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The Impact of Grant Funding and Research Group Structure on Scientific Productivity

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Abstract

In this paper, we examine the impact of receiving a Senior Clinical FWO investigator fellowship on subsequent publication output and citations as well as on the researcher's development as principal investigator. We compare the productivity of the 78 Senior Clinical FWO Investigators granted during the period 2000-2012, with a sample of 107 matched controls. Additionally, we run a complementary survey in order to examine explanatory factors that might affect success or failure in the post-grant time-span. Our findings show that only the most promising researchers are selected into the FWO fellowship and that they act more as principal investigator and publish more subsequent to the grant allocation. Nevertheless, examining the heterogeneity within this FWO-granted sample, we provide evidence that researchers' time-budgets, clinical obligations, research support and effective clinical replacement have a significant influence on their post-grant publication outcomes.

Jelcodes:O31,O32

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Abstract

In this paper, we examine the impact of receiving a Senior Clinical FWO investigator fellowship on subsequent publication output and citations as well as on the researcher's development as principal investigator. We compare the productivity of the 78 Senior Clinical FWO Investigators granted during the period 2000 – 2012, with a sample of 107 matched controls. Additionally, we run a complementary survey in order to examine explanatory factors that might affect success or failure in the post-grant time-span. Our findings show that only the most promising researchers are selected into the FWO fellowship and that they act more as principal investigator and publish more subsequent to the grant allocation. Nevertheless, examining the heterogeneity within this FWO-granted sample, we provide evidence that researchers' time-budgets, clinical obligations, research support and effective clinical replacement have a significant influence on their post-grant publication outcomes.

Keywords: Economics of science, scientific productivity, structure of research groups

JEL Classifications: O31, O32

1. Introduction

In today's global world, generating new knowledge and its translation into new products and services is essential to preserve and enhance one's competitive position. Excellence in innovation positively impacts our lives in very different ways: through enhanced medicines, more efficient and sustainable energy resources, and with new technological solutions to protect the environment and the security of citizens (EC, 2007). In this paper we focus on the scientific productivity of the Belgian biomedical and biotech sector. A strong scientific knowledge base is one of the Belgian biotech sector's key assets and has allowed it to become world class: Belgium has the 5th most productive drug pipeline per capita in the world, holds the number one position with regard to clinical trials per capita within Europe, and 30% of the European biotech industry (by market value) is based in Belgium (KBC Securities, 2013). Nevertheless, the global position of the Belgian biotech sector is currently being confronted by a changing research landscape (EC, 2007).

Biomedical university faculty are expected to perform a multitude of tasks to fulfill their obligations. They are charged with clinical duties, undertake research, teach, supervise Ph. D. students, they participate in faculty and department tasks, evaluate other researchers' work, apply for funding, and so forth (Kyvik, 2005). As a result, the picture that emerges of the causes of their research productivity is complex. Nevertheless, it is exactly this group of well-educated and clinical experienced people that is believed to be able to conduct highly valuable and applicable research, given they are provided the right incentives to focus on their research and are not too distracted by the intensity of clinical care and other tasks (Mankoff et al., 2004; Littman et al., 2007; VRWB, 2008; Norga, 2009; Grady, 2010).

The aim of this paper is to contribute to a better understanding of what incentives precisely allow these scientists to focus on their own research projects and act more as principal investigator. We study the impact of the availability of resources on biomedical scientific performance, while distinguishing between two kinds of resources: financial resources on one side, and human resources such as PhD students and research assistants on the other side. Specifically, we investigate the impact of grant funding on biomedical researcher's scientific productivity, while explaining the heterogeneity between them by understanding differences in their research position, organization and staffing.

Our empirical analysis relies upon examining the scientific productivity of clinical researchers funded by the ‘Research Foundation Flanders (Fonds voor Wetenschappelijk Onderzoek – FWO). FWO’s Senior Clinical Investigator fellowships aim to offer clinical researchers the chance to obtain a part-time leave from their clinical position in order to focus on their research projects. First, we estimate the effect of 78 Senior Clinical Investigator FWO grants by contrasting several bibliometric quantity and quality indicators of the granted clinicians with a sample of 107 matched controls that were not granted the FWO fellowship, but however hold very similar characteristics concerning academic-age, gender, department and university. Additionally, we run a complementary survey in order to examine explanatory factors regarding the possible heterogeneity between the different researchers that obtained the Senior Clinical Investigator fellowship, and to get a better insight into the factors that might affect success or failure in the post-grant time-span by analyzing their timetables, clinical obligations and research support.

The rest of this paper proceeds as follows: In the next section, we discuss prior literature on the impact of grant funding and the organization of research on scientific productivity. In section 3, we provide a brief background on the analyzed Senior Clinical FWO Investigator fellowship. Section 4 describes our data and section 5 discusses the methodology used in our empirical analysis. Section 6 presents the main results and section 7 concludes.

2. Theoretical Background

The analysis presented in this paper fits within the larger literature stream on the economics of science (e.g. Stephan, 1996), but is especially related to prior studies on the determinants of scientific productivity and the impact of research funding on research output. The aim of this literature survey is not to present a detailed and comprehensive review of all determinants of research productivity, but rather to focus on some specific (additional) determinants examined in our paper. Our data allows us to answer questions related to the impact of grant funding on scientific productivity and to examine the impact of the structure of the research group surrounding the granted researcher and his/her research position on the individual scientist's academic output.

The literature review is structured as follows: First, a number of empirical studies that already explored the impact of grant funding on scientific productivity are discussed. Second, (the few) studies that investigated the impact of research group structures on research output are reviewed.

The Impact of Grant Funding on Scientific Productivity

Previous research on the impact of scientific research grants showed that however the relationship between financial incentives and the efficiency of university systems is ambiguous (Auranen and Nieminen, 2010), there exists empirical evidence that the competitive allocation of research grants has an impact on scientific behavior and activities (Grimpe, 2012). Research grants appear to increase one's individual productivity (Stephan, 1996; Arora and Gambardella, 1998, 2005; Jacob and Lefgren, 2007; Chudnovsky et al., 2008; Lee and Bozeman, 2005), notwithstanding this positive impact will depend on the researcher's career stage (Arora and Gambardella, 2005) and the size of the grant (Godin, 2003). However, the majority of these studies did not take selection bias into account, which might have led them to overstate the true impact of funding (Jacob & Lefgren, 2011).

Arora and Gambardella (1998) evaluate the effect of an Italian funding program on academic biotechnology research and find a low average elasticity of research output with respect to funding. In their 2005 study examining the impact of the National Science

Foundation (NSF) granted research projects, they find a modest increase in publications as well as in citations subsequent to the allocation of this grant, especially for junior researchers. Chudnovsky et al. (2008) come to the same conclusion using data on research funding in Argentina.

Jacob and Lefgren (2007) estimate the impact of receiving a National Institutes of Health (NIH) grant on subsequent publications and citations. They show that either the receipt of a NIH postdoctoral fellowship or research grant leads to about one additional publication over the next 5 years, representing only a 7% increase in the publication rate.

Azoulay et al. (2010) compare the careers of investigators granted by the Howard Hughes Medical Institute (HHMI), which tolerates early failure, rewards long-term success, and gives its appointees great freedom to experiment; with NIH grantees, which are subject to short review cycles, pre-defined deliverables, and renewal policies unforgiving of failure. They find that HHMI investigators produce high-impact papers, publications in the top percentile of the citation distribution, at a much higher rate than the NIH-funded researchers.

Nevertheless this empirical evidence, in the case of clinical researchers, the scientists may in practice still be too distracted by the intensity of clinical care to be able to seriously conduct valuable research and transfer their findings from bench to bedside and back. Some consider clinical care and research as joint activities, that reinforce each other. Others regard them as "conflicting roles with different expectations and obligations" (Fox, 1992; Carayol & Matt, 2004). For that reason, we expect an effective clinical replacement subsequent to the allocation of the grant to be a key determinant of the researcher's post-grant scientific productivity and his/her development as principal investigator.

The Impact of the Structure of the Research Group on Scientific Productivity

Apart from an effective (clinical) replacement, prior evaluations of research productivity show that there may exist large differences between groups, departments and institutions explaining possible heterogeneity within the granted sample. Individual determinants of scientific productivity have been studied analyzing differences in age (Zuckerman and

Merton, 1972; Diamond, 1986; Stephan and Levin, 1997), cohort (Weiss and Lillard, 1982), training (Garcia-Romero and Modrego, 2001) and gender (Stephan, 1998). Other work has underlined the importance of differences in institutional factors of the productivity of individual scientists (Stephan, 1996). Due to the specificity of our data, we are able to control for these determinants and we can examine how differences relative to the structure of the research group surrounding the granted researchers and differences relative to the granted researchers' position (effective replacement versus no effective replacement) account for differences in their scientific performance.

The importance of non-permanent researchers (Ph. D.s and post-docs) on permanent ones' (university professors) productivity is often ignored in the literature. Carayol and Matt (2004) suggest in their paper that there are specific links between permanent and non-permanent researchers. Nevertheless, the contribution of Ph. D.-students to the permanent researchers scientific output is not straightforward. On the one hand supervising Ph. D. students may be time-consuming for a professor. In addition, Ph. D. students are found to be much less productive in terms of number of publications than more established researchers (Kyvik, 1991; IVA, 2012). On the other hand, Ph. D. students are important work force in the science system and do a lot of time-consuming experimental work, which otherwise would have to be done by the professor him/herself (Kyvik, 1991; IVA, 2012). Furthermore many supervisors hold the last author position on publications mainly written by their graduate students (IVA, 2012). Kyvik (1991) investigated the determinants of scientific publishing at Norwegian universities and finds the positive effects related to Ph. D. students to dominate the negative ones.

However, the personal research group of an experienced professor does not only consist of Ph. D. students, research assistants as well may play an important role. Just as Ph. D. students, research assistants are expected to contribute to the professor's scientific output by conducting time-consuming tasks such as data collection and data analysis, while at the same time they are expected to need less supervision time of the professor, due to the nature of their tasks and/or prior education. To the best of our knowledge, prior literature does not distinguish between Ph. D. students and research assistants while examining their contribution to professors' scientific output.

3. Institutional Background

The Research Foundation – Flanders (FWO) is an independent agency, founded in 1928, that supports fundamental research in all disciplines in Flanders, Belgium. The FWO provides funding on the basis of an interuniversity selection with scientific excellence as the only criterion[1].

In our study we examine the impact of the Senior Clinical FWO investigator fellowship. This fellowship was brought into existence to support doctors and researchers who want to pursue a full-fledged career in translational research. Translational research focuses on the translation of novel insights or hypotheses, obtained from clinical observations or from fundamental or strategic basic research, into novel or better preventive, diagnostic or therapeutic applications (Littman et al., 2007; VRWB, 2008; Norga, 2009; Grady, 2010). To serve this purpose, the beneficiaries of this grant are offered the chance to obtain a part-time leave from their clinical position for 5 years, with two possible 5 year extensions, in order to work and focus on their translational research projects.

The research grant related to the Senior Clinical mandate, is half the salary of the FWO candidate at the expense of the university hospital, with a maximum of € 50.000 per year. This research grant, reimbursed by the FWO to the university hospital, has to be entirely devoted to the clinical replacement of the FWO candidate. Researchers granted with the Senior Clinical FWO fellowship are required to report annually to the FWO about their research progress.

To be eligible for the Senior Clinical FWO investigator fellowship, candidates must be a medical specialist, general practitioner or pharmacist specialist in clinical biology (younger than 46) with a Ph. D., who have a full-time clinical role at a university hospital. The candidates must have a permanent employment contract at a university hospital in the Flemish Community, where they are exclusively performing an at least 80% clinical role when the fellowship starts (1 October). When candidates are recognized as general practitioner, they must have an employment contract at a university department of general

[1] http://www.fwo.be/Fundamenteel-klinisch-mandaat.aspx

practitioner medicine and at the same time performing a role in general practitioner medicine for the remaining time[2].

[2] http://www.fwo.be/Fundamenteel-klinisch-mandaat.aspx

4. Data and Sample Characteristics

Database Construction

Our sample contains those researchers that were granted the Senior Clinical Investigator FWO fellowship during the period from 2000 to 2012, a total of 78 researchers. In the absence of information on the runner-ups of the FWO's Senior Clinical Investigator Fellowship, we rely on observable characteristics to create a viable control group. With the help of field experts, the control group is carefully constructed containing 107 researchers that were not granted a Senior Clinical Investigator FWO fellowship, but however hold very similar characteristics as the researchers in the treatment group: we match on academic-age, gender, department and university. Thus, in total the sample contains 185 researchers, 78 treated and 107 non-treated individuals.

Dependent Variables

We make use of the data provided by *the Institute for Scientific Information* (ISI) more precisely *the Science Citation Index* (SCI), *the Social Sciences Citation Index* (SSCI) and *the Journal citation reports* (JCR), to collect all publication data[3] for every selected researcher over the analyzed time frame, going from 5 years before the fellowship was granted till 3 years after[4]. Following the collection of these data, four different bibliometric indicators are constructed in order to measure scientific productivity and quality: the number of publications per researcher per year, the number of publications per researcher per year controlled for last author position[5], the number of citations per paper per researcher per year, and the number of citations per paper per researcher per year controlled for last author position.

In order to solve the problem of truncation concerning the citation indicators, we use a fixed two-year citation window. Truncation is the fact that older articles have more time to be cited, and as a result are more likely to reach the tail of the citation distribution (Azoulay et

[3] Publication titles, publication years, publication co-authors, author positions, source titles and their impact factor, the total number of citations and the number of citations per year per publication.
[4] We exclude review articles, editorials, and letters from the set when computing these measures.
[5] A robust social norm in the life sciences assigns first authorship to the junior author who was responsible for the actual conduct of the investigation, last authorship to the principal investigator, and divides the remaining credit to authors in the middle of the authorship list, generally as a decreasing function of the distance from the extremities of the list (Azoulay et al., 2010).

al., 2010). Nevertheless, the use of a fixed two-year citation window in combination with the 3 year follow-up period, results in the limitation of our dataset to those researchers that were granted the FWO fellowship up to 2007[6]: in the citation-analysis, we examine the citations of 52 FWO fellowship holders, matched with 80 researchers in the control group. Table 1 presents the descriptive statistics for the treated and control group with respect to the different publication output indicators.

Table 1: Descriptive Statistics Total Sample – Dependent Variables

	FWO Fellowship Holders Mean					Control Group Mean				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
Publications	667	5.14	4.86	0	46	930	2.94	3.10	0	22
Citations	468	3.63	4.85	0	43.33	720	2.22	6.40	0	104
LastAuthorPublications	614	1.05	1.75	0	17	651	0.84	1.55	0	12
Citations per LA Publication	423	3.56	4.57	0	43.33	477	1.96	2.95	0	31.87

Complementary Survey

Additionally, we ran a complementary survey in order to examine explanatory factors regarding the possible heterogeneity between the different researchers that obtained the Senior Clinical Investigator fellowship, and to get a better insight into the factors that might affect success or failure in the post-grant time-span by analyzing their timetables, clinical obligations and research support. Our survey sought to gather information on 5 dimensions: the research-dimension, the time-budget dimension, the research-support dimension, the funding-dimension and the social dimension of each researcher and its environment. The survey was carefully constructed and tested with the help of 8 clinical researchers. We sent out the survey to all of the 78 researchers that were granted the FWO fellowship and got a response rate of about 55% (=43 researchers). Table 2 presents some of the key characteristics of the FWO researchers as identified by our survey, that will be used in the within FWO-sample analysis.

[6] The last year of the follow-up period for the FWO 2007-cohort is 2010. For papers published in 2010 we examine their citations received in 2010, 2011 and 2012.

Table 2: Key Characteristics FWO Researchers Within FWO Sample

	FWO Researchers				
	Obs.	Mean	Std. Dev.	Min	Max
Total working (h/week)	43	67.59	11.51	49	102
Research (h/week)	43	26.46	10.48	7	44
Clinical work (h/week)	43	30.27	11.84	8	60
Extra tasks (h/week)	43	8.47	6.55	1	32
Replacement post FWO grant (h/week)	43	7.63	8.45	0	25
# Ph. D. Students	43	2.82	1.76	0	7
# Research Assistants	43	1.88	2.45	0	10

One of the main features of the FWO Senior Clinical Investigator fellowship is the fact that this grant gives clinical researchers the chance to obtain part-time leave from their clinical position in order to focus (more) on their research activities. However, as follows from our survey findings, in practice this part-time leave from their clinical work does not always seem to be the case. Thus, the effective replacement subsequent to the allocation of the FWO grant, time spent on research, the number of Ph. D. students and the number of research assistants will be key variables in our within FWO sample analysis.

5. Methodology

In a first step, the impact of the FWO fellowship on the created quantity and quality indicators is tested by conducting difference-in-difference analyses as well as a pooled Poisson quasi-maximum likelihood (QML) regression and a fixed effect Poisson QML regression. Additionally, we conduct count quantile regressions to examine the impact of the FWO fellowship on the likelihood of publishing 'top' publications, as measured by citations.

Difference-in-Difference Analysis

A difference-in-difference analysis is based on estimating the effect of a treatment, which in this case is receiving the FWO fellowship. This is done by taking the difference between the subjects pre- and post-treatment. To exclude time based effects, the difference is calculated for the treated group (those that received the FWO fellowship) from which the difference for the untreated group (those that did not) is subtracted. For a treated group with mean M_t and an untreated group with mean M_u in period pre-treatment a and post-treatment b the estimator D will appear as follows:

$$D = (M_{tb} - M_{ta}) - (M_{ub} - M_{ua})$$

The main advantage of the difference-in-difference estimator is that it is does not impose any functional form and can be used with most kinds of data (e.g. count data) and still takes into account changes over time. The primary assumption of a difference-in-difference is that the sample on which the analysis is performed behaves as if it was randomly chosen. We have therefore matched our sample on any stable criteria but not on the amount of publications prior to the possibility of obtaining an FWO fellowship. This is not necessarily a problem for as long as the group that obtains the FWO fellowship produces, on average, a constant amount of publications extra per time unit. This is because this constant will then be removed in the first difference.

Nevertheless, a difference-in-difference estimation is only valid when the average outcome for the treated and control groups would have followed parallel paths over time in the absence of the treatment. This assumption is implausible since FWO fellowship appointments are driven by certain expectations about the potential of researchers. For that reason granted researchers might have experienced very similar outcomes had they not been selected (Azoulay et al., 2010).

Count Models

Due to the nature of the constructed bibliometric indicators of scientific productivity, which are positive (integer) variables, we estimate count data models conducting a pooled Poisson quasi-maximum likelihood (QML) estimator as well as a fixed effect Poisson QML estimator[7]. By making use of the QML Poisson estimators, we control for the issue of over-dispersion encountered in our dataset (i.e. the variance in our count data is larger than the mean).

The advantage of the pooled Poisson is that it does not impose the strict exogeneity assumption. By clustering the standard errors at the individual researcher level, dependence over time is taken into account. Estimating fixed effect models, we can correct for (unobserved) individual research ability. Individual-specific characteristics of the different scientists, such as gender and field, are not included in the specification: as they usually do not change over time, these characteristics are absorbed by the individual-specific effect (Czarnitzki & Toole, 2010).

For our pooled and panel analysis, the main independent variable is the treatment dummy *FWO Fellowship* which is 1 in the years in which a researcher received the FWO fellowship and 0 otherwise. The other variables that are included in the panel data analysis are the following: a dummy variable *Year* to take temporal effects into account; and a dummy variable *FWO* to correct for any unobserved ability that has been taken into account by the FWO selection procedure but not by our matching.

Table 3: Independent Variables Used in Pooled & Panel Analysis

FWO Fellowship	Researcher holds an FWO Fellowship in this year
FWO	Researcher receives the FWO Fellowship in any year
Year	Dummy variable for year

[7] To estimate the model, we use the QML Poisson fixed effect STATA routine by Tim Simcoe, University of Toronto.

Quantile Regression

Additionally, we conduct count quantile regressions to examine the impact of the FWO grant on the likelihood to publish a top 50, top 25 and top 10 % publication, as measured by citations. Quantile regressions models can provide us with information about the relationship between the outcome *y* and the regressors *x* at different points in the conditional distribution of *y* (Cameron & Trivedi, 2009)[8].

[8] To estimate the model, we use the qcount STATA routine by Alfonso Miranda, Boston College Department of Economics.

6. Results

In this section, we first discuss the impact of the FWO grant on the created bibliometric indicators. Next, we analyze how differences between researchers concerning time-budget, research-support, clinical obligations and effective replacement explain the heterogeneity between the different researchers that obtained the FWO fellowship.

Total Sample

Our first measure of scientific productivity is publications per year. The graph plotting this indicator (Figure 1) as well as the difference-in-difference estimation (Table 4) propose that even though a difference exists between selected and non-selected researchers, the effect increases substantially when FWO funding is actually awarded. This significant effect is confirmed by the pooled Poisson QML estimation (Table 5), where we find the FWO fellowship to have a marginal effect of 26% [=exp(0.234)-1], as well as by the fixed-effect QML Poisson estimation (Table 6), where we find the FWO grant to have a marginal effect of 18% [=exp(0.169)-1] on publication output. Additionally, does the positive significant effect of the dummy variable *FWO* in the pooled Poisson QML estimation (Table 5), with a marginal effect of 61% [=exp(0.475)-1] on publication output, provide evidence of a successful selection process by the Research Foundation Flanders (FWO). Put in a nutshell, the allocation of the FWO grant leads to almost one additional publication per researcher per year subsequent to the allocation of the FWO grant, while selection into the FWO-sample results in almost two additional publications per researcher per year.

Next, we examine the impact of the FWO grant on the evolution of the researcher as principal investigator by analyzing the grant's impact on the number of last author publications. The difference-in-difference analysis in Table 4 and the graph plotting this indicator (Figure 3) indicate a strong increase in the number of last author publications during the FWO fellowship period. These expectations get confirmed by the different regressions conducted (Table 5 & 6): we find an increase of almost 50% [=exp(0.395)-1] in the number of last author publications per researcher per year as a result of the Senior Clinical FWO grant, or roughly 0.4 extra last author publications per researcher per year. As opposed to total publications, the *FWO* dummy in the pooled Poisson QML estimation (Table 5) does not present significant evidence that selection into the FWO-sample has an impact on the number of last author publications (Table 5). Thus the increase in last author publications appears to be solely driven by the allocation of the FWO fellowship.

Subsequent to discussing the impact of the FWO grant on the bibliometric quantity indicators, we continue our analysis by examining the impact of the grant on the created quality indicators. Concerning the impact of the FWO fellowship on the number of citations per paper and the number of citations per last author paper received in the post-grant time-span, none of our Poisson QML estimations (Table 5 & 6) find the FWO grant to have a significant impact.

Table 7 presents the results from the count quantile regressions on citations per publication for the 50th, 75th, 90th and 95th percentile. Table 8 presents the same analysis for citations per last author publication. We find that the allocation of the FWO fellowship only seems to have a weak positive significant impact on the number of top 5 % publications, as measured by citations. Furthermore, does the positive significant effect of the *FWO* dummy variable in both our quantile regressions (Table 7 & 8) provide evidence of a successful quality selection process by the Research Foundation Flanders (FWO).

Summarized our total sample findings show that the clinical researchers, granted with a FWO grant, publish more subsequent to the grant and start acting more as principal investigator, as indicated by the increase in last author publications. Additionally, we find evidence that the Research Foundation Flanders selects the most promising researchers into the FWO fellowship. As a result, it seems that the FWO grant has the desired effect: the best researchers are selected into the fellowship, they act more as principal investigator and publish more subsequent to the grant allocation.

Table 4: Difference-in-Difference Estimations

Outcome Variable	Pre-FWO Fellowship			Post-FWO Fellowship			Diff-in-Diff
	Control	Treated	Difference	Control	Treated	Difference	
Publications	2.699	4.342	1.643***	3.462	7.020	3.558***	1.916***
	(0.113)	(0.183)	(0.215)	(0.206)	(0.433)	(0.479)	(0.525)
Citations	2.073	3.125	1.052**	2.517	4.631	2.115***	1.062
	(0.33)	(0.24)	(0.408)	(0.277)	(0.46)	(0.537)	(0.674)
Last Author Publications	0.684	0.676	-0.009	1.184	1.945	0.761***	0.769***
	(0.064)	(0.058)	(0.087)	(0.132)	(0.177)	(0.221)	(0.237)
Citations per LA Publication	1.548	3.208	1.66***	2.78	4.272	1.492***	-0.168
	(0.113)	(0.261)	(0.284)	(0.328)	(0.409)	(0.524)	(0.596)

Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 5: Pooled Poisson Quasi Maximum Likelihood Estimations

	Publications	Citations per Publication	Last Author Publications	Citations per LA Publications
FWO	0.475***	0.397	0.263	0.729***
	(4.16)	(1.87)	(1.15)	(5.24)
FWO Fellowship	0.234***	0.346	0.498***	-0.299
	(2.98)	(1.39)	(2.97)	(-1.58)
Joint significance of 9 time dummies	$\chi^2 = 81.75$	$\chi^2 = 6.59$	$\chi^2 = 77.48$	$\chi^2 = 38.58$
	(0.000)	(0.5817)	(0.0000)	(0.0000)
Log-likelihood	-4630.1252	-3917.6132	-2091.8745	-2342.4386
N	1597	1179	1240	900

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 6: Fixed-Effect Panel Quasi Maximum Likelihood Poisson Estimations

	Publications	Citations per Publication	Last Author Publications	Citations per LA Publications
FWO Fellowship	0.169**	0.199	0.395***	-0.299
	(2.22)	(0.78)	(2.58)	(-1.59)
Joint significance of 9 time dummies	$\chi^2 = 86.76$	$\chi^2 = 8.33$	$\chi^2 = 89.07$	$\chi^2 = 38.97$
	(0.000)	(0.4023)	(0.0000)	(0.0000)
Log-likelihood	-2607.5699	-2698.8478	-1002.1579	-1715.7113
N	1597	1179	1240	900

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 7: Count Quantile Regressions on Citations per Publication

	Cit. p(50)	Cit. p(75)	Cit. p(90)	Cit. p(95)
FWO	0.878***	0.583***	0.523***	0.475***
	(7.06)	(6.37)	(3.75)	(2.76)
FWO Fellowship	-0.084	0.020	0.300	0.450*
	(-0.47)	(0.14)	(1.34)	(1.85)
Joint significance of 9 time dummies	$\chi^2 = 20.48$	$\chi^2 = 14.94$	$\chi^2 = 2.75$	$\chi^2 = 36.30$
	(0.087)	(0.0603)	(0.9493)	(0.0000)
_cons	0.215	0.928***	1.475***	2.273***
	(1.55)	(9.62)	(7.36)	(15.03)
N	1188	1188	1188	1188

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 8: Count Quantile Regressions on Citations per Last Author Publication

	Cit. p(50)	Cit. p(75)	Cit. p(90)	Cit. p(95)
FWO	0.687***	0.582***	0.702***	0.771***
	(6.03)	(6.01)	(4.64)	(2.79)
FWO Fellowship	-0.211	-0.152	-0.405	-0.357
	(-1.14)	(-1.16)	(-1.03)	(-0.95)
Joint significance of 9 time dummies	$\chi^2 = 24.40$	$\chi^2 = 24.43$	$\chi^2 = 6.87$	$\chi^2 = 41.93$
	(0.0020)	(0.0020)	(0.5502)	(0.0000)
_cons	0.559***	1.036***	1.984***	2.437***
	(3.43)	(12.89)	(3.80)	(14.71)
N	900	900	900	900

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Robustness

A possible concern regarding our total sample analysis could be the limited 3 year follow-up period subsequent to the allocation of the grant. One might argue that the impact of the FWO fellowship on scientific productivity can only truly be analyzed using a longer follow-up period. In table 9 we re-estimate our fixed effect Poisson quasi-maximum likelihood (QML) regression for those researchers that were granted the FWO fellowship between 2000 and 2003. Focusing on the early FWO fellowship cohort[9] and its controls allows us to examine a 10 year follow-up period, instead of the 3 year follow-up period for the total sample. These findings (Table 9) are

[9] 23 researchers were granted the FWO Fellowship between 2000 and 2003.

consistent with the interpretation of our total sample results (Table 4, 5 & 6) that researchers publish more subsequent to the FWO grant and start acting more and more as principal investigator, as measured by the increase in last author publications.

Table 9: Fixed-Effect Panel Quasi Maximum Likelihood Poisson Estimations

	Publications	Citations per Publication	Last Author Publications	Citations per LA Publications
FWO Fellowship	0.257**	0.630	0.441*	0.289
	(0.130)	(0.416)	(0.265)	(0.478)
Joint significance of 16 time dummies	$\chi^2 = 298.94$	$\chi^2 = 72.84$	$\chi^2 = 363.64$	$\chi^2 = 97.68$
	(0.000)	(0.000)	(0.000)	(0.000)
Log-likelihood	-1853.9859	-1632.0144	-1077.0262	-824.31023
N	781	614	763	380

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Within FWO Sample

Descriptive Analysis

Analyzing the characteristics of the different researchers within the FWO sample, Table 2 already suggested large differences with respect to the researchers' time-budgets, clinical obligations, research support and effective replacement. Here we present the impact of the number of Ph. D. students guided by the researcher on the bibliometric indicators (Table 10). Next, we show the impact of the number of research assistants assisting the researcher on the different publication output indicators (Table 11) and in Table 12 we describe the impact of time spent on research (h/week), on these measures in the post-allocation time span.

We identified researchers guiding more than the average number of Ph. D. students and researchers assisted by more than the average number of research assistants, using dummy variables *Ph. D. Average* and *Res. Assist. Average* (Table 10 & 11). Due to the nature of their tasks and/or prior education, we differentiate between Ph. D. students and research assistants. Following from the literature, we expect Ph. D. students and research assistant to support the granted researcher in different ways: Ph. D. students will rather conduct time-consuming and experimental work, while we forecast research assistants to conduct less experimental work and to need less supervision than the Ph. D. students (Kyvik, 1991; IVA, 2012). Likewise did we identify the group of researchers that truly spend at least 50% of their workweek on research using a dummy variable *Research Time Top* (Table 12) [10].

Based on this descriptive analysis, we expect the number of Ph. D. students to have a positive impact on the quantity output indicators, but a negative impact on the quality output indicators. A larger number of research assistants and more time spent on research are expected to have a positive impact on both the quantity as quality publication output indicators.

[10] We define a normal workweek as 5 working days of each 9 hours (9.00 – 18.00). Thus, researchers identified as spending at least 50% of their workweek on research, spend at least 22.5 hours per workweek on research.

Table 10: Within FWO Sample – Impact number of Ph. D. students

	Ph. D. > average					Ph. D. < average				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
Publications	57	8.97***	7.48	0.50	31.50	72	5.43	3.15	0.50	12.75
Citations	39	4.27***	2.51	1.27	9.97	36	5.81	3.75	2.20	16.29
LastAuthorPublications	54	2.39***	2.42	0.00	9.75	60	1.27	1.17	0.00	4.33
Citations per LA Publication	39	4.27***	2.51	1.27	9.97	30	5.92	4.11	2.20	16.29

* p < 0.10, ** p < 0.05, *** p < 0.01

Table 11: Within FWO Sample – Impact number of research assistants

	Res. Assist. > average					Res. Assist. < average				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
Publications	42	9.11***	5.53	2.00	23	87	5.98	5.60	0.50	31.50
Citations	21	6.06***	2.78	2.83	9	54	4.61	3.34	1.27	16.29
LastAuthorPublications	39	2.13**	1.73	0.25	5	75	1.63	2.03	0.00	9.75
Citations per LA Publication	24	6.02***	2.60	2.83	9	45	4.44	3.64	1.27	16.29

* p < 0.10, ** p < 0.05, *** p < 0.01

Table 12: Within FWO Sample – Impact of time spent on research

	Research Time > 50% of workweek					Research Time < 50 % of workweek				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
Publications	78	8.05***	6.81	.5	31.5	45	5.43	3.2	1.67	12
Citations	48	5.48***	3.73	1.27	16.29	27	4.18	1.92	2.2	8.90
LastAuthorPublications	75	2.10***	2.2	0	9.75	39	1.22	1.14	0	4.34
Citations per LA Publication	45	5.50***	3.85	1.27	16.29	24	4.02	1.97	2.2	8.90

* p < 0.10, ** p < 0.05, *** p < 0.01

The Determinants of Research Output within FWO Sample

As mentioned before and based on our descriptive analysis, we expect the effective clinical replacement subsequent to the allocation of the grant – resulting in more time to spend on research – to be one of key variables in our within FWO sample analysis. To take the effective replacement into account, we identified the group of researchers that indicate a higher than average clinical replacement (> 7.63 h/week) next to the grant allocation, using the dummy variable *Replacement above mean*[11].

Table 13 presents the results of a Pooled Poisson QML within our FWO survey sample on the post-grant publication output indicators[12]. We estimate the impact of *the number of Ph. D. students*, *the number of research assistants* and a clinical *replacement above mean* subsequent to the allocation of the FWO grant, while we control for *total work* (h/week), *university, department*, *FWO year* and *time* effects.

We find that a *'replacement above mean'* subsequent to the allocation of the FWO grant, has a strong positive significant impact on the number of publications and last author publications as well as on the number of citations per publication. Analyzing the marginal effects, we identify this replacement to lead to almost 4 additional publications per researcher and around 1.4 extra last author publications per researcher, while citations received increase by 93% [=exp(0.660)-1]. Furthermore do we find the number of research assistants per researcher to have a modest positive significant impact on the number of publications and last author publications. The number of Ph. D. students guided per researcher seems to have a negative impact (a -23% marginal effect [=exp(-0.258)-1]) on the number of citations per publication, but at the same time has a small positive impact on the number of last author publications.

[11] Remark that this is substantially less than the indicated part-time leave from the researchers' clinical position by the FWO: If we define a normal workweek as 5 working days of each 9 hours (9.00 – 18.00), a part time leave should equal 22.5 hours.

[12] The years subsequent to the allocation of the grant: t7 – t9

Table 13: FWO Within Sample Analysis – Pooled Poisson Quasi Maximum Likelihood Estimations

	Publications	Citations	LA Publications	LA Citations
# Ph. D. Students	0.076	-0.258**	0.133**	-0.220
	(1.62)	(-2.43)	(2.36)	(-1.50)
# Research Assistants	0.139***	0.082	0.130***	0.076
	(5.32)	(1.00)	(3.06)	(0.95)
Replacement_above_mean	0.597*	0.660**	0.952**	0.529
	(1.74)	(2.01)	(2.37)	(0.96)
Total Work	-0.011	-0.005	-0.025	-0.002
	(-0.71)	(-0.33)	(-1.39)	(-0.15)
_cons	-82.273	62.409	37.188	67.640
	(-1.53)	(0.67)	(0.45)	(0.72)
Department	Incl.	Incl.	Incl.	Incl.
University	Incl.	Incl.	Incl.	Incl.
FWO Year	Incl.	Incl.	Incl.	Incl.
Time Dummy	Incl.	Incl.	Incl.	Incl.
N	105	81	105	72

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 14 and 15 present the results from the count quantile regressions on citations and last author citations for the 50th, 75th and 90th percentile. These results provide us with additional information on the impact of the replacement on the citation distribution. We find that a *replacement above mean* has a strong significant effect on the top 10% publications, as measured by citations, both for total publications (marginal effect of 98%) as for last author publications (marginal effect of 95%) (Table 14 & Table 15). We also remark the smaller positive significant impact of the number of research assistants and the negative significant impact of the number of Ph. D. students on the different citation percentiles (Table 14). However, this does not seem to be the case for citations per last author publication (Table 15).

Table 14: Count Quantile Regressions on Citations per Publication – Within FWO Sample

	Cit. p(50)	Cit. p(75)	Cit. p(90)
# Ph. D. Students	-0.155**	-0.227***	-0.299***
	(-1.97)	(-5.29)	(-2.92)
# Research Assistants	0.142*	0.157**	0.141***
	(1.88)	(2.53)	(3.76)
Replacement_above_mean	0.322	0.353	0.667***
	(1.62)	(0.67)	(4.07)
Total Work	0.001	-0.014	-0.034***
	(0.08)	(-1.26)	(-7.59)
_cons	1.088	3.332**	4.441***
	(0.71)	(2.32)	(6.13)
Department	Incl.	Incl.	Incl.
University	Incl.	Incl.	Incl.
FWO Year	Incl.	Incl.	Incl.
Time Dummy	Incl.	Incl.	Incl.
N	81	81	81

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 15: Count Quantile Regressions on Citations per Last Author Publication – Within FWO Sample

	Cit. p(50)	Cit. p(75)	Cit. p(90)
# Ph. D. Students	-0.109	-0.143	-0.268
	(-1.45)	(-0.01)	(-1.32)
# Research Assistants	0.139***	0.136	0.107
	(2.58)	(0.03)	(1.34)
Replacement_above_mean	0.210	0.199	0.684**
	(0.98)	(0.00)	(2.06)
Total Work	0.002	-0.009	-0.005
	(0.13)	(-0.01)	(-0.15)
_cons	0.527	1.803	1.026
	(0.46)	(0.02)	(0.28)
Department	Incl.	Incl.	Incl.
University	Incl.	Incl.	Incl.
FWO Year	Incl.	Incl.	Incl.
Time Dummy	Incl.	Incl.	Incl.
N	72	72	72

T statistics in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

Table 16: Correlation Matrix Research Support & Self-reported Nature of Publications

	Basic Publ.	Clinical Publ.	Translational Publ.	# Ph. D. Students	# Res. Assistants	Replacement (h/week)
Basic Publ.	1					
Clinical Publ.	-0.6267	1				
Translational Publ.	-0.1034	-0.7103	1			
# Ph. D. Students	0.2524	-0.2439	0.0834	1		
# Res. Assistants	-0.0205	0.195	-0.2304	0.0255	1	
Replacement (h/week)	0.0564	-0.1791	0.1777	0.3558	-0.1699	1

Table 16 presents the correlations between the different variables of interest in our within FWO-sample and the self-reported nature of the publications, next to the allocation of the FWO fellowship. First of all we remark the positive correlation between the number of hours of clinical replacement and the translational nature of the publications, and the negative correlation between the number of hours of clinical replacement and the clinical nature of publications. This does not provide any strong evidence, but signals that a larger replacement might indeed lead to a less clinical focus and stimulates translational research, as intended by the FWO fellowship.

Furthermore does this correlation matrix (Table 16) offer a possible explanation for the negative impact of the number of Ph. D. students on citations which we found in our pooled Poisson QML estimation (Table 13). Table 16 confirms the fact that Ph. D. students in the biomedical science contribute mainly to basic research (correlation of 0.2524) while research assistants contribute more to clinical research (correlation of 0.195). Opthof (2011) finds that clinical publications benefit in general from a higher citation-rate than fundamental or basic publications. Thus, the higher the number of Ph. D. students guided by the granted researcher, the higher the share of 'basic' publications in his/her portfolio. As a result the average citation rate of the researchers' publications decreases. Another (additional) explanation might be that supervising and guiding Ph. D. students should be seen as an investment towards the future and early Ph. D. students cannot be expected to publish papers of a similar quality than more established researchers.

Summarized, as expected do we find researchers' time-budgets, clinical obligations, research support and effective replacement to have a significant influence on the post-grant publication outcomes within the sample of granted researchers.

7. Conclusion

Well-educated and clinical experienced scientists are believed to be able to conduct highly valuable and applicable research. It is exactly this group of researchers that holds the possibility to transfer its research findings from bench to bedside and back, given they are provided the right incentives to focus on their research and are not too distracted by the intensity of clinical care and other tasks. With this paper, we aimed to contribute to the understanding of what incentives precisely allow biomedical researchers to focus on their research and release them partially from their clinical duties and other tasks. Specifically, we investigated the impact of grant funding on these researchers' scientific productivity, while explaining the heterogeneity between them by understanding the differences in their research position and research group structure.

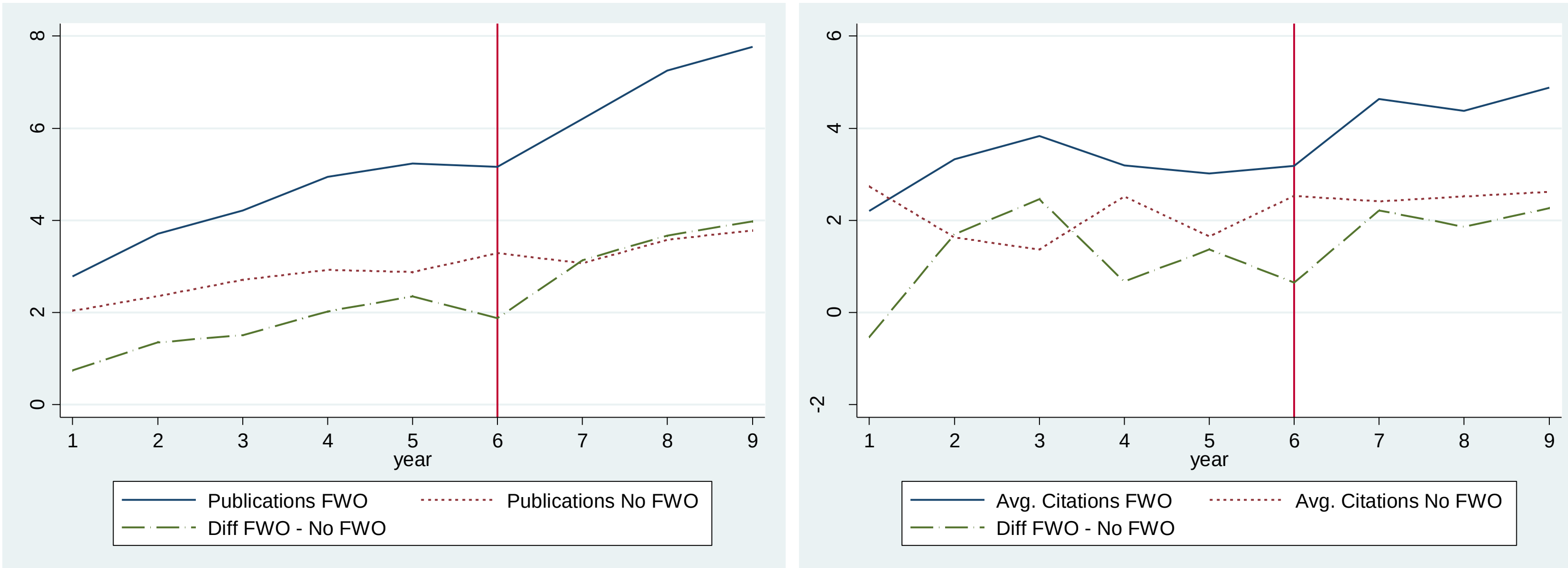
Our empirical analysis of FWO-supported clinical researchers finds that selection into the Senior Clinical Investigator fellowship leads to an 18% increase in the number of total publications and a substantial increase of about 50% in the number of last author papers published. Additionally, we see that the Research Foundation Flanders (FWO) succeeds in only selecting the most promising researchers into this fellowship. Thus, the FWO grant seems to have the desired effect: the best researchers are selected, publish more and start acting more as principal investigator subsequent to the grant.

Nevertheless, examining the heterogeneity within this FWO-granted sample, significant differences concerning researchers' time budgets, clinical obligations, research support and effective replacement appear. We find an effective clinical replacement subsequent to the grant allocation to have a strong (additional) positive significant impact of the number of (last author) publications and citations as well as on the number of publications in the top percentile of the citation distribution. Regarding the impact of human resources surrounding the granted researcher, the number of research assistants is found to have a positive significant impact on the quantity indicators, while the number of Ph. D. students guided per researcher seems to have a positive effect on the number of last author publications but a negative effect on citations. However, this negative effect might be explained by the basic nature of their publications and by the interpretation of Ph. D. students as an investment towards the future.

These findings are important for a couple of reasons. First, from a policy perspective it is essential to get a better understanding on the impact of funding and its interrelation with research time on scientific productivity. Second, from an organization point of view, it is important to grasp how human resources, in our study by means of the number of research assistants and the number of Ph. D. students, surrounding the granted researcher influence his/her research output.

Finally, we would stress the limitations of our study. Firstly, a possible concern could be the limited size of our sample. Nevertheless, it is important to realize that in this study the sample is equal to the population, thus a straightforward extension of this research is not possible. Another limitation of this paper is the fact that due to the lack of an adequate classification mechanism we were not able to determine the basic, clinical or translational nature of the analyzed publications. Hence, it was not possible to precisely examine the impact of the FWO fellowship on the nature of the following publications. Furthermore, due to the nature and the size of our sample, issues concerning the generalizability of our study may be raised. Nonetheless, we think that this study certainly has potential for applications in other sectors.

Figure 1 & 2: Average Publications per Researcher per Year & Average Citations per Publication per Researcher per Year



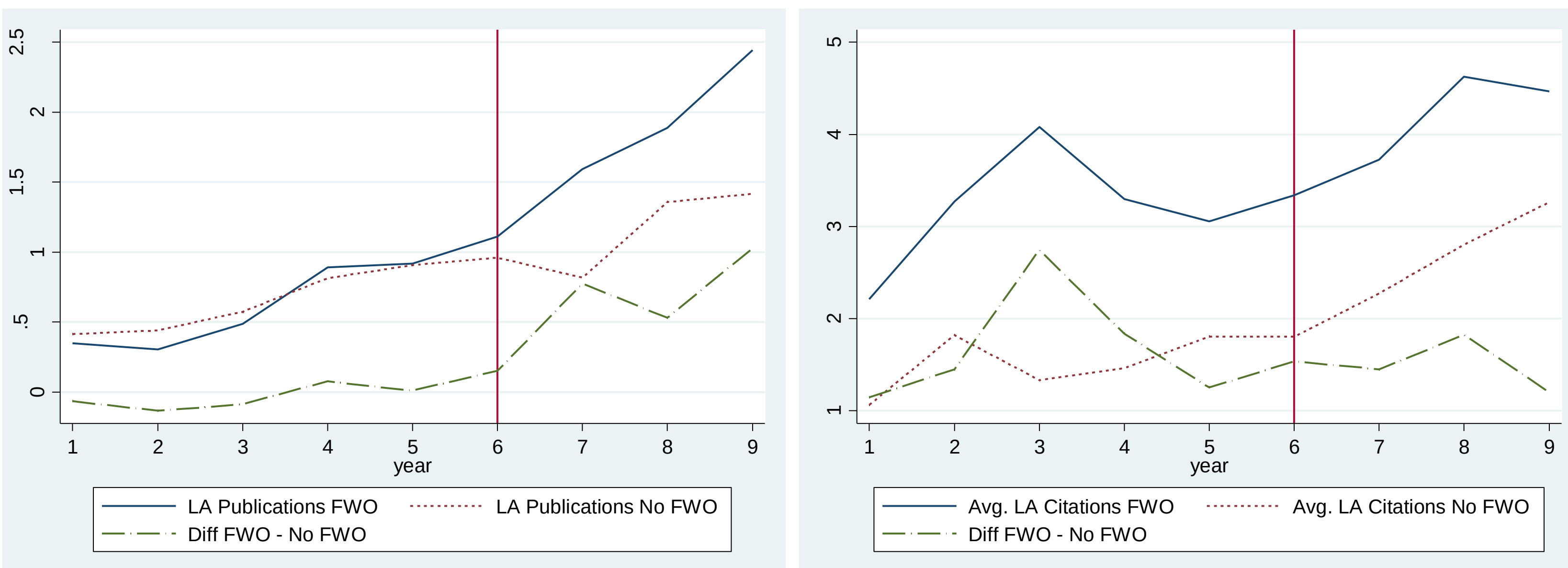


Figure 3 & 4: Average Last Author Publications per Researcher per Year & Average Citations per Last Author Publication per Researcher per Year

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