zero otherwise; $g(ts_{it})$ is the polynomial function of the normalized T-score. We also include a cross term between D_{it} and $g(ts_{it})$.

We need to define the cutoff for using the RD approach. The proposals with higher scores are not always awarded grants since the review committee sometimes switches the order in the ranking in the second stage, thus funding proposals with scores below the cutoff. Fortunately, as mentioned above, the number of funded proposals is almost entirely determined before the selection process, based on the government budget and the number of applications in all disciplines and subfields. Therefore, the proposal award rate is not significantly different across the six subfields in economics. Figure A2 shows the time series of the average award rate in each subfield for GSR-C and GYS-B, confirming that the award rates are similar across subfields in each year. The subfield "economic doctrines and economic thought" often deviates from other fields probably because the number of applications in this subfield is low (i.e., accepting one more application causes a discrete jump in the award rate).

Since the number of applications funded is decided ex-ante, we order the proposals according to the score, and then, we define the cutoff at the lowest score within the number of applications funded from the top. In other words, the cutoff is the lowest score among the proposals that would have been awarded if the selection decision had been made by the score order. We calculate the cutoff for each subfield and year for GSR-B, C, and GYS-B. For the GAS, we calculate the cutoff in all subfields together because the same reviewers score all subfields. As mentioned above, some proposals are awarded below the cutoff. Therefore, we examine how the probability that a given application is funded depends on its score, to determine whether the probability increases when the score crosses the cutoff. In Figure 1, the probability of applications being funded is illustrated as a function of scores using a kernel-weighted local polynomial regression for the full sample of GSR-B, GSR-C, and GYS-B+GAS. We observe a jump in the probability of the proposal award rate at the cutoff. The award rate becomes zero at lower scores or one at higher scores, far from the cutoff.

To obtain a robust estimation, we focus on the local sample near the cutoff. To this end, we need to choose an appropriate bandwidth around the cutoff. The distribution of the score is bumpy primarily because the raw score that each reviewer gives is an integer from five to one, although the funding agency tries to smooth the distribution by calculating the T-score and taking the average over the reviewers. The right- and left-hand side upper panels of Figure 2 show the distributions of the scores and T-scores in the sample, respectively. The distribution of the T-scores is somewhat smoother than that of scores, but even the T-score distribution is bumpy. The left-hand side bottom panel of Figure 2 presents the distribution of the normalized T-score in the full sample, and the right-hand side bottom panel shows the distribution of the scores near the cutoff. Substantial unevenness is observed near the cutoff because the row score is discrete. The ±0.23 bandwidth is likely a suitable choice because a deviation from the cutoff due to one person raising or reducing his/her score by one corresponds to ±0.22 in the T-score assuming three reviewers, the minimum number of reviewers per proposal.[10] When estimating Equations (1) and (2) using this local sample, we discard $f(ts_{it})$ and $g(ts_{it})$, the polynomial functions of the normalized T-score, because the sample distribution is locally discrete around the cutoff.

The key assumption in an RD design is that applicants cannot raise their scores—the forcing variable—beyond the cutoff when necessary. It is a reasonable assumption because nobody, even reviewers in the first stage, knows the cutoff in advance.[11]

Another issue in our quasi-experimental design is that applicants who failed to obtain the grant in a year may succeed in the subsequent year. In this case, those included in the control group in year t will be double-counted in the treatment group in year $t + 1$ because the study's unit of observation is the applicant-application year (instead of the application). These two observations in consecutive years presumably exhibit very similar research productivity given that four years overlap, as illustrated in Figure 3, leading to the underestimation of the effect of the KAKENHI on research outcomes. Table A5 shows that the average award rate, the award rate for applicants who failed to obtain the KAKENHI in the previous year, and the award rate for applicants who failed to obtain the grant for a small margin in the

[10] The number of reviewers may be reduced to two if one reviewer declines to evaluate a proposal because of some conflict of interest.

[11] While reviewers in the first stage do not know the exact cutoff in their review process, they can predict whether the proposal will be awarded or not based on their own score. For example, if a reviewer gives the lowest score (1) for a proposal, this means that the proposal will not be awarded. However, they cannot predict whether the proposal will be awarded or not near the cutoff.

previous year. The award rate is lower but substantial (around 20–25%) when applicants apply in the subsequent year after the initial failure in the full sample, and it becomes significantly higher among those who did not obtain the grant by a slight margin (around 30–40%), implying the presence of severe double-counting issues. We address this problem by discarding the unsuccessful applications whose applicants were awarded a grant within three years after the rejection. As stated earlier, a researcher can apply for the KAKENHI only once a year for only one category, such as GSR-B and GSR-C, except for some special-purpose categories that we do not target in this study. This rule mitigates the underestimation problem present in other studies (Jacob and Lefgren 2011). The double-counting problem is harder to deal with when applicants are allowed to apply for grants several times in a year, as is the case of Grant 01 in the NIH in the US.

6. Results

6.1 Graphical analysis

We first graphically represent the relationship between the review score and research outcomes. We use a kernel polynomial function to approximate the relationship above and below the cutoff, which allows observing the presence of a discontinuity or a jump in research outputs around the cutoff. The results are reported in Figure 4. The left-hand side panels in Figure 4 show the relationships between the score and each of the outcome measures—publications (top) and citations (bottom) –for the full sample, and the right-hand side panels show the same relationships for the local sample, which includes applications with scores within the ±0.23 bandwidth around the cutoff. We do not find any discontinuity at the cutoff in the top panel, while we observe jumps at the cutoff in the bottom panels of Figure 4. This result does not necessarily imply that the national research grant had no effect on publications because "non-compliers" on both sides of the cutoff—grant recipients whose score is below the cutoff and non-recipients whose score is above the cutoff—likely contaminate our estimates of the productivity effect of the KAKENHI. Figure 5, which restricts the sample to "compliers," tends to exhibit a larger jump at the cutoff for outcome measures, including the number of publications. The results support the general perception that the KAKENHI enhances research outputs.

Apart from the jump near the cutoff, we find that the score given by the reviewers is generally positively associated with subsequent research outcomes. Further, the research outputs dramatically increase with the score toward the highest score level. This result shows that reviewers in the KAKENHI can correctly identify high-quality projects, which are expected to generate substantially higher research outputs in terms of both quality and quantity.

6.2 Estimation results

Table 1 presents the ordinary least squares (OLS) and IV regression results for Equation (1) using the full sample. The outcome variables include the logarithm of the number of publications and the logarithm of the number of citations. In the IV estimation, the *Kleibergen-Paap Wald F statistics* of the first stage is 1669, indicating that the estimation does not suffer from the weak instrument problem. The coefficients for KAKENHI are positive and significant. Receiving a KAKENHI grant increases the number of publications by 10%~15% (columns 2 and 3) and the number of citations by 20%~26% (columns 5 and 6) in the second stage, where the estimation conducted using the local sample tends to give greater effects. Further, the coefficients for KAKENHI are higher for the number of citations than for the number of publications, validating the positive impact of the grant on both the quantity and the quality of the research output. This shows that the KAKENHI encourage awarded researchers to pursue high-impact research as well as initiating more research projects. The coefficients in the OLS estimation are larger than those in the IV estimation, confirming our prediction that the former are overestimated due to selection.

One concern is whether the predetermined covariates are balanced at the cutoff. This assumption could be violated when some reviewers have control over the chance of crossing the cutoff (e.g., some reviewers are better informed of how other reviewers' rate AND motivated to bias the decision). We examine the relationship between the score and a past performance measure, such as the number of publications in the last five years, the incidence of KAKENHI participation in the last five years, and the concurrent participation in other KAKENHI projects for those around the cutoff. The relationship is approximated by a kernel polynomial function of the score shown as solid curves in Figure 5.

The top, middle, and bottom panels of Figure 5 present past publications, past KAKENHI experience in the last five years, and joining other KAKENHI projects, respectively. The left panels show the results for the full sample, while the right panels correspond to the sample within ±0.23 bandwidth around the cutoff. While the discontinuities at the cutoff are not observed for past publications, we find striking discontinuities for the past KAKENHI experience. Since the reviewers in the first stage do not know the exact cutoffs, this is a surprising result. The bottom panel also suggests the presence of a potential discontinuity for concurrent co-investigator status in other KAKENHI projects. The reason behind these results might be that the sample distribution below the cutoff is quite thin because of the discrete distribution of the score, as shown in Figure 2 (c), and this may lead to inaccurate smoothing lines at the cutoff. However, this result may also be caused by reviewers' tendency to assign a slightly higher score to applicants who obtained the KAKENHI in the past when they feel that the quality of an application is close to the cutoff. Having obtained the KAKENHI grant before is a signal that past reviewers gave the applicant a higher assessment. We conduct three robustness checks to cope with this potential bias. First, we estimate the equation restricting the sample to those who applied for the KAKENHI for the first time. Second, we estimate the same equation using randomly sampled applicants so that the average past KAKENHI experience becomes the same below and above the cutoff within the local bandwidth.[12] Third, we further restrict the sample to those who applied for KAKENHI for the first time and had no concurrent co-investigator status in other KAKENHI projects. The results are reported in columns (1)-(5) of Table 2. We only report the results obtained using the logarithm of the number of citations as the dependent variable as the results for the different output variables are similar. The coefficients on KAKENHI are all significant and positive for the number of citations. The effect of the KAKENHI grant on the number of citations is 26–30% in the estimations using the local sample, higher than the estimated effect using the original sample. This result implies that the findings reported in Table 1 are not biased because researchers' past experience in KAKENHI is not balanced.

Finally, the data include category-subfield-year groups for which second-stage reviewer committees did not change the order of score rankings around the cutoff, thus allowing sharp RD at the cutoff for the subsample within ±0.23 bandwidth. Columns (6) and (7) of Table 2 present the OLS results and show that the funding is significantly and positively associated with the number of citations.

Although the results are not presented, we conducted various robustness checks using (1) all applicants except those whose research outputs are in the top 1% to eliminate the influence of outliers; (2) the number of publications and citations with different time windows to account for longer publication lag in economics; and (3) experience and its square term to control for the experience effect on research performance. We obtained qualitatively similar results.[13]

6.3 Estimation by categories and subfields

In this subsection, we investigate how the impact of KAKENHI grants on research outcomes vary across categories and subfields in KAKENHI. Although these analyses give us implications on how the research grant should be allocated, we interpret the results with caution because the availability of alternative funding sources may also depend on the classifications. Columns (1)-(6) in Table 3 show the baseline two-stage least squares (2SLS) regression results for the number of citations by a subsample of KAKENHI

[12] We first divided the local sample of applicants into four groups: above/below the cutoff and having/not having past KAKENHI experience. We next adjusted the sample size of each group by re-sampling so that the ratio of those having obtained the KAKENHI in the past five years is the same below and above the cutoff. We then estimated Equation (2) using 2SLS, as shown in Table 1. To confirm the results, we re-estimated it with repeated random sampling (ten times), and we obtained similar results to the ones shown in Table 2.

[13] In the third exercise, we obtained information at the researchers' starting year of their careers from their webpage. Unfortunately, since not all researchers have personal websites or fully disclose their academic career, we only obtained 6,152 observations in the full sample and 2,167 in the local sample.

grant categories. The coefficients on the GSR-B grant are positive for both the full and local samples but only significant for the latter. The coefficients on the GSR-C and GYS-B+GAS are significant and positive for both specifications.

The results in Table 3 only show the statistical and economic significance of the impact of KAKENHI grants. The amount of the grant, however, significantly varies across grant categories–the average amount of a grant is 14.1, 3.5, and 2.8 million yen for GSR-B, GSR-C, and GYS-B, respectively. To perform a cost-benefit analysis, we calculate the impact on the number of citations per one million yen by dividing the effect on the number of citations on the extensive margin (how many more citations a researcher can receive in the future by obtaining one additional KAKENHI grant) by the average amount in millions. The result in Table 4 shows large differences in this measure. The impact of GYS-B and GAS, the grants mainly earmarked for young researchers, is more than three times larger than that of GSR-B, which is typically awarded to more established researchers. This result is consistent with Arora and Gambardella (2005), Chudnovsky et al. (2008), and Jacob and Lefgren (2011), who show that funding is more effective among younger scientists.

Next, we look at how the return from KAKENHI grants varies across subfields in economics. We re-classify seven subfields into two groups: "*theoretical fields,*" comprising *economic theory*, *economic doctrines* and *economic thought,* and *economic statistics*, and "*applied fields,*" including *applied economics*, *economic policy, public finance and monetary economics,* and *economic history*. One may predict that theorists can conduct most projects with little difficulty without research fund. Thus, we hypothesize that the impact of research grants will be smaller in the former than in the latter group. Columns (7)-(10) in Table 3 report the estimation results. While applicants significantly increase the outputs in applied fields after their projects are funded, the same effect is not observed in theoretical fields, supporting the prediction.

6.4. Estimation by academic positions and affiliated institutions

Next, we study how the impacts of research grants differ depending on applicants' academic positions, which might mediate the effects of age, experience, reputation in the academic community, and the ability to find alternative funding sources. We compare four positions: professor, associate professor, assistant professor with tenure, and assistant professor/researcher/postdoc without tenure. As we above mentioned, young researchers concentrate in positions with the assistant professor title and those without tenure will often face insufficient research funding or bad research environment, and therefore, obtaining a KAKENHI grant boosts their research productivity. We limit the sample to university staff because other institutes might have other research budgets, such as internal funding. We show the estimation results using the number of publications, citations, and authors per publication as dependent variables. Panels A and B of Table 5 show that KAKENHI grants have smaller impacts on the number of citations for professors than for other academic positions, especially when we use the local sample near the cutoff. In line with the interpretation of the results for the grant categories, the effects on professors are likely to be underestimated because senior and more established researchers may have access to alternative funding opportunities. The results suggest that receiving grants significantly increases the number of publications among assistant professors/researchers/postdocs without tenure in both the full and the local sample, while this effect is not observed among assistant professors with tenure. This result shows that younger scientists without tenure tend to pursue quantity over quality, on average. In other words, researchers without tenure tend to pursue outcomes in the short run. In Japan, since the tenure-track system was not very common during the estimation period, many younger researchers without tenure were faced with the need to move to other positions within a short period regardless of their research outcomes, and therefore, they needed to accomplish their research quickly.[14] This situation is likely to affect younger researchers' behavior. In contrast, the results suggest that researchers with tenure can focus on research quality, while those without tenure also maintain their research quality roughly. Further, the results in panel C of Table 4 indicate that obtaining the KAKENHI grant significantly reduces the number of authors per publication for assistant professors with tenure, while the grant does not have a similar effect for other positions. This finding indicates that grants help younger researchers conduct research more independently.[15]

Finally, we also attempt to identify whether the impact of the research grants varies depending on region or university ranks. Researchers in rural area or in lower ranked university face less alternative funding source and poor research environment or difficult to access research network. Therefore, the funding will help them to proceed their research more than research with better funding, environment or network. We constructed two sub-samples based on whether the applicants' institutions are located in a metropolitan area. We define Tokyo (Tokyo-Kanagawa-Saitama-Chiba) and *Keihanshin* (Kyoto-Osaka-Kobe) areas as the metropolitan area. The two subsamples are balanced in terms of size. The coefficient on KAKENHI is large and significant for applicants in the metropolitan area, while the coefficient on those living in other areas is insignificant when we use the full sample, as shown in columns (1) and (3) of Table 6. Although the impact of the grants on applicants in the metropolitan area is twice larger than in other areas in the full sample, thus implying that financial resources are complementary to regional

[14] The tenure-track system formally adopted in Japan in 2007 by revised government policy (Shibayama 2011) only gradually spread among institutions and have not become the mainstream recruitment channel for entry-level positions except for top-ranked schools as of now.

[15] Women are also disadvantaged in terms of resources due to lower promotion rate, lower salary, parenting burden, and smaller research network. Thus, we also evaluate gender differences in the impact of the funding on research performance. But, we did not find any significant differences between men and women partly due to a very small sample of female researchers.

advantage, the difference is much smaller and insignificant when the coefficients are compared in the local sample near the cutoff, as shown in columns (2) and (4) of Table 6.

Further, we re-estimate the same equation with subsamples of affiliated institutions categorized by the university ranking in obtaining KAKENHI grants. The first tier includes six universities that received more than 300 KAKENHI grants, and the second tier includes 19 universities that obtained 299-100 KAKENHI grants. Column (5)-(11) of Table 6 report the result. Interestingly, the impact of the KAKENHI does not significantly increase research performance among the top tier group. KAKENHI grants have significantly greater impacts on the other two groups. This result may imply that research funds are inefficiently concentrated within the top-six universities. However, it may also be the case that the additional impact of the KAKENHI is marginal in top research universities because these institutions are likely to have alternative financial resources, such as opportunities to participate in their coworkers'/coauthors' KAKENHI projects, or because there may be positive spillovers from colleagues who obtain large grants.

We also examine whether the impacts of KAKENHI grants vary depending on the type of funding entities, namely, the institutions that applicants belong to, national universities or private universities, as the former are the most affected by the recent government austerity measures. The results are reported in columns (11)-(14) of Table 6. No significant differences are observed in the impact of the grants between the two types of institutions.

7. Discussion

While our main results show that the impact of KAKENHI grants is significantly positive for publications and citations, the latter indicator is higher than the former one in most estimations. This suggests that having KAKENHI grants enhance their research quality as well as their quantity. This result is in line with, Ebadi and Schiffauerova (2016), Gush et al. (2017) and Wang et al. (2018) but in contrast with Benavente et al. (2012), who, using the same RD design approach, found that the public research grants in Chile only increase the number of publications but not the number of citations per publication. The difference may reflect the fact that Chilean grants require paper submissions within the funding period and strictly impose this rule. Such a policy might induce Chilean researchers to set less ambitious goals and submit very preliminary works with less novel results. This interpretation is in line with Azoulay et al. (2011), who show that early tolerance for failure encourages innovative research output. This also explains the findings of Wang et al. (2018) that the competitive funding (the almost all part is the KAKENHI) in Japan increase highly novelty outputs among senior researchers, despite their concern that competitive funds might induce less risky and challenging research than block funding.

Our cost-benefit analysis results present that the effect of the grants on academic outcomes is higher for young (GYS-B) than senior researchers (GSR-B). This is also consistent with the findings of previous studies (Arora and Gambadella 2002; Chudnovsky et al. (2008); Jacob and Lefgren 2011). One possibility is that the applicants for the GSR-B are more established researchers, thus likely to have other alternative sources of funding, such as the allocation to co-investigators from other KAKENHI projects. In contrast, applicants for the GSR-C and GYS-B+GAS are younger and less established researchers and, therefore, they may need to revise or give up their research plan if they are not funded. Nonetheless, the stark difference in the impact seems to suggest that the JSPS may need to raise the research budget for young researchers to improve cost-effectiveness. This result supports the JSPS's recent policy shift, which has determined to allocate a larger share of the budget to younger researchers. The award rates for GYS and GAS were raised to 40.0% and 37.5% in 2019 from 30.7% and 25.3% in 2018, respectively.

It is notable that only young researchers without tenure tend to prioritize research quantity. The result is intuitive because those researchers are hired in fixed-term positions and need to accomplish their research in shorter periods to obtain next jobs. This pressure would induce them to pursue more publications. Another important finding is that only assistant professors with tenure tend to do their research more independently after getting KAKENHI grants. This is not necessarily intuitive because research grants generally help the recipients to expand research network and increase their coauthors (e.g., Hicks et al. 2019; Ubfal et al. 2011). One obvious reason might be that GYS-B for which many assistant professors apply for do not allow co-investigators. However, this is unlikely to be the primary reason because running the same estimation for the GYS-B sample produces only insignificant coefficient for authors per publication. Another and more plausible interpretation is that young researchers do not need to rely on senior researchers' research fund any more once they acquire research grant successfully and start focusing on their own research project.

Finally, our results show that the impact of KAKENHI grants on research productivity is insignificant and even negative for researchers in top ranked universities, while it is highly positive and significant for those in the other universities. This may show that inefficiently skewed allocation of research budgets for those universities. Such concentration of the research funding has been critically pointed out by previous studies (Hand and Wadman 2008; Shibayama and Baba 2015), and some of those studies find that the marginal productivity of the funding is substantially reduced by the concentration (Mongeon et al. 2016; Nag et al. 2013). While our result is in line with those studies, other interpretations are also possible. For example, researchers in top ranked universities can more easily find other funding sources such as joining their colleagues KAKENHI projects or rely on safety-net support from the university that can use more internal block fund. It is also possible that research grants have substantial externalities such as knowledge spillovers. If top ranked universities attract many research grants, even those who are not awarded grants may benefit from the resources or knowledge brought by the recipients of the grants (Lee et al. 2010).

8. Conclusion

This study examines the impact of KAKENHI grants, the Japanese national funding program for academic research, on research outcomes in economics. We apply an RD design to novel administrative data using peer-review scores as the forcing variable in order to identify a causal relationship between funding and publication productivity. We find that research grants increase the numbers of papers and citations by 10–15% and 20–26%, respectively. Our cost-benefit analysis shows that the effect is roughly three times greater for the recipients of GYS-B+GAS who are under 39 years old than for those of the GSR-B. Further, young researchers without tenure tend to increase the number of publications after receiving the grant without decreasing research quality, while those with tenure seems to focus more on improving the research quality and start independent projects. In contrast, the funding does not significantly increase research outputs for researchers in top ranked universities. The impact of the grant does not change significantly across regions or between national and private universities.

One implication of our findings is that a desirable policy should allocate a higher budget to young researchers and those working at less prestigious universities since the impact of the grant is heterogeneous. In addition, to encourage younger scientists to pursue quality rather than quantity, the government should offer more stable employment to those without tenure. Although our results indicate that the effect of funding is limited for senior researchers and those in top ranked university, we also have reservations about substantially reducing the allocation to these groups because of the expected externalities. First, as we have already argued, researchers in those groups may simply have alternative funding sources. However, forcing them to rely on alternative funds will certainly reduce the money for other projects. Therefore, reducing the research grants for them may have a limited negative consequence individually but could cause a significantly loss to the community as a whole. Second, our results solely reflect the relationship between funding and the principal investigator’s output in the short-term. Thus, it is also possible that cutting funds for senior researchers and those in top ranked university may reduce the resources to train younger researchers and knowledge spillover in the long-term. At least, before reforming the national policy, the impact of KAKENHI grants should be carefully assessed using broad information about all sources of funding. Note that we have only examined the KAKENHI projects in economics, and the results could be very different in other fields. So, we need to be cautious about generalizing our policy implications.

There is one caveat from our analysis. Our balance check test reveals that past KAKENHI funding experience and concurrent co-investigator status in another KAKENHI projects significantly raise the grant probability around the cutoff, implying that peer reviewers are highly sensitive to the applicant's KAKENHI experience, especially for marginal applicants. This may suggest that the initial luck in obtaining a grant or participating in someone's KAKENHI projects as a co-investigator may have long-term impacts on research productivity by increasing the chance of obtaining grants in subsequent years. Investigating the long-term effect of the initial luck of obtaining a KAKENHI grant on academic outcomes we well as a potential bias in reviewers' assessment is a likely direction for future research.

Appendix A KAKENHI system

The KAKENHI is the largest government funding program, supporting research based on researchers' proposals. The KAKENHI began in 1939 and has significantly developed and expanded since then. The total amount of the allocation was 237 billion yen (approximately 2.2 billion US dollars) in 2019. It covers all disciplines and has various types of programs.

The main programs are the Grant-in-Aid for Scientific Research (S) (A) (B) (C) and the Grant-in-Aid for Young Scientists (S) (A) (B). These (S) (A) (B) (C) categories indicate the budget limitations. GSR-S and A target bigger projects, and the maximum budgets are 200 million yen and 50 million yen, respectively. GAS-S and A are for younger scientists planning larger projects, and the maximum budgets are 100 million yen and 30 million yen, respectively. Unfortunately, since those four categories do not have sufficient applicants to construct treatment and control groups, and the award rates are extremely low, we discarded them from the estimation. We use Grant-in-Aid for Scientific Research (B) (C) and the Grant-in-Aid for Young Scientists (B). In addition, we also use the Grant-in-Aid for Young Scientists start-up. Although this grant is similar to GSR-B, the submission period is different. Researchers are required to submit their proposals for the KAKENHI in October, and then, successful applicants start their projects from next April. By contrast, researchers can submit a proposal for the GYS in May because newly employed academic researchers in universities or research institutions cannot apply for a regular KAKENHI in April. However, only researchers who hold an academic position are eligible for this grant. Grant-in-Aid for Research Activity start-up replaced the Grant-in-Aid for Young Scientists start-up in 2010. Therefore, we count this grant as GSR-B in our analysis. Table A1 shows the number of applications across categories in the field of economics. Table A2 presents a summary of the characteristics across the KAKENHI categories.

Appendix B Variable definitions of covariates

We construct our covariates as follows.

Past publications: We count the number of publications in the five years before the application. We collect the relevant data from Scopus. The procedure is the same as that used for the outcome variables.

Past KAKENHI dummy: This variable is equal to one if an applicant received the KAKENHI as a principal investigator within five years from an application, and zero otherwise.

Joining other KAKENHI dummy: This variable is equal to one if an applicant has been a co-investigator in another KAKEN, and zero otherwise. In the KAKENHI, co-investigators can have their own budgets, although the amount is decided by the applicant (as a principal investigator) of the project. We obtain this information from the KAKENHI Grants database (https://kaken.nii.ac.jp/en/), where all projects awarded the KAKENHI are reported.

Female dummy: If an applicant is female, this variable is equal to one, and zero otherwise. Since our administrative database does not have gender information, we identify this information from the applicant's name. We use a Macro program in Excel that identifies gender in Japanese.[16] Further, we manually check names that the program cannot identify using the personal webpage and google image of the author. We use a dummy variable for those for whom we cannot eventually identify the gender.

Foreign applicant dummy: If an applicant is a foreigner, this variable is equal to one, and zero otherwise. We manually check all applicant names and identify typical Japanese names (having Chinese characters and longer names).

Applicant degree dummies: We use applicants' degrees as covariates. We employ three variables: the PhD dummy, the MD dummy, and others. We identify whether an applicant has a PhD degree using CiNii Dissertations provided by the National Institute of Informatics.[17] We also collect applicant degree information from university or personal webpages. We use a dummy for those for whom we cannot determine the degree.

Academic position dummies: Our data include professor, associate professor, assistant professor, and others as applicants' academic positions. We construct those four measures as mutually exclusive dummy variables.

University prestige dummies: Applicants' affiliation is an important indicator of their potential ability. Arora and Gambardella (2005) find that applicants from prestigious institutions receive more funding than others after controlling for review scores. To control for this phenomenon, we use three prestige dummies: first-class prestige, second-class prestige, and others. We count the number of KAKENHI-funded projects

[16] This program called "GenderEstimate" is available free of charge at: https://gist.github.com/lunark/4344906. We thank the developers of this code.

[17] The database is available at: https://ci.nii.ac.jp/d/?l=en.

in each university in our sample, and then, we define more than 300 as a top tier (top-six university), and 299~100 as second-tier (top 7~26 university).

We also use grant category dummies, subfield dummies, and year dummies. Table A3 shows the summary statistics of our variables, and Table A4 presents the correlation matrix.

References

Arora, Ashish, and Alfonso Gambardella. 2005. The impact of NSF support for basic research in economics. *Annales d'Économie Et De Statistique* (79): 91-117.

Arrow, Kenneth J. 1962. Economic welfare and the allocation of resources for invention. In *The rate and direction of inventive activity: Economic and social factors.*, ed. Richard R. Nelson. Princeton: Princeton University Press.

Azoulay, Pierre, Joshua S. Graff Zivin, and Gustavo Manso. 2011. Incentives and creativity: Evidence from the academic life sciences. *The Rand Journal of Economics* 42 (3): 527-54.

Benavente, José Miguel, Gustavo Crespi, Lucas Figal Garone, and Alessandro Maffioli. 2012. The impact of national research funds: A regression discontinuity approach to the Chilean FONDECYT. *Research Policy* 41 (8): 1461-75.

Björk, Bo-Christer, and David Solomon. 2013. The publishing delay in scholarly peer-reviewed journals. *Journal of Informetrics* 7 (4): 914-23.

Chudnovsky, Daniel, Andrés López, Martín A. Rossi, and Diego Ubfal. 2008. Money for science? the impact of research grants on academic output. *Fiscal Studies* 29 (1): 75-87.

Ebadi, Ashkan, and Andrea Schiffauerova. 2016. How to boost scientific production? A statistical analysis of research funding and other influencing factors. *Scientometrics* 106 (3): 1093-116.

Fedderke, Johannes, and Myra M. Goldschmidt. 2015. Does massive funding support of researchers work?: Evaluating the impact of the South African research chair funding initiative. *Research Policy* 44 (2): 467-82.

Fukuzawa, Naomi 2012. An empirical analysis of the research facilitation effect of the 21 Century COE Program on research outcomes: A study of the life sciences fields, the information sciences, electrical and electronic engineering fields, and the social sciences fields. *The Journal of Science Policy and Research Management* 26 (1_2): 40-51.

Gush, Jason, Adam Jaffe, Victoria Larsen, and Athene Laws. 2018. The effect of public funding on research output: The New Zealand Marsden fund. *New Zealand Economic Papers* 52 (2): 227-48.

Hand, E., and M. Wadman. 2008. 222 NIH grants: 22 researchers. *Nature* 452 (7185): 258.

Hicks, Daniel J., David A. Coil, Carl G. Stahmer, and Jonathan A. Eisen. 2019. Network analysis to evaluate the impact of research funding on research community consolidation. *PloS One* 14 (6): e0218273.

Iida, Masuo. 2007. *History of KAKENHI*. The science news press: Tokyo.

Jacob, Brian A., and Lars Lefgren. 2011. The impact of research grant funding on scientific productivity. *Journal of Public Economics* 95 (9): 1168-77.

Jaffe, Adam B. 2002. Building programme evaluation into the design of public Research-Support programmes. *Oxford Review of Economic Policy* 18 (1): 22-34.

Jaffe, Adam B., Manuel Trajtenberg, and Rebecca Henderson. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics* 108 (3): 577-98.

Lee, Kyungjoon, John S. Brownstein, Richard G. Mills, and Isaac S. Kohane. 2010. Does collocation inform the impact of collaboration? *PloS One* 5 (12): e14279.

Mongeon, Philippe, Christine Brodeur, Catherine Beaudry, and Vincent Larivière. 2016. Concentration of research funding leads to decreasing marginal returns. *Research Evaluation* 25 (4): 396-404.

Nag, Sharmistha, Hui Yang, Steven Buccola, and David Ervin. 2013. Productivity and financial support in academic bioscience. *Applied Economics* 45 (19): 2817-26.

Sandström, Ulf. 2009. Research quality and diversity of funding: A model for relating research money to output of research. *Scientometrics* 79 (2): 341-9.

Shibayama, Sotaro. 2011. Distribution of academic research funds: A case of Japanese national research grant. *Scientometrics* 88 (1): 43-60.

Shibayama, Sotaro, and Yasunori Baba. 2015. Impact-oriented science policies and scientific publication practices: The case of life sciences in japan. *Research Policy* 44 (4): 936-50.

Ubfal, Diego, and Alessandro Maffioli. 2011. The impact of funding on research collaboration: Evidence from a developing country. *Research Policy* 40 (9): 1269-79.

Wang, Jian, You-Na Lee, and John P. Walsh. 2018. Funding model and creativity in science: Competitive versus block funding and status contingency effects. *Research Policy* 47 (6): 1070-83.

Figure 1. The relationship between review score and award rate

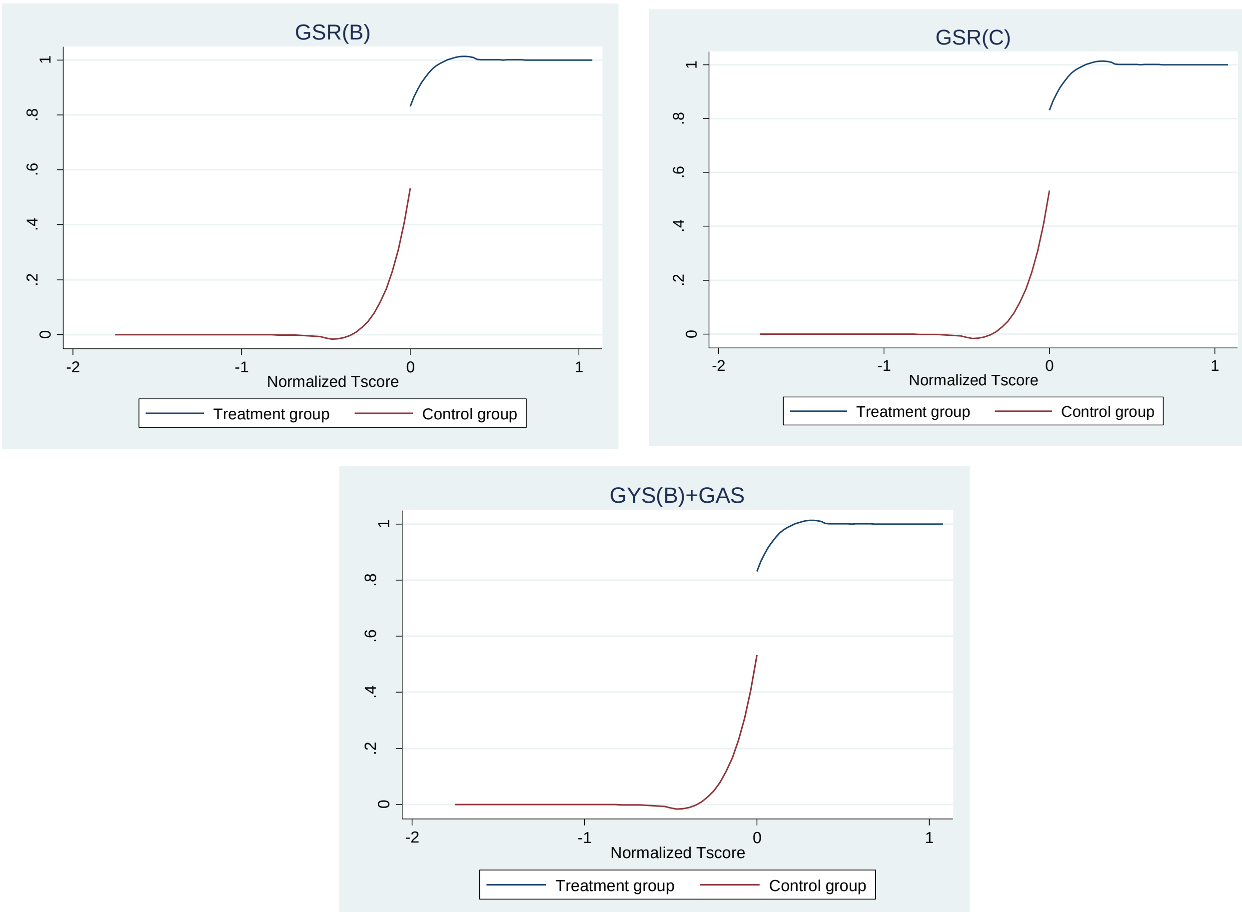
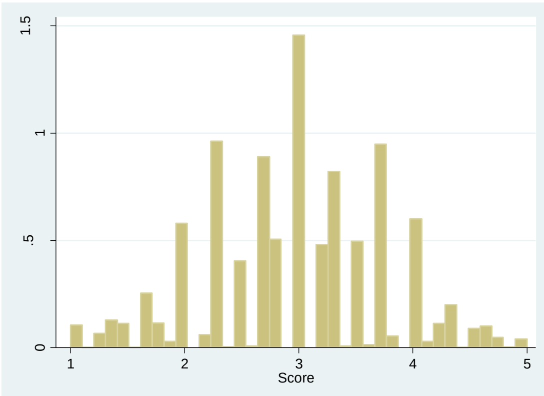
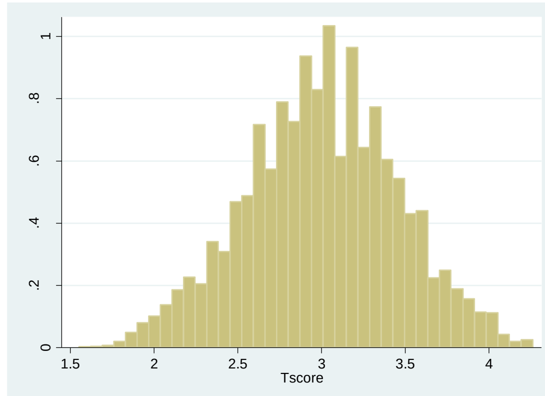


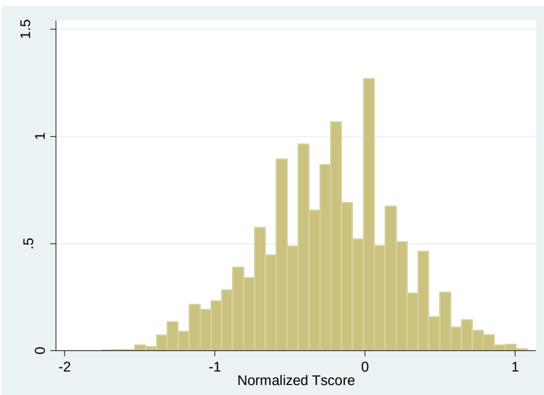
Figure 2. The distribution of the score, T-score, and normalized T-score



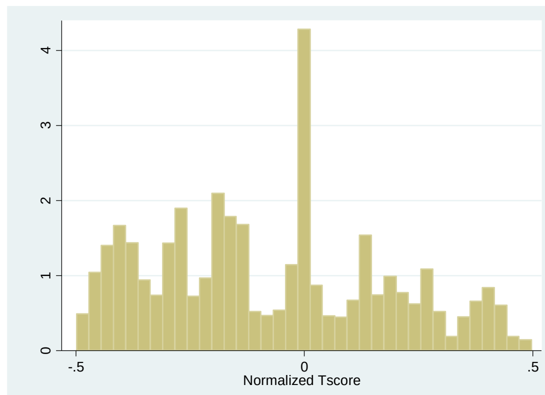
(a) The distribution of scores



(b) The distribution of T-scores



(c) The distribution of normalized T-scores



(c) The distribution of normalized T-scores in local bandwidth

Figure 3. The case of the treatment and controls in the same applicant

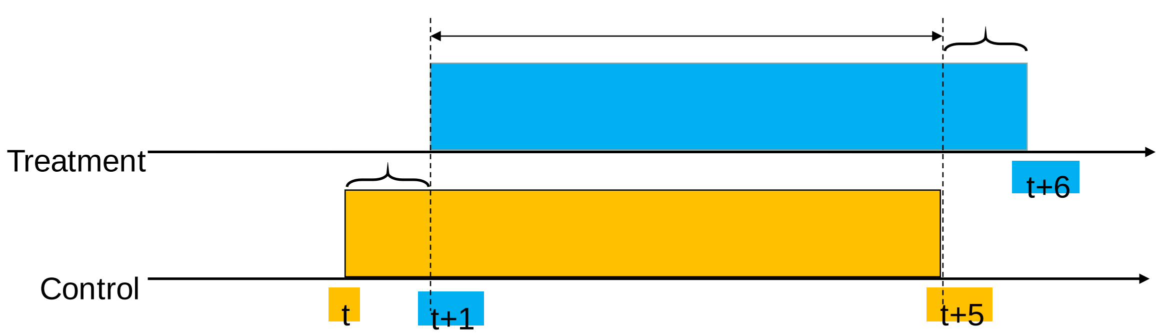
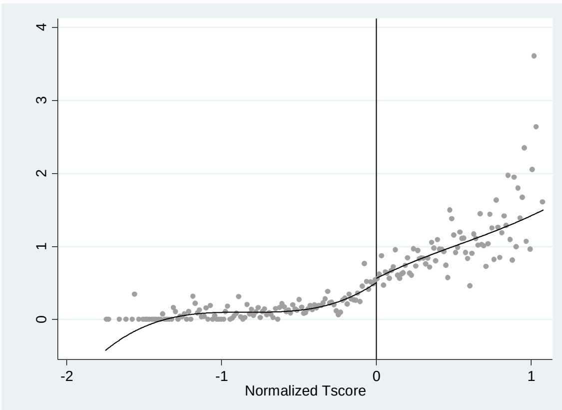
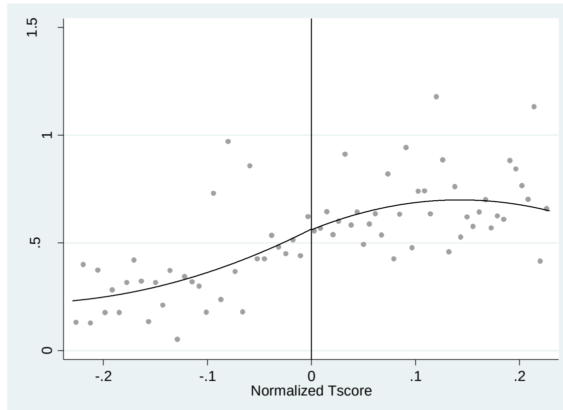


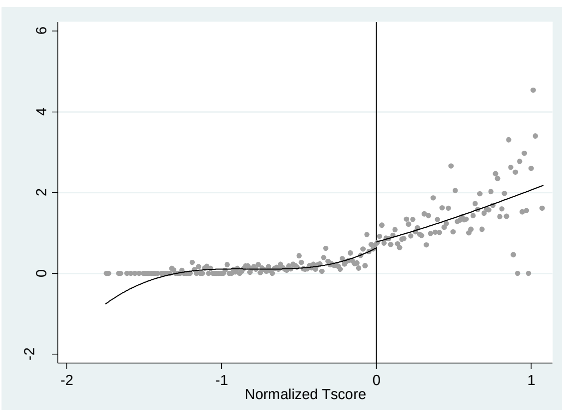
Figure 4. The relationship between normalized T-score and research outcomes



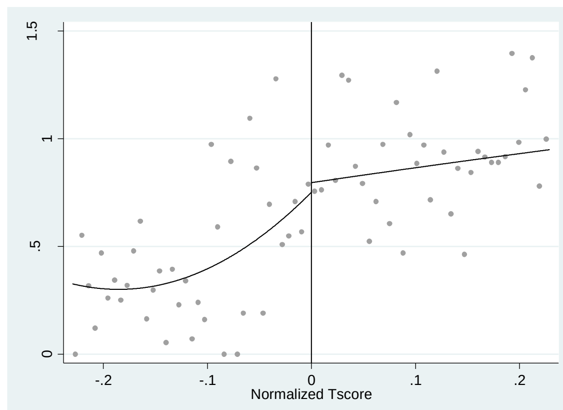
(a) Publications with full sample



(b) Publications with local sample

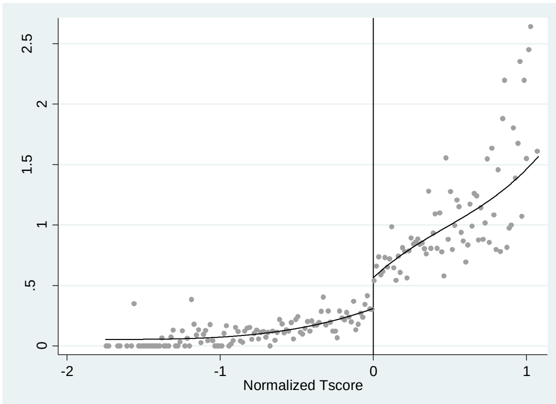


(c) Citations with full sample

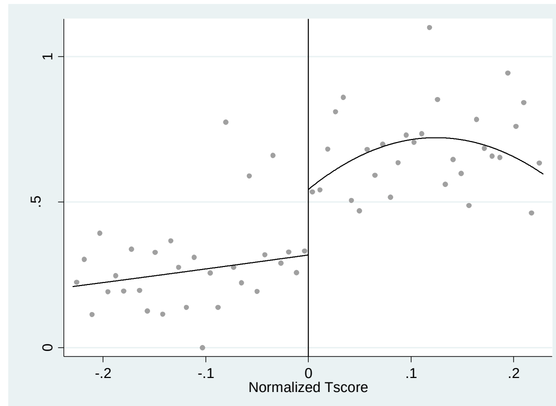


(d) Citations with local sample

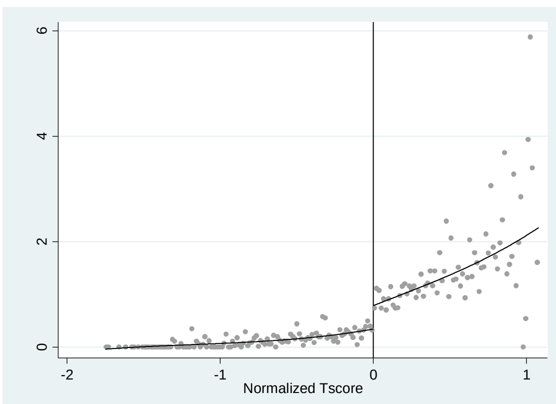
Figure 5. The relationship between normalized T-score and research outcomes without non-compliers



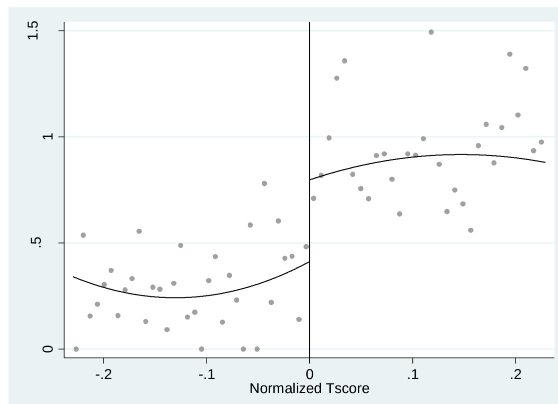
(a) Publications with full sample



(b) Publications with local sample

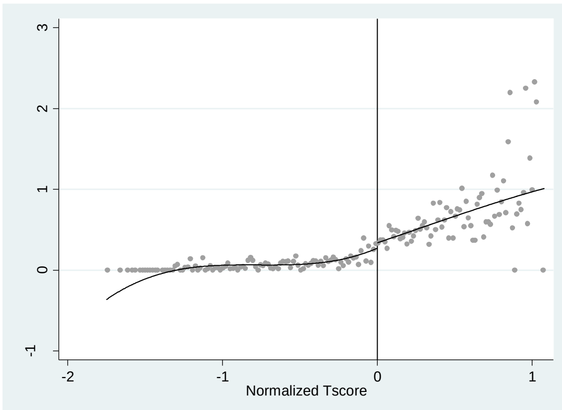


(c) Citations with full sample

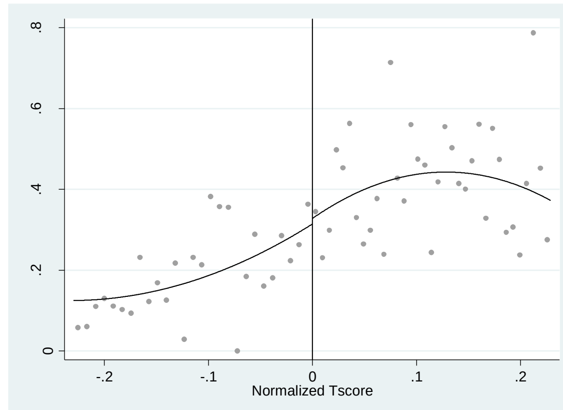


(d) Citations with local sample

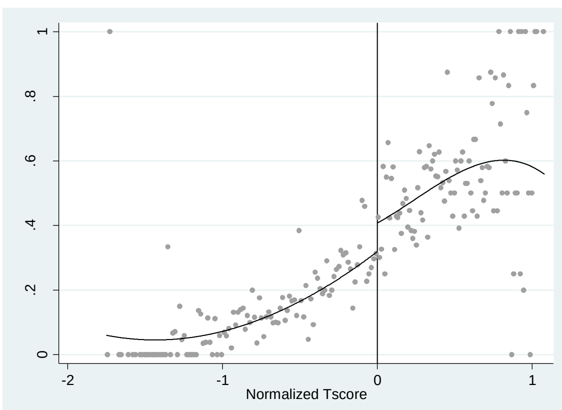
Figure 6. The relationship between the score and selected covariates



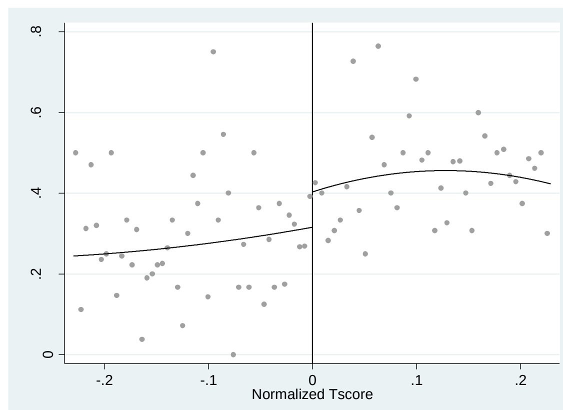
(a) Past publications with all sample



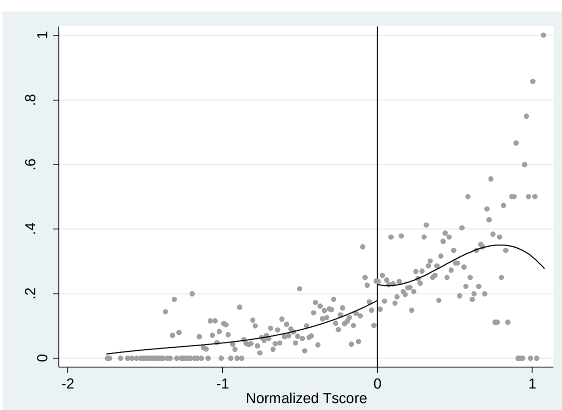
(b) Past publications with local sample



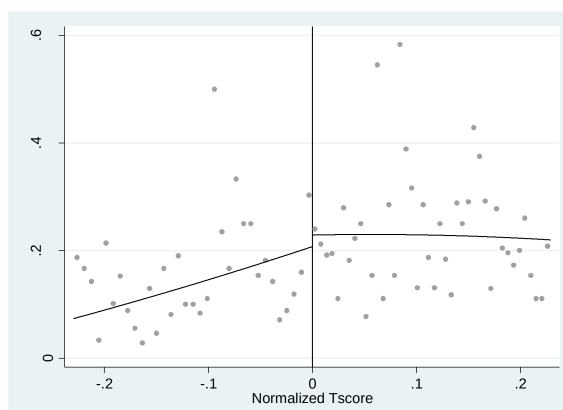
(c) Past KAKENHI with all sample



(d) Past KAKENHI with local sample



(e) Joining other KAKENHI with all sample



(d) Joining other KAKENHI with local sample

Figure A1. The average publications in a year before and after receiving KAKENHI grants.

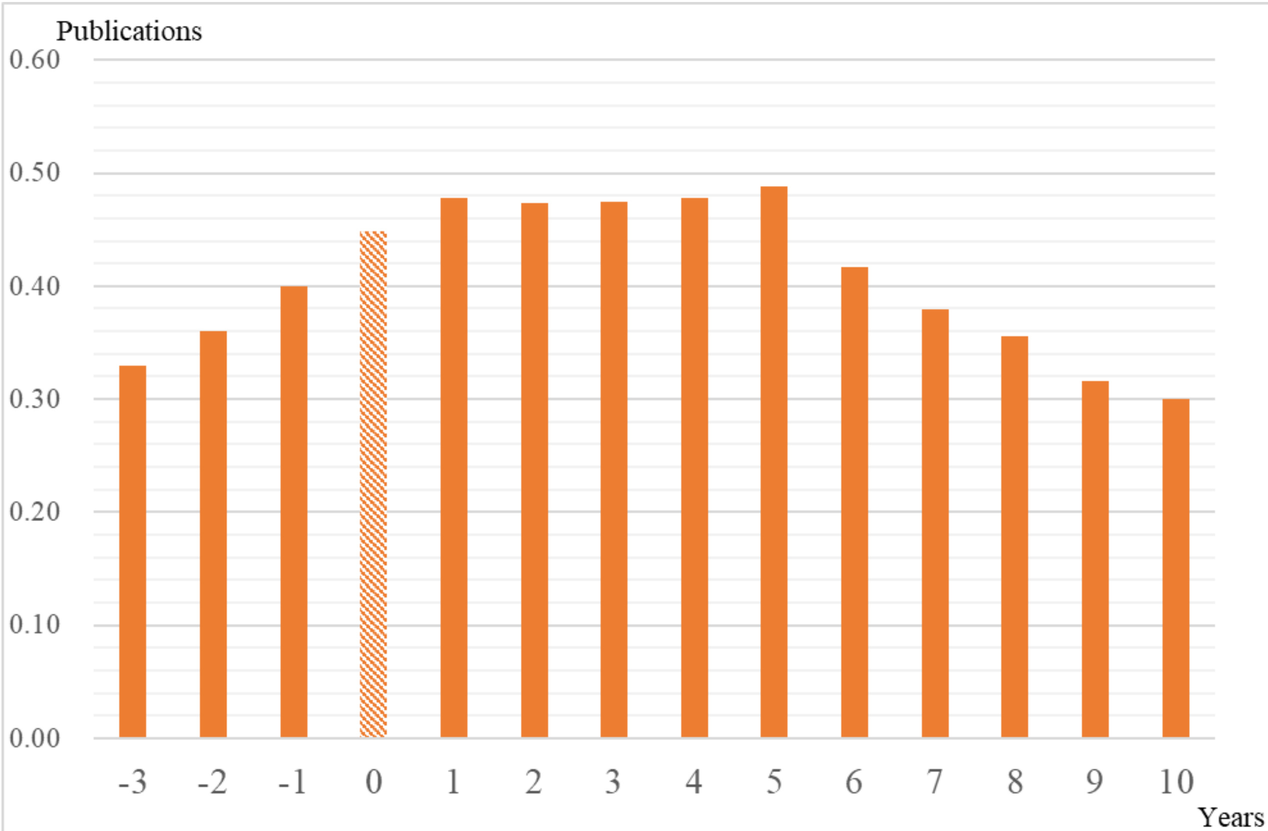
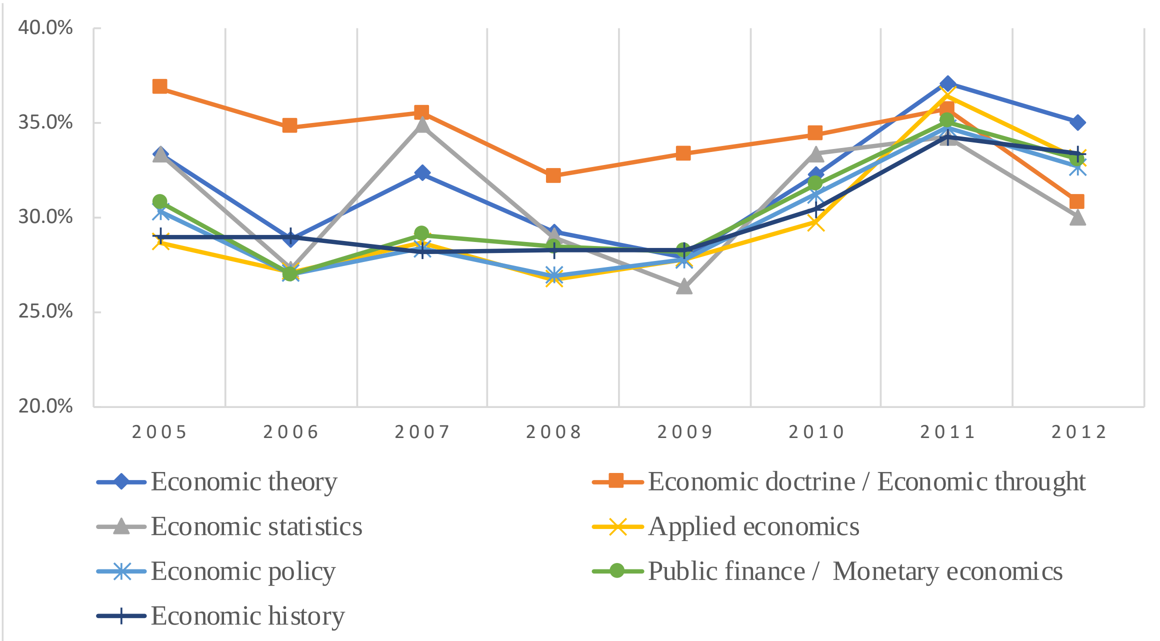
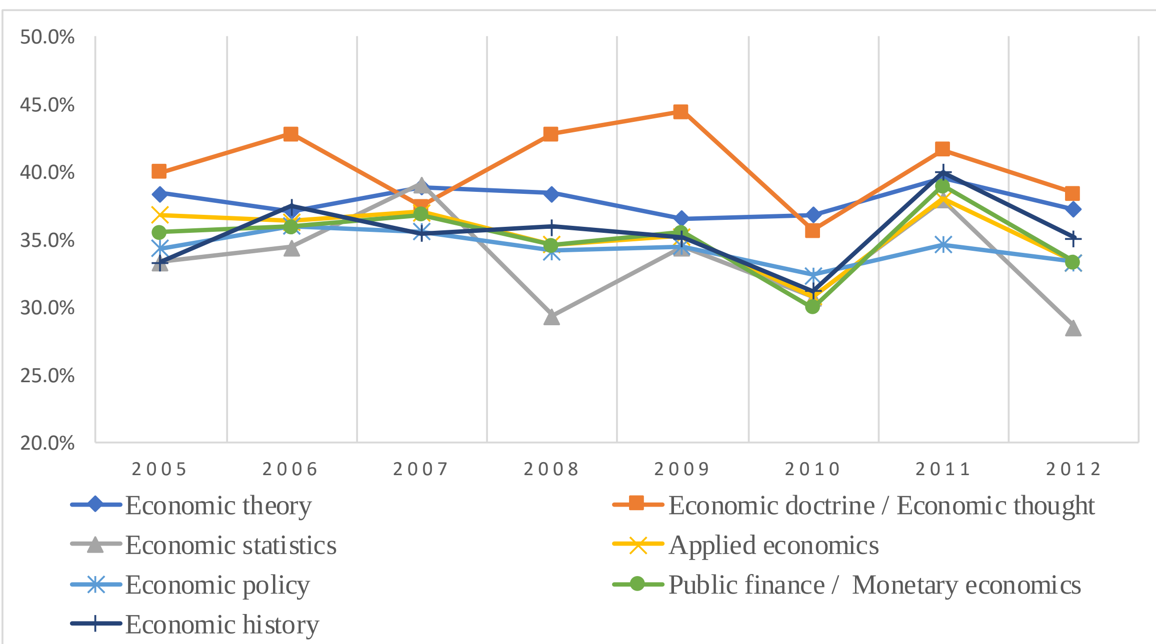


Figure A2. The award rate in a year across subfields



(a) GRS-C



(b) GYS-B

Table 1. The relationship between KAKENHI and research outcomes using OLS and IV: baseline results

	The number of publications (log)			The number of citations (log)		
	OLS	IV	Local sample	OLS	IV	Local sample
	Full sample	Full sample	(-0.23<ts<+0.23)	Full sample	Full sample	(-0.23<ts<+0.23)
	(1)	(2)	(3)	(4)	(5)	(6)
KAKENHI	0.161***	0.103**	0.147***	0.283***	0.196***	0.261***
	(0.030)	(0.040)	(0.039)	(0.049)	(0.066)	(0.063)
T-score	0.234***	0.300***		0.289***	0.389***	
	(0.038)	(0.045)		(0.061)	(0.074)	
T-score^2	0.096**	0.086**		0.227***	0.212***	
	(0.041)	(0.041)		(0.071)	(0.071)	
T-Score^3	-0.010	-0.046		0.068	0.013	
	(0.030)	(0.031)		(0.052)	(0.054)	
Past publications (log)	0.672***	0.675***	0.661***	0.884***	0.888***	0.907***
	(0.023)	(0.023)	(0.035)	(0.040)	(0.039)	(0.059)
Past KAKENHI	-0.012	-0.010	-0.016	-0.045	-0.043	-0.052
	(0.019)	(0.019)	(0.029)	(0.031)	(0.031)	(0.049)
Joining other KAKENHI	0.113***	0.115***	0.147***	0.182***	0.184***	0.205***
	(0.025)	(0.024)	(0.039)	(0.041)	(0.041)	(0.064)
Female	-0.055**	-0.056**	-0.074*	-0.053	-0.055	-0.068
	(0.025)	(0.025)	(0.039)	(0.042)	(0.041)	(0.067)
Foreign applicant	0.009	0.009	-0.065	0.070	0.070	-0.012
	(0.038)	(0.038)	(0.071)	(0.064)	(0.063)	(0.118)
Master's degree	-0.029	-0.031	-0.052	0.001	-0.000	-0.062
	(0.040)	(0.040)	(0.099)	(0.051)	(0.051)	(0.118)
PhD degree	-0.083**	-0.085**	-0.113**	-0.088*	-0.091**	-0.151*
	(0.034)	(0.034)	(0.054)	(0.046)	(0.046)	(0.084)
Professor dummy	0.133**	0.111	-0.065	0.025	0.180	0.011
	(0.052)	(0.069)	(0.140)	(0.088)	(0.115)	(0.270)
Associate Prof. dummy	0.152***	0.131*	-0.011	0.066	0.222**	0.174
	(0.052)	(0.068)	(0.138)	(0.087)	(0.113)	(0.269)
Assistant Prof/Pos-doc dummy	0.204***	0.185***	-0.006	0.090	0.248**	0.174
	(0.058)	(0.071)	(0.140)	(0.096)	(0.116)	(0.270)
Top tier	0.152***	0.153***	0.147***	0.297***	0.299***	0.352***
	(0.043)	(0.042)	(0.055)	(0.074)	(0.074)	(0.093)
Second tier	0.016	0.016	0.018	0.052*	0.052*	0.085*
	(0.019)	(0.019)	(0.032)	(0.030)	(0.030)	(0.049)
Year dummies	Y	Y	Y	Y	Y	Y
Caetgory dummies	Y	Y	Y	Y	Y	Y
Subfield dummies	Y	Y	Y	Y	Y	Y
Year dummies * categories dummies	Y	Y	Y	Y	Y	Y
Year dummies * subfield dummies	Y	Y	Y	Y	Y	Y
Kleibergen-Paap Wald F statistics		1669.30	2440.20		1669.30	2440.20
Adj.R	0.51	0.50	0.40	0.43	0.43	0.34
Observations	7145	7145	2350	7145	7145	2350

Standard errors are clustered by researchers (seen in parentheses and * p<0.1, ** p<0.05, *** p<0.01).

Table 2. Robustness checks

	Dependent variable: log of the number of citations						
	Researchers who applied for KAKENHI at the first time		Randomly selected sample to balance the mean of past KAKENHI experience on both sides of the cutoff	Researchers who applied for KAKENHI for the first time and had no concurrent co-researcher status in other KAKENHI projects		The sample with Sharp discontinuity (*OLS estimations*)	
	Full sample	Local sample (-0.23<ts<+0.23)	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
KAKENHI	0.203***	0.270***	0.300***	0.186**	0.262***	0.400***	0.479***
	(0.076)	(0.076)	(0.071)	(0.080)	(0.078)	(0.139)	(0.127)
Kleibergen-Paap Wald F statistics	1346.03	1795.20	1847.60	1234.26	1586.70	-	-
Observations	5070	1477	1920	4522	1266	1022	357

All estimations include the same covariates in column (5) or (6) in Table 1. Standard errors are clustered by researchers (seen in parentheses and * p<0.1, ** p<0.05, *** p<0.01).

Table 3. KAKENHI categories and research fields

	Dependent variable: The number of citations (log)									
	GSR-B		GSR-C		GYS-B and GAS		Theoretical fields		Applied fields	
	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
KAKENHI	0.137	0.461**	0.151*	0.202***	0.200*	0.318***	0.098	0.026	0.225***	0.300***
	(0.205)	(0.199)	(0.082)	(0.070)	(0.121)	(0.119)	(0.175)	(0.206)	(0.069)	(0.066)
Kleibergen-Paap Wald F statistics	115.103	165.921	914.923	1094.665	621.941	1107.611	201.79	217.562	1544.949	2362.503
Observations	874	305	3830	1134	2442	908	1513	503	5633	1846

All estimations include the same covariates in column (5) or (6) in Table 1. Standard errors are clustered by researchers (seen in parentheses and * p<0.1, ** p<0.05, *** p<0.01).

Table 4. Cost-benefit analysis

	Extensive Margins per Million
GSR-B	0.041
GSR-C	0.063
GYS-B+GAS	0.133

Table 5. Academic positions

Panel A								
	Dependent variable: The number of publications (log)							
	Professor		Associate Prof.		Assistant Prof. (tenured)		Assistant Prof./ Researchers/ Postdoc (untenured)	
	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
KAKENHI	0.055	0.106*	0.183**	0.144**	-0.032	0.127	0.263*	0.303**
	(0.058)	(0.058)	(0.074)	(0.071)	(0.111)	(0.106)	(0.137)	(0.127)
Kleibergen-Paap Wald F statistics	781.218	820.130	436.742	659.617	217.252	331.499	160.873	298.357
Observations	3209	909	2218	774	874	334	655	255
Panel B								
	Dependent variable: The number of citations (log)							
KAKENHI	0.072	0.188**	0.307**	0.268**	0.180	0.348**	0.307	0.381*
	(0.095)	(0.084)	(0.123)	(0.122)	(0.179)	(0.165)	(0.232)	(0.212)
Kleibergen-Paap Wald F statistics	781.218	820.130	436.742	659.617	217.252	331.499	160.873	298.357
Observations	3209	909	2218	774	874	334	655	255
Panel C								
	Dependent variable: The number of authors per publication							
KAKENHI	-0.310	0.055	0.430*	0.147	-0.906***	-0.876*	0.344	-0.054
	(0.259)	(0.320)	(0.252)	(0.245)	(0.347)	(0.499)	(0.396)	(0.286)
Kleibergen-Paap Wald F statistics	79.615	68.806	83.340	99.104	64.826	43.638	47.849	83.574
Observations	640	245	697	290	276	128	219	106

The sample are limited for university staffs in university position sample. All estimations include the same covariates in column (5) or (6) in Table 1. Standard errors are clustered by researchers (seen in parentheses and * p<0.1, ** p<0.05, *** p<0.01).

Table 6. Regions and affiliation

	Dependent variable: The number of citations (log)													
	Metropolitan area		Other areas		The top tier (6 universities)		The second tier (19 universities)		Other institutes		National universities		Private universites	
	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)	Full sample	Local sample (-0.23<ts<+0.23)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
KAKENHI	0.210**	0.263***	0.108	0.226**	-0.037	0.104	0.284**	0.341***	0.155*	0.237***	0.188*	0.244***	0.230**	0.271***
	(0.101)	(0.089)	(0.083)	(0.091)	(0.350)	(0.279)	(0.112)	(0.105)	(0.081)	(0.079)	(0.097)	(0.090)	(0.094)	(0.091)
Kleibergen-Paap Wald F statistics	737.408	1359.838	875.719	961.709	164.516	254.085	448.565	805.842	1187.217	1522.895	939.909	1212.316	709.601	1078.002
Observations	3616	1355	3530	994	831	319	2089	789	5057	1560	3888	1236	3100	1049

All estimations include the same covariates in column (5) or (6) in Table 1. Standard errors are clustered by researchers (seen in parentheses and * p<0.1, ** p<0.05, *** p<0.01).

Table A1. The number of applications across KAKENHI categories.

Categories	N	Percentage (N)	Percentage ($grant)
Grant-in-Aid for Scientific Research (S)	62	0.4%	7.7%
Grant-in-Aid for Scientific Research (A)	422	2.9%	19.1%
Grant-in-Aid for Scientific Research (B)	**1,709**	**11.8%**	**25.1%**
Grant-in-Aid for Scientific Research (C)	**7,295**	**50.3%**	**30.5%**
Grant-in-Aid for Young Scientists (S)	15	0.1%	0.4%
Grant-in-Aid for Young Scientists (A)	66	0.5%	1.1%
Grant-in-Aid for Young Scientists (B)	**3,965**	**27.3%**	**14.0%**
Grant-in-Aid for Research Activity start-up	**582**	**4.0%**	**1.4%**
Grant-in-Aid for Young Scientists start-up	**382**	**2.6%**	**0.8%**

Table A2. The main characteristics of KAKENHI categories

Name	Maximum budged (Yen)	Period	Co-applicants	Age
GSR-B Grant-in-Aid for Scientific Research (B)	More than 5 - less than 30 million	3 - 5 years	Yes	No limitation
GSR-C Grant-in-Aid for Scientific Research (C)	Less than 5 million	2 - 4 years	Yes	No limitation
GYS-B Grant-in-Aid for Young Scientists (B)	Less than 5 million	2 - 4 years	No	Under 27 until 2008 and under 29 after 2009
GAS Grant-in-Aid for Young Scientists start-up and its continuous grant: the Grant-in-Aid for Research Activity start-up	Less than 1.5 million	Less than 2 years	No	A researcher who is entitled to apply for the KAKENHI.

Table A3. Summary statistics of the variables of interest

	Full sample					*Awarded applicants*					*Non-awarded applicants*				
Variables	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
Log of the number of publications	7,145	0.42	0.75	0	5.06	2,829	0.83	0.92	0	5.06	4,316	0.15	0.44	0	3.26
Log of the number of citations	7,145	0.54	1.14	0	6.93	2,829	1.13	1.47	0	6.93	4,316	0.16	0.61	0	5.08
The number of citations per publication	7,145	0.94	3.71	0	151.4	2,829	1.90	4.77	0	151.4	4,316	0.31	2.62	0	129
KAKENHI	7,145	0.40	0.49	0	1	2,829	1.00	0.00	1	1	4,316	0.00	0.00	0	0
Score (Normalized T-score)	7,145	-0.23	0.50	-1.75	1.08	2,829	0.26	0.24	-0.40	1.08	4,316	-0.55	0.34	-1.75	0.29
Past publications (log)	7,145	0.26	0.56	0	3.93	2,829	0.53	0.72	0	3.93	4,316	0.08	0.31	0	2.64
Past KAKENHI	7,145	0.29	0.45	0	1	2,829	0.49	0.50	0	1	4,316	0.16	0.37	0	1
Joining other KAKENHI	7,145	0.16	0.36	0	1	2,829	0.26	0.44	0	1	4,316	0.09	0.28	0	1
Female dummy	7,145	0.10	0.30	0	1	2,829	0.11	0.31	0	1	4,316	0.10	0.30	0	1
Foreign applicant	7,145	0.06	0.23	0	1	2,829	0.05	0.21	0	1	4,316	0.07	0.25	0	1
PhD degree	7,145	0.01	0.11	0	1	2,829	0.00	0.06	0	1	4,316	0.02	0.13	0	1
Master's degree	7,145	0.05	0.22	0	1	2,829	0.02	0.15	0	1	4,316	0.07	0.25	0	1
Professor	7,145	0.45	0.50	0	1	2,829	0.38	0.48	0	1	4,316	0.50	0.50	0	1
Associate Prof.	7,145	0.31	0.46	0	1	2,829	0.37	0.48	0	1	4,316	0.28	0.45	0	1
Assistant Prof./Pos-doc	7,145	0.12	0.33	0	1	2,829	0.13	0.34	0	1	4,316	0.12	0.32	0	1
Top tier	7,145	0.12	0.32	0	1	2,829	0.22	0.41	0	1	4,316	0.05	0.22	0	1
Second tier	7,145	0.29	0.45	0	1	2,829	0.34	0.48	0	1	4,316	0.26	0.44	0	1

Table A4. Correlation matrix

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1.	Log of the number of publications	1.00																
2.	Log of the number of citations	0.88	1.00															
3.	The number of citations per publication	0.41	0.63	1.00														
4.	KAKENHI	0.44	0.41	0.21	1.00													
5.	Score (Normalized T-score)	0.43	0.40	0.20	0.79	1.00												
6.	Past publications (log)	0.64	0.57	0.26	0.39	0.38	1.00											
7.	Past KAKENHI	0.23	0.20	0.08	0.35	0.36	0.31	1.00										
8.	Joining other KAKENHI	0.22	0.21	0.11	0.24	0.24	0.22	0.21	1.00									
9.	Female dummy	-0.02	-0.01	0.01	0.01	0.05	-0.03	-0.03	-0.01	1.00								
10.	Foreign applicant	-0.01	0.00	0.00	-0.04	-0.05	-0.02	-0.06	-0.02	0.03	1.00							
11.	PhD degree	-0.05	-0.05	-0.03	-0.07	-0.09	-0.05	-0.04	-0.05	-0.02	-0.03	1.00						
12.	Master's degree	-0.08	-0.08	-0.03	-0.11	-0.11	-0.06	-0.04	-0.02	-0.02	-0.04	-0.03	1.00					
13.	Professor	-0.12	-0.11	-0.06	-0.12	-0.13	-0.02	0.06	0.00	-0.16	-0.05	0.04	0.07	1.00				
14.	Associate Prof.	0.07	0.07	0.04	0.10	0.10	0.09	0.11	0.06	0.06	0.01	-0.01	0.01	-0.61	1.00			
15.	Assistant Prof./Pos-doc	0.03	0.03	0.01	0.02	0.02	-0.05	-0.11	-0.04	0.06	0.01	-0.03	-0.05	-0.34	-0.25	1.00		
16.	Top tier	0.27	0.27	0.15	0.25	0.26	0.24	0.11	0.11	0.00	0.00	-0.04	-0.05	0.00	-0.08	-0.03	1.00	
17.	Second tier	0.05	0.05	0.03	0.09	0.12	0.07	0.13	0.08	-0.01	-0.04	-0.03	-0.03	0.07	-0.02	-0.11	-0.23	1.00

Table A5. Average award rate and initial failure

Grant name	Average award rate		Funded rate in subsequent year after initial failure		Award rate in subsequent year after initial failure near the cutoff	
	Applications	Award rate	Applications	Award rate	Applications	Award rate
GSR-B	1,709	29.4%	695	20.4%	124	30.6%
GSR-C	7,295	31.6%	3,884	20.5%	478	36.4%
GYS-B	3,965	34.7%	2,048	26.2%	254	38.2%
GAS before 2000	582	28.4%	12	33.3%	2	50.0%
GAS after 2001	382	25.1%	46	13.0%	5	20.0%