The Effect of Government Cuts of Doctoral Scholarships on Science*

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Abstract

I provide estimates of the impact of government cuts on PhD scholarships in Science. I leverage a unique quasi-natural experiment, the staggered cuts made by the Hungarian Government between 2010 and 2021 to expand Orbán's political influence over the university system. The political aim of the cut ensures that it is exogenous to the economic cycle and to the scientific activity of universities. My analysis couples the complete enrolment records of doctoral students in the country around the years of scholarship cuts with a generalized difference-in-differences approach. I find that while government cuts of PhD scholarships have an ambiguous effect on students' attainments, the policy has a clear negative effect on Science. That is, the severe reduction of scholarships increases the chance of completing the PhD by 1 pp, and the effect is stronger for female students. However, this positive effect is counterbalanced by a reduction of a similar amount of entry rates for females and non-traditional students. This suggests that besides training might improve, or the system might become more efficient, this is at the expense of social inclusion. Additionally, the effects of cuts on scientific production are negative both in terms of quantity and quality. The productivity of doctoral students drops by 2 pp while their scientific quality decreases between 0.2 pp and 1 pp. My results suggest that the reduction of doctoral scholarships might produce efficiency in terms of student attainment but at the expense of social inclusion, scientific production, and quality.

JEL codes: H75, I23, I24, I25

Keywords: Government Appropriation, Higher Education, Doctoral Scholarships, Event Study, Difference in Differences

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1 Introduction

Expanding government funding for higher education has been the pillar of 20th-century economic growth (Gennaioli et al., 2013; Sterlacchini, 2008; Goldin and Katz, 1999). However, despite increased demand for skilled labour (Blair and Deming, 2020), the last decades saw in most countries an opposing trend. A reduction of government appropriation and a decline in public funding per student. Past research warns about the danger of reducing State support for higher education concerning inequality, and human capital formation (Bound et al., 2010, 2019). Yet, the lack of causal studies and a blurry definition of budget cuts exacerbate the debate about government funds for higher education and their impact. For example, still is unclear under which conditions budget cuts at universities might improve efficiency. Part of the issue is that systematic studies with causal estimates are recent and U.S.-based. This empirical effort has documented that the reduction of government appropriation changes enrolment composition (Bound et al., 2020), reduces in-State student enrolment, students attainment, and scientific productivity (Bound et al., 2019), while it increases time to degree, debt, and deteriorates students' socio-economic status (Chakrabarti et al., 2020). However, the U.S. system has unique characteristics: the coexistence of private and public universities, high tuition fees, and the ability to attract foreign talents. In contrast, most European and emerging countries have smaller systems, less international integration and fewer possibilities to adjust to lower appropriations. In most countries research universities are public and few receive inflows of foreign (extra-EU) students who may be charged with high tuition fees.[1] Differences imply that reduced support of government appropriation in those countries in theory might have more accentuated effects or opposite outcomes than those found in U.S. studies. On the one hand, cuts of appropriation might have more negative effects since many European and emerging countries cannot leverage tuition fees and have more difficulties in attracting private funding. On the other hand, in contrast, the effects might be less negative and promote efficiency. Most of those countries have small knowledge systems and less dynamic labour markets. That is, their ability to absorb graduates is limited. Thus, a decrease in appropriation resulting in a size reduction might create efficiency in the system, allowing the entrance of those required in the job market and academia. These potential contrasting results require further investigation of higher education systems outside North America.

In this paper, I provide causal estimates of the impact in STEM of a specific cut of government appropriation to higher education in an Eastern European country, Hungary.[2] The system in Hungary is predominantly public and, in general, public Hungarian universities do not charge tuition fees.[3] The interest in the case of Hungary for the general literature is twofold. First, in contrast to the U.S. case, universities are less known internationally, and less able to attract private funding. Thus, the reduction of public funding might affect them more since it might impact the university's status and prestige. For example, many universities are non

[1] Most European universities are public especially research-oriented institutions. Tuition fees are generally low and Universities cannot charge higher fees to European citizens. Some countries charge extra-EU citizens more but this is not a generalised practice and numbers are low.

[2] Hungary has one of the most ancient and prestigious university systems in Eastern Europe and, as demonstrated by the high number of Nobel laureates, is forefront in many scientific disciplines.

[3] There are some exceptions but in general tuition when present is very low, and international students are charged more between 1,200 and 5,000 a year. See this website for an overview `https://www.mastersportal.com/articles/2871/tuition-fees-and-living-costs-in-hungary-in-2023.html`; accessed June 2023.

listed in international rankings and their perceived prestige can be volatile, as found in other emerging economies (González-Sauri and Rossello, 2023). Second, the specific case of the Hungarian universities after the second election of Orbán represents a perfect setting. It allows me to provide causal estimates of how severe government cuts of doctoral scholarships impact science by leveraging a unique quasi-natural experiment: the staggered cuts made by Orbán to increase his political control over the university system in 2010-2021.[4] Since cuts were made to persecute university deans who were in opposition to his government the cuts are exogenous to the business cycle, to university evolution, to students' behaviour, and to the scientific agenda of the ministry. To provide causal estimates, I rely on the official data on PhD students and scholars collected by the Hungarian Doctoral Council (HDC) in the years around state-funded scholarship reduction with a generalized difference-in-differences empirical strategy.

Notwithstanding recent improvements, the literature faces three main challenges that I address in this work: (1) the definition of cuts, (2) a lack of individual-level systematic studies, and (3) the endogeneity of changes in government higher education appropriations to the economic cycle.

First, considering the definition of cuts, most studies address general funding reduction. For example, Bound et al. (2020) consider a reduction of the difference between total state-level appropriations and the university's one, while Chakrabarti et al. (2020) use a calculation of shift-share of state-university appropriations as an instrument (i.e. the interaction of the baseline share of total revenue that comes from state appropriations at each public institution with yearly variation in state-level appropriations). However, general definitions do not address the impact of specific cuts. Indeed, each university decides how resources are allocated and, thus, responds differently to a reduction of appropriation, making a general cut often a non-homogeneous policy. Deming and Walters (2018) highlighted that institutions react to budget cuts through a mix of measures on prices and spending. They addressed this challenge by using the introduction of a tuition cup to isolate the effect of budget cuts from increased tuition. In Europe usually, the ability of universities to raise prices through tuition is limited, but the issue remains since budget cuts can impact the number of courses offered, infrastructures, or hiring. This makes it crucial to isolate the effect of a specific policy of cuts of government appropriation. In this paper, I overcome this issue. I examine the reduction of the number of government-paid scholarships for PhD students. This focus isolates the effect of a specific cut of appropriation without other confounding factors linked to universities' adjustment to shrinking funding. Therefore, my contribution examines a specific cut of government appropriation that operates on spending, reducing sizes: shrinking the number of students in doctoral programs. This policy is relevant to the literature because it represents a budget cut without an obvious negative outcome, and potentially affects efficiency and competition.

Second, systematic studies examining a university system focused on the aggregate impact of cuts on institutions but did not capture how reduced government appropriation affects individuals. Indeed, budget cuts might produce an internal re-organization of courses which potentially impacts students' careers differently. For example, a general decrease in graduation rates might be the net outcome of the decreased number of students enrolled and a composition

[4] These cuts were made as a "revenge" against universities opposing Orbán's plan to transform universities into private foundations (Kováts and Rónay, 2021). Such transformation was implemented in 2021. See the article in the Economist on May 1st 2021 titled "Viktor Orbán seizes control of Hungary's universities" `https://www.economist.com/leaders/2021/05/01/viktor-Orbn-seizes-control-of-hungarys-universities`; assessed June 2023.

effect of course composition (courses can disappear, be merged, or split) but at the same time, individuals enrolled in traditional tracks might benefit for the reduced number of students per class. Unfortunately, the only work that looked systematically at individual-level outcomes is Chakrabarti et al. (2020) which examines how changes in state appropriations affect the education outcomes of enrolled students. They concentrate on bachelor and master students examining student debt, and degree completion. They found evidence that an increase in state appropriation increases completion rates for Bachelor students but not for Graduate students. In contrast, I consider the effect of scholarship cuts on enrolled PhD students, examining how cuts affect the demographic composition by looking at the entry of female and non-traditional students in doctoral programs, students' probability of graduating, and students' scientific output in terms of quantity and quality of publications. The effect of scholarship has been studied before but results are not systematic and concentrate on a specific university or funding scheme. Bin et al. (2022) study the effect of receiving the Sao Paulo Research Foundation PhD scholarship in Brazil. They find that the research performance of PhD receiving the scholarship was higher than those with a rejected application. Most of the existing research concentrates, instead, on scholarships at the bachelor and master levels. For example, Cohodes and Goodman (2014) use a regression discontinuity approach comparing students just above and below the eligibility threshold of a merit grant for first-year college students in Massachusetts. They find that since the scholarship shifted enrolment towards second-tier institutions the programme reduced completion rates of students. In a recent contribution Minaya et al. (2022), examined the effect of more stringent performance requirements for receiving aid scholarships in an Italian University, Politecnico of Milano. They found that the change improved the performance of higher and medium-ability students but it discouraged the others from continuing in their studies. However, there are no studies which study the impact of a reduction of government-funded scholarships. I contribute to existing research providing systematic and individual-level estimates of government cuts of PhD scholarships in an emerging economy.

Third, the main issue I address is that government appropriations for higher education are endogenous to the economic business cycle. For example, cuts in government appropriation might follow a financial crisis that affects the willingness of students to enter higher education. In such a case, enrolment declines might cause budget cuts, rather than the other way around. An additional issue is that the government might invest in some universities to develop specific capabilities. For example, institutions specialized in specific topics (e.g. climate change, artificial intelligence, robotics, green transition) can attract political attention and receive more funding. Past research addresses this issue using an instrumental variable approach or a shift-share identification strategy. Bound et al. (2019) use as an instrument the logarithm of aggregate state appropriation arguing that a State aggregate appropriations does not depend on a specific institution enrolment decisions or research output. Instead, Deming and Walters (2018) and Chakrabarti et al. (2020) use a shift-share approach considering the combination of the share of state-level and institutional-level appropriations, based on the idea that state-wide changes in appropriations for higher education will have different effects on institutions based on their underlying reliance on state fund. In contrast, I use a difference-in-differences empirical strategy exploiting the staggered massive reduction of doctoral scholarships made by the Orbán government in his attempt to seize control of Hungary's universities. This policy was unexpected at universities and hit universities unaligned with the conservative government with different timing. The cut of government-funded scholarships has been the first policy made by Orbán to exert control over academia in an effort to root out opposition and to tame university deans to the privatization transition of universities. Other examples of Orbán's acts reducing higher education autonomy included shutting down the Central European University in 2019, banning gender studies in 2018, reducing the Academy of Sciences' independence in 2019, and in 2022 passing control of the 11 main state universities to private foundations controlled by his allies. Because a conservative political agenda might impact research in Social Sciences and Humanities I focused on STEM disciplines. The specific case of Orbán's cuts of doctoral scholarships is particularly apposite to provide causal estimates for state appropriation cuts because the cuts were punitive for political oppositions of university deans and can be considered exogenous to the economic cycle and the government investment agenda in university institutions.

By taking these three issues highlighted by the literature I provide causal estimates on the effect of severe cuts of government appropriations operating with a shrinkage of sizes in government-funded PhD scholarship. My estimates are the first considering an entire university system outside the U.S. and the first study that examined a reduction of government appropriation which operates only by cutting budget reducing sizes. I found that the reduction of state-funded PhD scholarships had a negative impact on the diversity of new students enrolled. In particular, severe cuts in government-funded scholarships reduce the probability that female and non-traditional students enter PhD training in STEM by 1 pp. However, I found that size reduction improved the students' attainment suggesting some potential effect on efficiency. In particular, I found that a severe reduction of PhD scholarship increased the probability of students to graduate by 1 pp. Further, my results support past evidence that a reduction in state support for higher education have a negative effect on research productivity, reducing the number of paper produced by 2 pp. Additionally, I found a negative, although moderate, impact on research quality that is reduced between 0.2 and 1 pp. My results highlight that reducing the support of the government for higher education by reducing the size of scientific doctoral programs has a potential trade-off. On the one hand, it might improve the condition of those entering the system by reducing competition, improving training, or fostering efficiency as underlined by the increased graduation probability. But, on the other, these improvements are counterbalanced by a reduction of diversity, social mobility, research productivity and quality. The latter, suggests that Science is a collective effort and operates in teams where often big is "better", especially for what concerns metrics of quantity or "quality" of the research output.

The paper is organised as follows, in Section 2 I highlight the institutional features of the Hungarian university system. In section 3 I describe the data construction and sources. Section 4 describes the methodology used and the empirical identification strategy. Section 5 presents the results. In section 6 I discuss the results and section 7 concludes.

2 Background

In this section I will explain the context of the Hungarian university system and its recent changes.

The Hungarian University System Hungary is an emerging economy of almost 10 million people with an old and prestigious university system. Indeed, the first Hungarian university was funded in 1367. While, in the contemporary era, until 1989 the Hungarian university system was modelled on the Soviet one where universities had little autonomy from

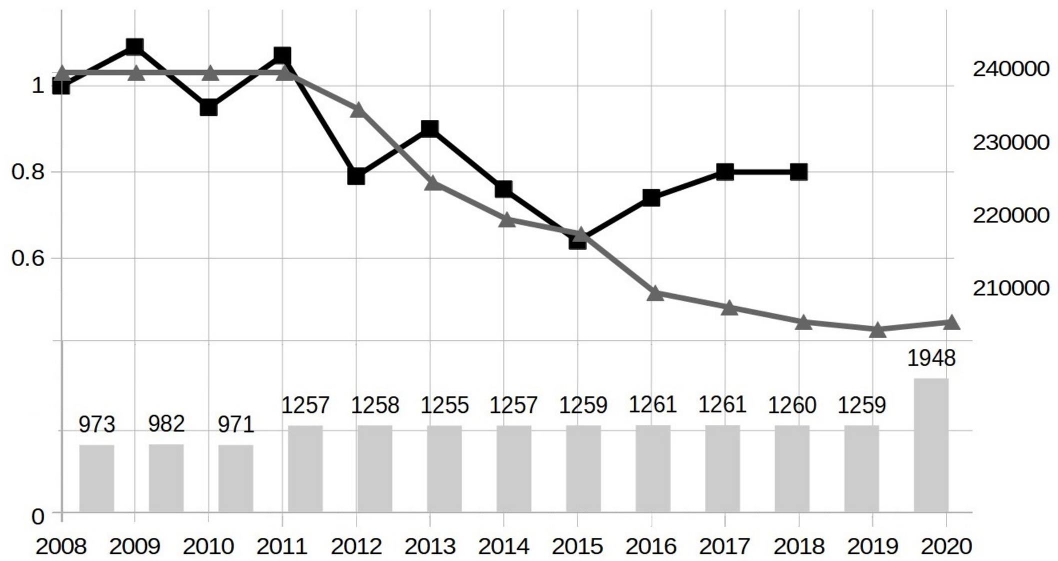

Figure 1: EVOLUTION OF THE HUNGARIAN UNIVERSITY SYSTEM 2008-2020

Notes: The black squares represent the government expenditure on tertiary education as a percentage of GDP(%) (left axis). Source: UNESCO Institute of Statistics. The gray triangles are the number of full-time students in higher education (right axis). Source: Hungarian Central Statistical Office 2021 (KSH). The light gray bars represent the total number of government-funded PhD scholarships.

the central government. After the regime changed in 1989 the university system became more similar to Western economies. Today universities have high degrees of university autonomy. The system is relatively small, there are 35 universities and among those 22 have STEM doctoral programs. In terms of subjects, since the system is relatively small it achieved several specializations to compete internationally. The university system is specialised in aspects of mathematics, chemistry, medicine, and physics where Hungarian scholars obtained important recognition as well as 13 Nobel prizes. Today the Hungarian University system is public and almost free for Hungarian students. Indeed, public universities account for the 89% of researchers and the 80% of students (Kováts and Rónay, 2021).

Figure 1 shows the evolution of funding and student enrolments between 2008 and 2020. The figure shows a significant reduction in the public support for higher education, the government expenditure on higher education as a percentage of GDP fell from 1% to 0.8% between 2008 to 2018. Kováts and Rónay (2021) underline that the government withdrew significant resources from the sector by 2010 which resulted in a decline in public support for higher education of almost 50% in real terms between 2008 and 2013. Looking at student enrolment over time the figure shows a decline, full-time students decreased by 40’000 units. In contrast, the total number of government-funded PhD scholarships stays pretty constant over time with a slight increase in the last period. However, besides aggregate figures, the number of funded scholarships was inconstant and subject to severe cuts and reallocation between fields and universities. In the next section, I will explain how this took place and why it represents a unique and apposite quasi-experiment setting to examine the impact of government scholarship cuts on Science.

Orbán's Influence on Universities The central argument that guarantees the solidity of my identification strategy turns around the recent attempt of Orbán's government to seize its political control over the Hungarian university system. His attempt has been documented in the international press[5] and according to human rights NGOs is insert in the transformation of the country to an illiberal democracy.[6] Below I am going to explain the progression of Orbán's influence on the university system and later in the text I will turn to this with the details of my identification strategy.

After the year 2010, Hungary saw an increasing deterioration of its democracy. In 2010 Orbán was elected for the second time and with the Fidesz party obtained a strong majority in a context of political fragmentation of oppositions (Kovarek and Dobos, 2023). The strong majority allowed Orbán to start a series of reforms including the new constitution in 2011. The recent report commissioned by the Global Observatory of Academic Freedom underlines that the new constitution reduced academic freedom in several ways (Kováts and Rónay, 2021). For example, while the former 1989 Hungarian constitution protected the freedom of scientific and artistic expression, to learn, and to teach without any limitation; the new constitution introduced a series of limitations to these rights and indicated that they can be restricted or abolished by law. Moreover, the new constitution was accompanied by a series of amendments which created the legal basis for the government to determine and supervise the management of universities. Within this framework, the main lever used by the government to gain control over universities was financial. Kováts and Rónay (2021) argue that from 2012 onwards the Hungarian university system saw a significant reduction in performance-based financial resources and an increasing use of direct institutional funding and earmarked grants that "allowed the government to directly reward and punish institutions through financial subsidies or deductions". Orbán's use of government funding to expand its political power and bend oppositions has been documented in Hungary by Kovarek and Dobos (2023) which examined how the Fidesz party disarmed opposition by cutting off resources of municipalities. Within the university system, that was more subtle and happened mostly with cuts and reallocation of government-funded scholarships at all educational levels.

The first change regarding scholarships was made in 2010-2011 when a new contract for students on government scholarships was introduced. Students have been required to sign a contract and ensure that they will work in Hungary for twice the length of their education. Later, in 2011 the number of government-funded scholarships was severely cut and the allocation was considered opaque by many. For example, Zsófia Deák in an article by the Heinrich Böll Foundation, a human rights organization, highlights that "the numbers of admitted students and the distribution of places among institutions and faculties since then has been decided by the prime minister personally".[7] This supports my main conjecture: the distribution of scholarships among universities has been used by Orbán to expand his political control over universities. In particular, Opendemocracy.net in an article written by Károly Füzessi on the 11th February 2013 further investigates how the government might have used scholarships as

[5] See for example articles in the Economist `https://www.economist.com/leaders/2021/05/01/viktor-orban-seizes-control-of-hungarys-universities`, and the New York Times `https://www.nytimes.com/2021/04/27/world/europe/hungary-universities-orban.html`; accessed July 2023.

[6] See for example this article by Amnesty International `https://www.amnesty.nl/actueel/what-is-going-on-in-illiberal-democracy-hungary`; accessed July 2023.

[7] See Zsófia Deák's article at `https://www.boell.de/en/democracy/europe-north-america-hungary-the-new-education-act-15394.html`; accessed July 2023.

a political weapons.[8] Károly Füzessi is an activist within the Student Network and in this article describes the consequences of Orbán acts at universities, the protests, and the bargaining process with rectors and students.[9]

This staggered cuts and reallocation of government-funded scholarships linked with Orbán's aim of controlling universities is the base of my identification strategy. The political aim of Orbán implies that scholarship cuts are exogenous to the business cycle, to the university evolution, to students' behaviour, and to the research agenda of the Ministry of Education.

3 Data Sources and Description

My primary data source is the Hungarian Doctoral Data Base (HDDB). The Hungarian Doctoral Council (HDC) manages the database to monitor doctoral training in the country. The HDC is a consultative body funded in 1994 and formed by 27 university presidents. Its consultancy activity was formalized in 2007 with the Higher Education Act which recognized the council as a formal association. The HDDB is a web database of extraordinary quality that registers all doctoral activities, such as enrolment, supervision, graduation, and publications. The HDDB data collection began in 2001 when the Ministry of Education asked to electronically store all PhD theses in the country. The data collection improved over the years and by 2007 became comprehensive and managed by HDC. By the beginning of 2008, most data of the doctoral schools were uploaded, including past data, and from 2009 onwards data are complete. The HDDB is publicly available on the HDC website and comprises multiple datasets as well as individuals' and organizations' tables.

As a second source of information, the NKFI-EPR database contains data on scientific research projects funded since 2005 by the Hungarian Scientific Research Fund (OTKA) and the National Innovation Office (NKFIH). OTKA and NKFHI are the major funding agencies in the country. OTKA has provided funding for basic science since 1986 and is under the control of the Hungarian Academy of Sciences (HAS); while the NKFIK is the governmental body responsible for research funding.

Using the mentioned sources, I constructed several original datasets representing individual-level and university-level information. The first constitutes the base of the panel dataset of all Hungarian PhD, and the second serves for retrieving university information. Additionally, I reconstructed the staggered introduction of government scholarship cuts used as my identification strategy to draw causal conclusions. I did this by collecting the Hungarian documents presented each year by the HDC that show the number of government scholarships granted each year to each university.

Below I describe the process I used to complement the main datasets with additional individual-level and university-level information needed for the analysis, then, I provide summary statistics of the main panel dataset.

[8]The article is available at `https://www.opendemocracy.net/en/can-europe-make-it/higher-education-under-threat-in-hungary/`; accessed July 2023

[9]This has been reported by several alternative sources, for example https://esu-online.org/hungarian-students-make-headway-in-government-negotiations/; accessed July 2023.

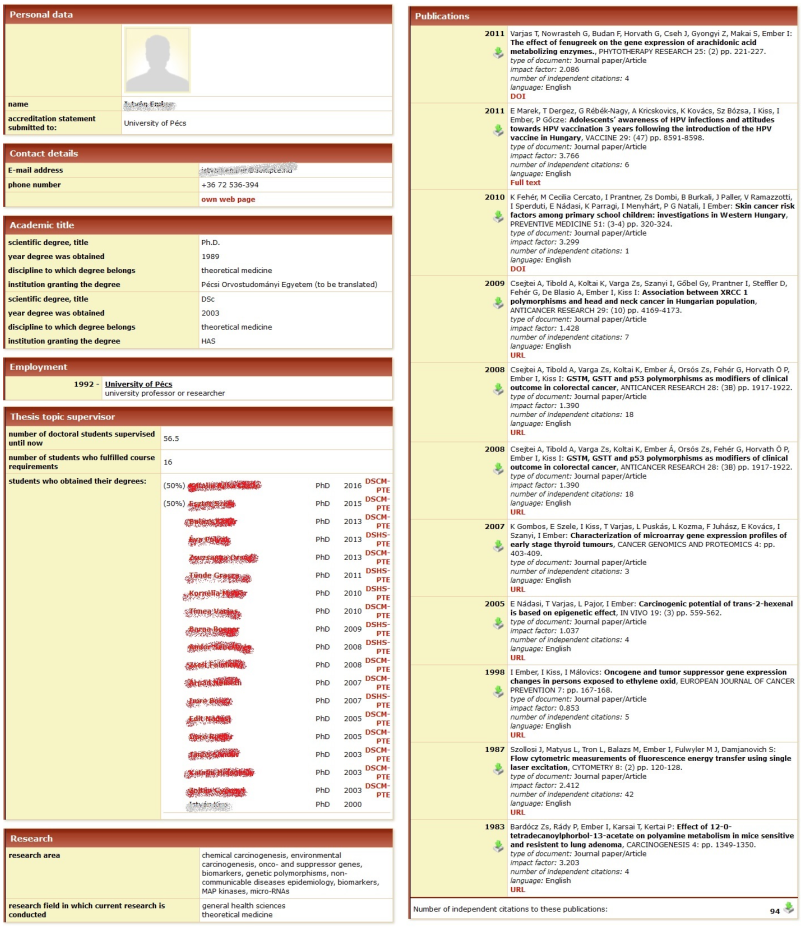

Figure 2: HDDB USER TABLE

Notes: An example of a user's individual table on the HDDB website

Individual Level Data The panel data I used for the analysis was obtained by merging 2 main HDDB tables where I integrated individual-level information by web-scraping the individual tables on the HDC website. The starting HDDB are: (1) the PhD enrolment data, containing 51,817 PhD student enrolment records between 1991 and 2022 which includes student and advisor name and surname, starting/end years, and PhD year; and (2) the defended PhD thesis, comprising 22,090 records of defended PhD thesis between 1995 and 2021 including student and advisor name and surname, date of defence, and thesis's title.[10]

I then web-scraped all individual tables in the HDC website creating 3 original datasets used to complement PhD data. An example of an individual's table is in Figure 2 and contains information such as university, field, and PhD information.[11] The 3 datasets I created to complement information about fields, institutions, and publications are (1) the advisor dataset which includes name, surname, institution, field, employment, and PhD information of PhD advisors; (2) The PhD students dataset which includes name, surname, supervisor, institution, field, and

[10]I merged the two for completing the data prior to 2008 where the collection was less systematic and inserted by each doctoral school.

[11]In particular, a user's table presents personal data, contact details, academic titles, employment, the list of students supervised, some information on the research areas of the user, and the list of publications. PhD students' tables are thinner if the student leaves academia and are not present if the student did not complete her/his PhD for this latter case I retrieve their information from advisor tables and enrolment data.

enrolment and PhD dates; (3) The Publication data which contains publication records of each user (both student and advisor) over time.

I then attached to students' and advisors' names the gender using the R package "gender" which guesses gender from names, this procedure allows to have a non-binary variable but an associated probability that the first name is masculine/feminine.[12] I then identified the extent of social mobility in the university system identifying non-traditional students as follows. I defined a non-traditional student as a student with a surname which was never observed previously among faculty members or PhD students. Additionally, to account for the quality of publications, I web-scraped the Scimago website and attached to each publication in the publication database its time-variant Scimago journal ranking.[13]

University Level Data My main university-level information comes from three original datasets: (1) the PhD government scholarship; (2) NKFI-EPR national grants; and (3) the number of Published articles. I constructed PhD government scholarship data collecting from HDC documents the number of scholarships granted by the government for each university for each year from 2006 to 2022. This database allows me to compute yearly variations of the number of PhD scholarships and thus the scattered reduction of PhD scholarships I used as the pillar of my identification strategy. I will turn to this later in section 4. To construct the university-level NKFI-EPR national grants I aggregated yearly the amount in millions of HUF granted to each university. From the Scopus database, I downloaded the number of papers published by each Hungarian university from 2005 to 2020.

The Final Dataset and Summary Statistics The final panel dataset contains 68,944 observations representing 10,083 PhD students and 3,639 Advisors. The students started their PhD between 2005 and 2020 and are followed over time from the year of first enrolment to two years after their graduation. The sample represents the entire population of PhD students in STEM and their advisors. PhD students in the sample graduate on average after 5.5 years (with a median of 5 years) which is in line with the duration of the PhD in Hungary which is between 3 and 6 years and usually it is longer for STEM fields. However, 65% of the students in the sample never graduate and this is striking considering that many university system does not report completion rates at the doctoral level. The inclusion of non-completing students is a value-added of this work and crucial for obtaining a reliable figure of a university system since attrition is often high. The PhD enrolled are evenly spread across scientific disciplines 8% in agronomy, 10 % in biology, 12% in chemistry, 10% in earth sciences, 16% in engineering, 8% in mathematics, 30% in medicine, 4% in physics, and 3% in veterinary. In terms of demographic characteristics across students, 45% are females and 55% are males, while, non-surprisingly, among advisor figures are skewed females are 22% and males 78%. In terms of social mobility of the university system as a whole, it is interesting to note that 58% of students starting a PhD are non-traditional students having a surname new to the system in the year of first enrolment. However, in this group, only 29% of students complete their PhD versus the

[12]I manually added the names that were not identified by the package. The R package uses NLP and is based on several census data to guess gender. To access the goodness of the gender guessed I picked a random sample and manually checked the accuracy that was over 95%. To avoid issues of gender assignment I used the probability guessed.

[13]Additional information about Scimago journal Ranking are available at `https://www.scimagojr.com/aboutus.php`; last access May 2023

43% of students with an incumbent surname. This observation suggests that the level of education of the family of origin matters for students in Hungary like elsewhere. In Table 1 I show summary statistics over time while all variable description and summary statistics are in Table 9 in the appendix.

Table 1: STATISTICS OF DOCTORAL STUDENTS OVER TIME

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Agronomy	16	30	53	67	94	148	192	250	317	362	409	445	472	493	493	522
col (%)	16	12	12	10	9	10	10	10	10	9	9	8	8	8	7	7
Biology	18	38	59	87	122	164	219	287	364	428	514	580	634	618	656	677
col (%)	18	15	14	13	12	11	11	11	11	11	11	11	10	10	9	9
Chemistry	10	21	38	64	112	155	220	280	371	466	541	636	695	752	816	848
col (%)	10	8	9	9	11	11	11	11	11	12	11	12	11	12	12	12
Earth Sciences	6	21	29	59	88	136	196	260	312	387	483	557	610	669	714	738
col (%)	6	8	7	9	9	9	10	10	9	10	10	10	10	10	10	10
Engineering	18	37	63	85	119	185	228	296	377	484	577	709	857	951	1,097	1,239
col (%)	18	15	15	13	12	13	12	11	11	12	12	13	14	15	16	17
Mathematics	8	19	34	55	87	125	173	225	278	330	383	438	486	509	549	595
col (%)	8	7	8	8	9	9	9	9	8	8	8	8	8	8	8	8
Medicine	20	71	121	212	321	452	602	793	1,023	1,235	1,498	1,686	1,854	1,941	2,082	2,145
col (%)	20	28	28	31	32	31	30	31	31	31	31	31	31	30	30	29
Physics	2	10	17	26	35	52	84	121	145	181	208	233	261	274	309	326
col (%)	2	4	4	4	3	4	4	5	4	5	4	4	4	4	4	4
Veterinary	3	8	12	20	29	49	64	76	99	129	147	180	194	204	226	234
col (%)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Female Student (Pr>0.5)	41	115	186	306	462	665	910	1,217	1,561	1,896	2,249	2,564	2,815	2,982	3,173	3,279
col (%)	41	45	44	45	46	45	46	47	48	47	47	47	46	47	46	45
Non -Traditional Students	59	156	266	407	580	817	1,078	1,375	1,729	2,112	2,510	2,938	3,322	3,599	3,985	4,320
col (%)	58	61	62	60	58	56	54	53	53	53	53	54	55	56	57	59
First Enrol	101	154	171	249	335	461	536	650	779	808	892	909	943	778	1,149	1,168
col (%)	100	60	40	37	33	31	27	25	24	20	19	17	16	12	17	16
Graduated	83	196	337	532	787	1,141	1,505	1,934	2,349	2,685	2,950	3,079	2,943	2,727	2,408	1,950
col (%)	82	77	79	79	78	78	76	75	71	67	62	56	49	43	35	27
Total	101	255	426	675	1,007	1,466	1,978	2,588	3,286	4,002	4,760	5,464	6,063	6,411	6,942	7,324

4 Empirical Strategy

In this section, I explain how I constructed the outcome variables, the treatment indicator, and the identification strategy I used.

Set of Outcome Variables To evaluate the effects of government cuts of doctoral scholarship I use 3 sets of dependent variables examining issues related to (1) enrolment; (2) graduation; and (3) research performance. The use of different sets of outcome variables mitigates concerns about cherry-picking outcomes and allows a holistic evaluation of the effect of scholarship cuts.

Enrolment – In terms of enrolment I considered two dependent variables representing the extent to which the university system changes its social composition through the entry of new PhDs. The first variable examines how the composition change across gender. The variable represents the probability that a student with a female name enters PhD training. Is obtained by the interaction of the dummy entry, equal to 1 if the PhD student is in her/his first enrolment year and zero otherwise, and the variable generated by the gender algorithm representing the probability that the name is feminine (i.e. the closer is to 1, the higher is the probability that the name is feminine)[14]. The second variable proxies social mobility and is a dummy variable equal to one if the student who enters PhD training has a surname that was not observed before in the dataset and zero otherwise. In principle, a surname that was not present in the university system before is a family name associated with a first generation of higher education students. I consider this variable as an upper bound of social mobility since there might be university graduates who left academia and are not tracked by HDDB database, to minimize this issue I coded the variable including all surnames of faculty and students in non-STEM fields that are excluded from the analysis. **Graduation –** In terms of graduation I used three variables. The first represents the probability that the student graduates in year t is equal to the number of years since enrolment over the total years of enrolment for students who graduate and zero otherwise. By construction, the variable is equal to one in the year of the student's PhD graduation. The other 3 variables are the interaction terms of the graduation probability variable with the dummy female, or new surname, or female with a new surname.[15] The two variables: (1) the probability that a female graduate, and (2) the probability that a student with a new surname graduates. **Research Performance –** To examine the outcomes of research performance I considered quantity and quality. Quantity is measured with the number of papers published in year t by the student. Instead as a proxy of quality, I take the average of the Scimago journal ranking of the papers published in year t by the doctoral candidate.

Treatment Indicator I construct the treatment indicator as follows. After collecting the yearly number of government scholarships for each university I computed their variation from year to year. In emerging economies often scholarships see few changes from one year to another, thus, I define as treated only those universities who suffer from severe cuts. I defined as "treated" only universities that experience severe cuts of scholarships, namely, when the yearly variation of funded scholarships is above the third quartile of the distribution of yearly changes in scholarships over the whole dataset. This method has the main advantage of identifying only variations exogenous to the university system. Indeed, small variations of the number of scholarships per university potentially interest one or few doctoral schools and can be endogenous to the evolution of the university system. For example, a loose definition of cuts in scholarship appropriations might capture the complex bargaining process between universities, field evolution, and the legislature. In contrast, a severe reduction in government appropriation of PhD scholarships was used by the government as a political instrument and is exogenous to PhD enrolment at a particular university, the evolution of the university system, and macroeconomic fluctuations. In my definition, a university is treated if it saw a cut of scholarships of 10 or more seats in comparison to the previous year. To accommodate concerns about the selected threshold, I ran several sensitivity analyses changing the treatment threshold and the results were unchanged.

Identification Strategy My main focus is to identify a causal link between the reduction of government appropriation of PhD scholarships and the performance of the university science system. The methodology I followed solved several issues concerning endogeneity as

[14]The R package computes the opposite, probability of masculine names thus I transformed it in the opposite (i.e. $Pr(F) = 1 - Pr(M)$)

[15]In this case, I used the dichotomous calculation done by my algorithm to assign gender to names.

reverse causality and omitted variable bias. For example, in such a context, the number of scholarships funded can decrease because the performance, popularity, or prestige of the university has changed. Alternatively, scholarships' fluctuation might reflect the evolution of the university system, the growth of enrolments, or their re-organizations. Some fields can become less popular experiencing a drop in enrolments and, thus, doctoral programs can disappear or split across universities. Therefore, I leverage the staggered scholarship cuts made by the Hungarian government between 2010 and 2021 to obtain estimates that can identify their causal effect on the Science System. Under the assumptions described below, the staggered cuts of scholarships generate a quasi-experimental variation that allows the estimation of the causal impact of PhD scholarship reductions using a generalized difference-in-differences strategy. The strategy compares the before-after difference in outcomes between PhD students in universities that saw a severe cut of PhD scholarships and students in colleges that did not see such a reduction between the two periods. The baseline specification is the following two-way fixed effect (TWFE) model estimated using OLS with clustered standard error at the student level:

$$Y_{ijugt} = \alpha_g + \delta_t + \beta \times PhD\ Scholarship\ Cut_{gt} + \mathbf{X}_i \times \theta + \mathbf{X}_j \times \gamma + \mathbf{X}_u \times \phi + \varepsilon_{ijugt} \quad (1)$$

where Y_{ijugt} represents an outcome for individual i who is supervised by advisor j at time t and was enrolled in university u that belongs to the scholarship cut group cohort g. α_g (or α_u) indicates the the scholarship-cut-group cohort (or university) fixed effects. $PhD\ Scholarship\ Cut_{gt}$ is a dummy variable equal to 1 if in year t there was a severe cut of PhD scholarship (a reduction $\geq$ 10 seats, i.e. the third quartile of the variation of scholarship cuts) and zero otherwise. $\mathbf{X}_i$, $\mathbf{X}_j$, and $\mathbf{X}_u$ are vectors of controls at the student-, advisor-, and university-level.

Controls at the individual levels are student's quality expressed as average Scimago journal ranking of her/his previous publications, student's productivity measure as number of papers weighted the number of co-authors per publication. Advisor-level controls are the advisor's gender (the associated probability that her/his name is a male name), the advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, the advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. University-level controls are the total millions of Forint (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers indexed in Scopus produced in year t. I estimate the equation using OLS and clustered standard error at the student level. In this way, the coefficient β identifies the average treatment effect on the treated (ATT) of the scholarships cut on enrolment, graduation, and research performance under the assumptions that the university-level average treatment effect is homogeneous across treated universities over time and the parallel trend assumption.

Under the described assumptions, the TWFE model can rule out the following concerns that impede to interpret results as causal. For example, one worry could be that more (less) prestigious universities have better (worse) student outcomes. I solve this and similar concerns driven by time-invariant differences in PhD outputs across universities including university fixed effects (or scholarship-cut-group cohort). A second issue could be that results are driven by the growth and evolution of the university system over time and that the latter affects student enrolments and outcomes across universities. For example, as the system matures the number of scholarships increases as the scientific production. Another example is that an economic crisis might negatively impact the career perspective of students and in turn, create an adverse selection of PhD students into the system. To solve this concern I added year fixed effects.

However, one concern might relate to the parallel trend assumption. In other words, universities that experience a severe scholarship cut at different time-frame might have different outcome trends of enrolment, graduation, and research performance. To address the issue I run the associated event study analysis estimating the dynamic TWFE model to account for the potential existence of pre-trend as follows:

$$Y_{ijugt} = \alpha_g + \delta_t + \beta \times \sum_{-8}^{13} D_{k(gt)} + \varepsilon_{ijugt} \tag{2}$$

Where $D_{k(gt)}$ is a dummy equal to one if the scholarship cut group cohort g is k years away from the cut in year t and zero otherwise. The baseline is the year before the cut ($k = -1$).

To ensure the reliability of the results I provide in the event study plots the alternative estimators of Sun and Abraham (2021) and Callaway and Sant'Anna (2021). Both are additional checks for the parallel trend assumption and they have the advantage of providing consistent estimates in the presence of heterogeneous treatment effects across time and or treated units. Those models have been developed to relax the assumption of homogeneity of the treatment effects allowing units treated before/after to experience different trends. This is particularly apposite here since a cut of scholarship affects the treated cohorts for all of their enrolment period and effects might grow with time.

As additional checks for the parallel trend assumption I added to the main tables (1) a model adding scholarship-cut-group cohort linear time trends that account for linear time trends; and (2) I ran a model that relaxed the assumption of linear time trend and uses the interaction of university and years fixed effects and that compares students within the same university-year who were exposed to cuts for different lengths of time based on the year in which they entered PhD.

5 Results

Table 2: BASELINE RESULTS – FEMALE ENROLMENT

	A Female Name Enters PhD Training			
	(1)	(2)	(3)	(4)
PhD Scholarship Cuts	−0.0001	−0.0005	−0.002	−0.002
	(0.004)	(0.004)	(0.004)	(0.004)
Observations	68,944	68,944	68,944	68,944
N Students	10,083	10,083	10,083	10,083
N Advisors	3,639	3,639	3,639	3,639
Year fixed effects	✓	✓	✓	✓
University fixed effects	✓		✓	
Group-scholarship-cuts fixed effects		✓		
Group-scholarship-cuts linear time trends				✓
Field dummy			✓	✓
Controls			✓	✓

Note: This table explores the effect of a government cut of funded PhD scholarships on the probability that a female name enters PhD training in STEM. Specifically, it presents estimates of coefficient β from equation (1), with the outcome variable representing the probability that a female name enters PhD in year t. The variable is greater than 0 and smaller than 1 if the student enters the sample and zero otherwise, where values closer to 1 are associated with the probability that the student has a feminine name. Column 1 estimates equation (1) without controls with university fixed effects; column 2 estimates equation (1) including instead cut-expansion groups fixed effects; column 3 includes advisor-specific and university-specific controls and scientific fields dummies to the previous specification in column 1; and column 4, instead, add to controls the cut-expansion groups linear time-trends. My controls consist of the advisor's gender (the associated probability that her/his name is a male name), the advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, the advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years included the actual one. University-specific controls are the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers produced which are listed in the Scopus database. Standard errors in parentheses are clustered at the student level. Significance codes: *p<0.1; **p<0.05; ***p<0.01

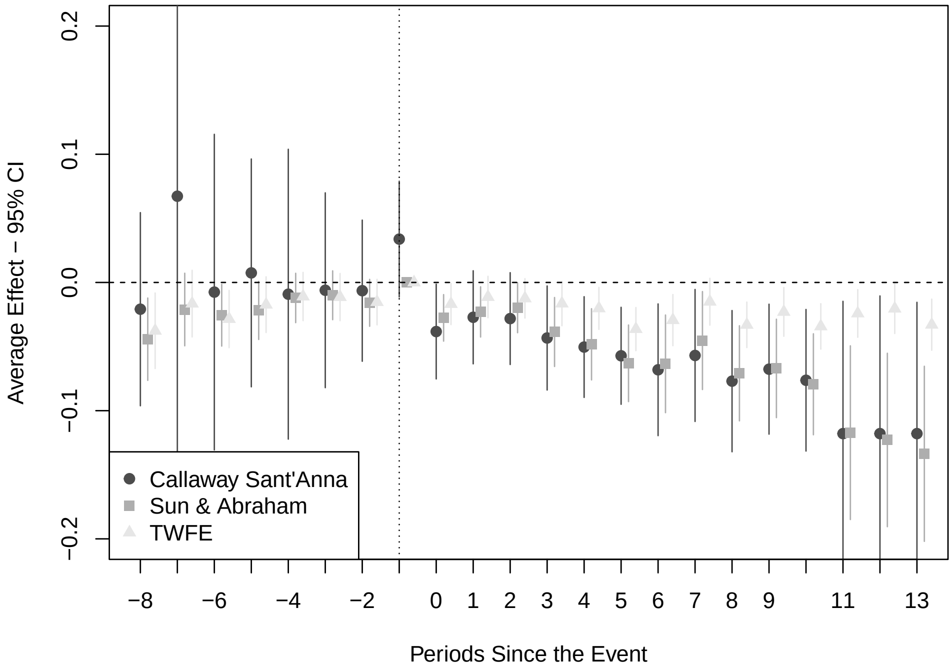

Figure 3: EFFECTS OF GOVERNMENT CUTS OF PHD SCHOLARSHIPS ON FEMALE ENTRY BASED ON DISTANCE TO/FROM CUTS INTRODUCTION

Notes: The figure shows overlays of the event-study plots constructed using three different estimators: (1) a dynamic version of the TWFE model, (2) Sun and Abraham (2021), and (3) Callaway and Sant'Anna (2021). The outcome variable is the probability that a student with a female name enters PhD training in year t and zero otherwise. In estimations (1) and (2) the baseline period is -1 and they include control variables and standard errors clustered at the student level. The controls used are: advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. Additional university-specific controls are: the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers produced which are listed in the Scopus database. Estimation (3) uses doubly robust estimation and the baseline control group is the not yet treated one.

In what follows I present how scholarship cuts affect the three sets of dependent variables on enrolment, graduation, and research performance showing the main regression and the event study plot described above.

Enrolment Results – Table 2 shows estimates of β in equation 1 on the probability that a feminine name is enrolled as a PhD. Columns one and two are baseline difference-in-difference estimations with years fixed effects and university fixed effects or scholarship-cut-group cohort fixed effects. Columns three and four add field dummies and additional controls of students, advisors, and universities described above. Additionally, the model in column three controls (as column one) for years fixed effects and university fixed effects; while model four controls for scholarship-cut-group cohort linear time trends. I found consistent estimates that scholarship cuts decreased the likelihood that a female name enters PhD training by 0.1-0.2 pp, however, the effect is not statistically significant at 10% significance level. In contrast, the dynamic analysis in Figure 3 shows that the effect of government appropriation for PhD scholarship is not immediate and grows over time. After the third year, the estimates become different than zero at 5% significance level. Additionally, the dynamic TWFE systematically underestimates the effect suggesting a heterogeneous effect linked to treatment cohorts. In particular, both estimations of Callaway and Sant'Anna (2021) and Sun and Abraham (2021) suggest an average effect of around 5 pp, corresponding to a decrease in female entry rates of 75%. Moreover, the effect growth over time from 5 pp in the medium run (3-9 years after the cuts) to more than 10 pp after 10 years. The growth and persistence of the effect over time is impressive and I will turn to this in the discussion.

Table 3: BASELINE RESULTS – NON-TRADITIONAL STUDENT ENROLMENT

	A New Surname Enters PhD Training			
	(1)	(2)	(3)	(4)
PhD Scholarship Cuts	-0.014^{***}	-0.015^{***}	-0.010^{**}	-0.014^{***}
	(0.004)	(0.004)	(0.005)	(0.004)
Observations	68,944	68,944	68,944	68,944
N Students	10,083	10,083	10,083	10,083
N Advisors	3,639	3,639	3,639	3,639
Year fixed effects	✓	✓	✓	✓
University fixed effects	✓		✓	
Group-scholarship-cuts fixed effects		✓		
Group-scholarship-cuts linear time trends				✓
Field dummy			✓	✓
Controls			✓	✓

Note: This table explores the effect of a government cut of funded PhD scholarship on the probability that a surname new to the university system enters PhD training in STEM. Specifically, it presents estimates of coefficient β from equation (1), with the outcome variable equal to one if a student with a surname that was not present before enters PhD training and zero otherwise. Column 1 estimates equation (1) without controls with university fixed effects; column 2 estimates equation (1) including instead cut-expansion groups fixed effects; column 3 includes advisor and university-specific controls and scientific fields dummies to the previous specification in column 1; and column 4, instead, add to controls the cut-expansion groups linear time-trends. My controls consist of the advisor's gender (the associated probability that her/his name is a male name), the advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, the advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. University-specific controls are the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers produced indexed in Scopus. Standard errors in parentheses are clustered at the student level. Significance codes: *p<0.1; **p<0.05; ***p<0.01

Table 3 examined how the decrease of government appropriation for PhD scholarship affects social mobility presenting the estimates of equation 1 where the dependent variable indicates whether the student entering doctoral education has a surname new to the university system. The estimates show a seizable and significant effect at 1% significance level. The probability that a student with a new surname enters PhD training decreased by 1.4 pp after a severe cut of government scholarships. This is striking, corresponding to a 16% decrease in the entry rate of non-traditional students. The event analysis in Figure 4 shows a less significant effect when the heterogeneity of the treatment timing is considered and the peak of the effect

5-6 years after the scholarship reduction.

Overall the analysis of enrolment outcomes highlights a negative impact of the decrease in government appropriation of PhD scholarships on the entry rate of females and non-traditional students with effect that persists for a decade after the cuts. This is not surprising given the well-known inertia and stratification of university systems in general and of those of emerging economies in particular (Rossello, 2021; Cowan and Rossello, 2018; González-Sauri and Rossello, 2023).

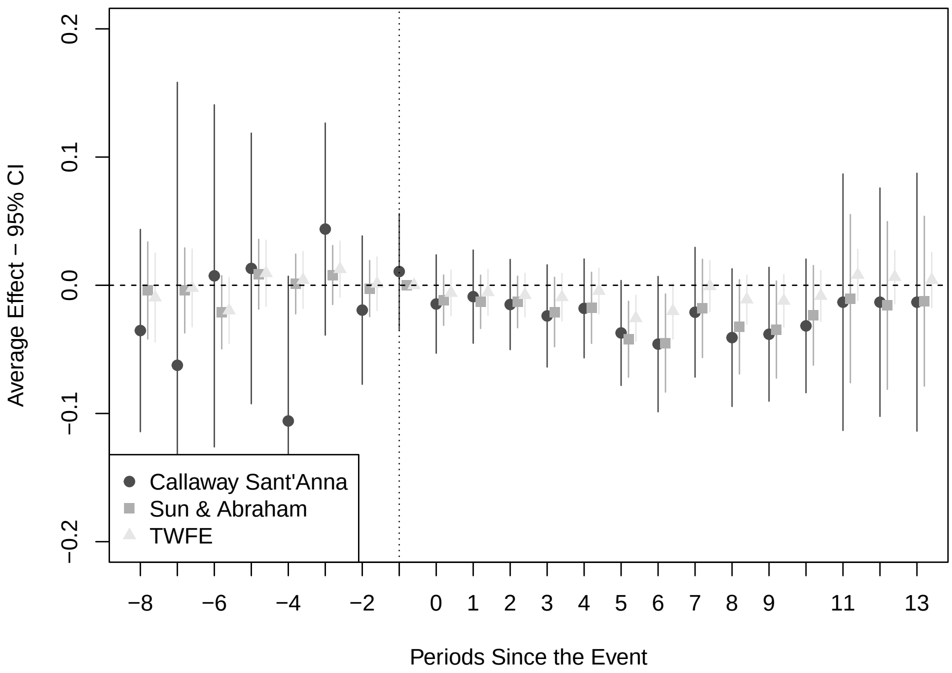

Figure 4: EFFECTS OF GOVERNMENT CUTS OF PHD SCHOLARSHIPS ON NEW SURNAME ENTRY BASED ON DISTANCE TO/FROM CUTS INTRODUCTION

Notes: The figure shows the overlays of the event-study plots constructed using three different estimators: (1) a dynamic version of the TWFE model, (2) Sun and Abraham (2021), and (3) Callaway and Sant'Anna (2021). The outcome variable is equal to one if a student with a surname new in the university system enters and zero otherwise. In estimations (1) and (2) the baseline period is -1 and they include control variables and standard errors clustered at the student level. The controls used are: advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. Estimation (3) uses doubly robust estimation and the baseline control group is the not yet treated one.

Table 4: BASELINE RESULTS – GRADUATION PROBABILITY

	A Student Graduates as PhD			
	(1)	(2)	(3)	(4)
PhD Scholarship Cuts	0.004	0.008	0.005	0.011
	(0.009)	(0.009)	(0.009)	(0.009)
Observations	68,944	68,944	68,944	68,944
N Students	10,083	10,083	10,083	10,083
N Advisors	3,639	3,639	3,639	3,639
Year fixed effects	✓	✓	✓	✓
University fixed effects	✓		✓	
Group-scholarship-cuts fixed effects		✓		
Group-scholarship-cuts linear time trends				✓
Field dummy			✓	✓
Controls			✓	✓

Note: This table explores the effect of a government cut of funded PhD scholarships on the probability that a student graduates. Specifically, it presents estimates of coefficient β from equation (1) with my variable representing the probability that the student graduates in year t as the outcome variable. The outcome variable is equal to the probability of graduating in year t and zero if the student never graduates. Column 1 estimates equation (1) without controls with university fixed effects; column 2 estimates equation (1) including instead cut-expansion groups fixed effects; column 3 includes student, advisor, and university-specific controls and scientific fields dummies to the previous specification in column 1; column 4, instead, add to controls the cut-expansion groups linear time-trends. My controls consist of students' quality expressed as the average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. University-specific controls are the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers indexed in Scopus produced. Standard errors in parentheses are clustered at the student level. Significance codes: *p<0.1; **p<0.05; ***p<0.01

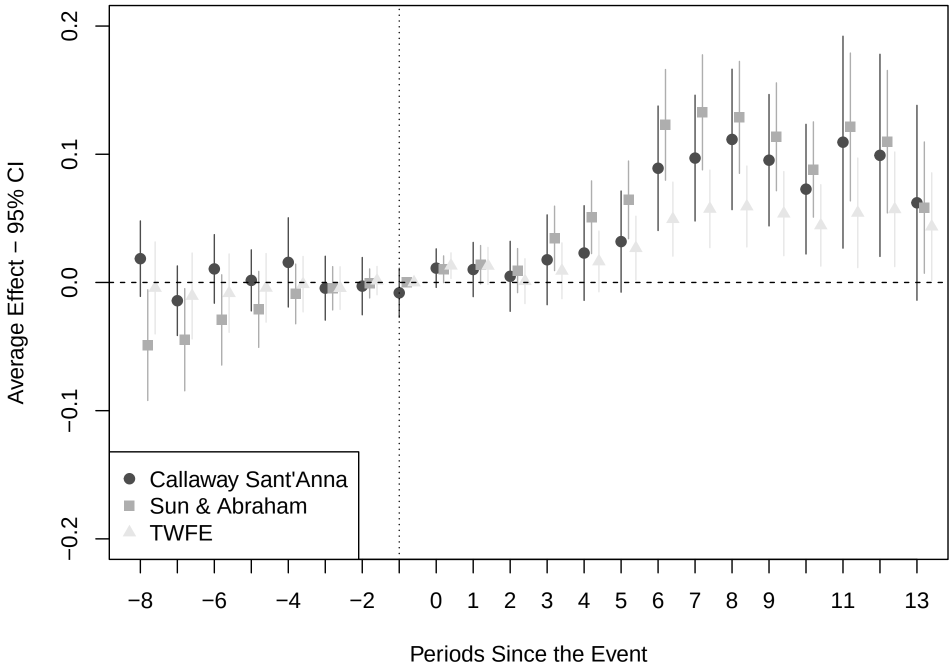

Figure 5: EFFECTS OF GOVERNMENT CUTS OF PHD SCHOLARSHIPS ON STUDENT GRADUATION BASED ON DISTANCE FROM/TO CUTS INTRODUCTION

Notes: The figure shows the overlays of the event-study plots constructed using three different estimators: (1) a dynamic version of the TWFE model, (2) Sun and Abraham (2021), and (3) Callaway and Sant'Anna (2021). The outcome variable is equal to the probability that a student graduates and zero otherwise. In estimations (1) and (2) the baseline period is -1 and they include control variables and standard errors clustered at the student level. The controls used are: students' quality expressed as average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. Estimation (3) uses doubly robust estimation and the baseline control group is the not-yet-treated one.

Graduation Results – Table 4 shows the estimates, β, of equation 1 of the effect of scholarship cuts on the probability that a student has to graduate in year t. The Table shows an increase of the graduation probability by 1 pp, however, the ATT is not different than zero at 10% significance level. This might relate to the dynamic of the effect, by definition such an effect has a lagged impact on the dependent variable. In principle, the most affected students are those entering PhD in the year of the shock but since the doctoral education last in Hungary between 3 and 6 years the main impact is expected after such a lag. Indeed, this is exactly what is found in Figure 5 where the dynamic after the event shows a significant effect after 3 years and a peak of the effect after 6 years. After 6 years the graduation probability increases by 10 pp, a 37% increase in graduation rates.

Table 5: BASELINE RESULTS – FEMALE GRADUATION PROBABILITY

	A Female Name Graduates as PhD			
	(1)	(2)	(3)	(4)
PhD Scholarship Cuts	0.014**	0.016**	0.010	0.015**
	(0.006)	(0.006)	(0.007)	(0.006)
Observations	68,944	68,944	68,944	68,944
N Students	10,083	10,083	10,083	10,083
N Advisors	3,639	3,639	3,639	3,639
Year fixed effects	✓	✓	✓	✓
University fixed effects	✓		✓	
Group-scholarship-cuts fixed effects		✓		
Group-scholarship-cuts linear time trends				✓
Field dummy			✓	✓
Controls			✓	✓

Note: This table explores the effect of a government cut of funded PhD scholarships on the probability that a female student graduates. Specifically, it presents estimates of coefficient β from equation (1) with my variable representing the probability that a female name graduates as PhD as the outcome variable. The outcome variable is equal to the probability of graduating in year t if the student has a female name (probability that the name is feminine > 0.5) and zero otherwise. Column 1 estimates equation (1) without controls with university fixed effects; column 2 estimates equation (1) including instead cut-expansion groups fixed effects; column 3 includes student, advisor, and university-specific controls and scientific fields dummies to the previous specification in column 1; column 4, instead, add to controls the cut-expansion groups linear time-trends. My controls consist of students' quality expressed as the average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. University-specific controls are the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers indexed in Scopus produced. Standard errors in parentheses are clustered at the student level. Significance codes: *p<0.1; **p<0.05; ***p<0.01

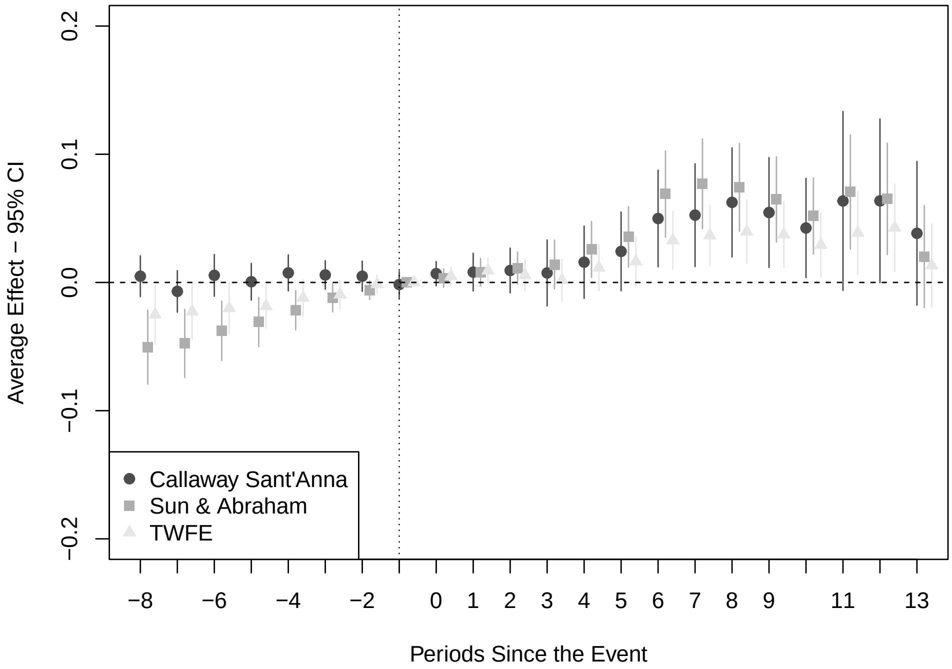

Figure 6: EFFECTS OF GOVERNMENT CUTS OF PHD SCHOLARSHIPS ON FEMALE GRADUATION BASED ON DISTANCE FROM/TO CUTS INTRODUCTION

Notes: The figure shows the overlays of the event-study plots constructed using three different estimators: (1) a dynamic version of the TWFE model, (2) Sun and Abraham (2021), and (3) Callaway and Sant'Anna (2021). The outcome variable is equal to the probability that a student with a female name graduates and zero otherwise. In estimations (1) and (2) the baseline period is -1 and they include control variables and standard errors clustered at the student level. The controls used are: students' quality expressed as average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. Estimation (3) uses doubly robust estimation and the baseline control group is the not yet treated one.

Table 5 and Figure 6 show respectively estimates for equations 1 and 2 where the dependent variable is the graduation rates of students with a female name. In the baseline specifications, estimates are consistent and statistically significant at 5% significance level. In particular, I found that the severe decrease in government PhD scholarship appropriation increases the graduation rates of female students by 1.5 pp implying an increase of 13%. The event study highlights again that the peak of the effect is after 6 years, reaching an increase of 5 pp which corresponds to a 42% increase in female graduation rates lasting 5 years.

Table 6: BASELINE RESULTS – NON-TRADITIONAL STUDENTS GRADUATION PROBABILITY

	A New Surname Graduates as PhD			
	(1)	(2)	(3)	(4)
PhD Scholarship Cuts	0.005	0.007	0.007	0.010
	(0.007)	(0.007)	(0.007)	(0.007)
Observations	68,944	68,944	68,944	68,944
N Students	10,083	10,083	10,083	10,083
N Advisors	3,639	3,639	3,639	3,639
Year fixed effects	✓	✓	✓	✓
University fixed effects	✓		✓	
Group-scholarship-cuts fixed effects		✓		
Group-scholarship-cuts linear time trends				✓
Field dummy			✓	✓
Controls			✓	✓

Note: This table explores the effect of a government cut of funded PhD scholarships on the probability that a non-traditional student graduates from PhD training. Specifically, it presents estimates of coefficient β from equation (1) with the outcome variable representing the probability that a student with a surname new to the university system graduates. The outcome variable is equal to the probability of graduating in year t if the student has a surname new to the university system and zero otherwise. Column 1 estimates equation (1) without controls with university fixed effects; column 2 estimates equation (1) including instead cut-expansion groups fixed effects; column 3 includes student, advisor, university-specific controls, and scientific fields dummies to the previous specification in column 1; column 4, instead of fixed effects controls for cut-expansion groups linear time-trends. My controls consist of students' quality expressed as the average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. University-specific controls are the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers indexed in Scopus produced. Standard errors in parentheses are clustered at the student level. Significance codes: *p<0.1; **p<0.05; ***p<0.01

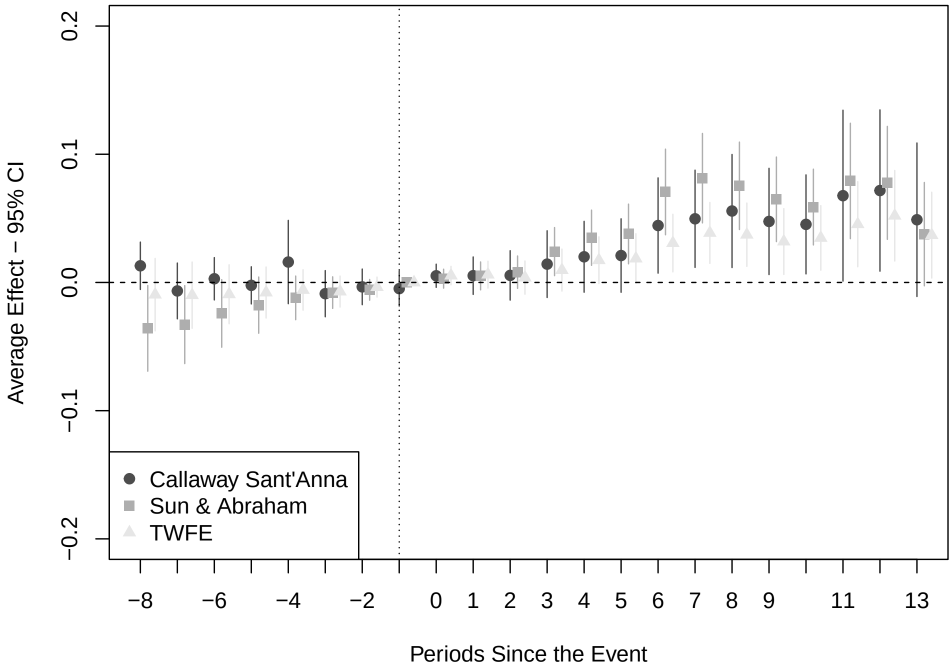

Figure 7: EFFECTS OF GOVERNMENT CUTS OF PHD SCHOLARSHIPS ON NON-TRADITIONAL STUDENTS GRADUATION BASED ON DISTANCE FROM/TO CUTS INTRODUCTION

Notes: The figure shows the overlays of the event-study plots constructed using three different estimators: (1) a dynamic version of the TWFE model, (2) Sun and Abraham (2021), and (3) Callaway and Sant'Anna (2021). The outcome variable is equal to the probability that a student with a surname new to the system graduates and zero otherwise. In estimations (1) and (2) the baseline period is -1 and they include control variables and standard errors clustered at the student level. The controls used are: students' quality expressed as average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of student supervised by the advisor in the previous 3 years including the actual one. Estimation (3) uses doubly robust estimation and the baseline control group is the not yet treated one.

The last outcome variable related to student graduation I consider is the graduation rate of non-traditional students. As described above non-traditional students are defined with respect to their family name, that is, whether their surname is new to the system. This variable proxies social mobility, the success in attainment of students likely to have low university attainments in their family and relatives. Table 6 shows a positive increase of 1 pp but the effect is not statistically significant at 10% significance level. However, the effect is clearly significant at 5% significance level in the event plot in Figure 7, after 5 years, where the scholarship cuts increase graduation rates of non-traditional students by 5 pp, corresponding to a 38% increase.

Globally, in terms of students' attainment, I find that the reduction of the number of scholarships increases the graduation rates of students. The effect is particularly strong for female students and peaks after six years from the cuts.

Table 7: BASELINE RESULTS – STUDENT PRODUCTIVITY

	Number of Papers Published in Year t			
	(1)	(2)	(3)	(4)
PhD Scholarship Cuts	-0.017^{***}	-0.016^{***}	-0.020^{***}	-0.019^{***}
	(0.006)	(0.006)	(0.006)	(0.005)
Observations	68,944	68,944	68,944	68,944
N Students	10,083	10,083	10,083	10,083
N Advisors	3,639	3,639	3,639	3,639
Year fixed effects	✓	✓	✓	✓
University fixed effects	✓		✓	
Group-scholarship-cuts fixed effects		✓		
Group-scholarship-cuts linear time trends				✓
Field dummy			✓	✓
Controls			✓	✓

Note: This table explores the effect of government cuts of funded PhD scholarships on student productivity. Specifically, it presents estimates of coefficient β from equation (1) with my variable representing the number of papers published in year t as the outcome variable. Column 1 estimates equation (1) without controls with university fixed effects; column 2 estimates equation (1) including instead cut-expansion groups fixed effects; column 3 includes student, advisor, university-specific controls, and scientific fields dummies to the previous specification in column 1; column 4, instead of fixed effects controls for cut-expansion groups linear time-trends. My controls consist of the advisor's gender (the associated probability that her/his name is a male name), the advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, the advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. University-specific controls are the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers produced indexed in Scopus. Standard errors in parentheses are clustered at the student level. Significance codes: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

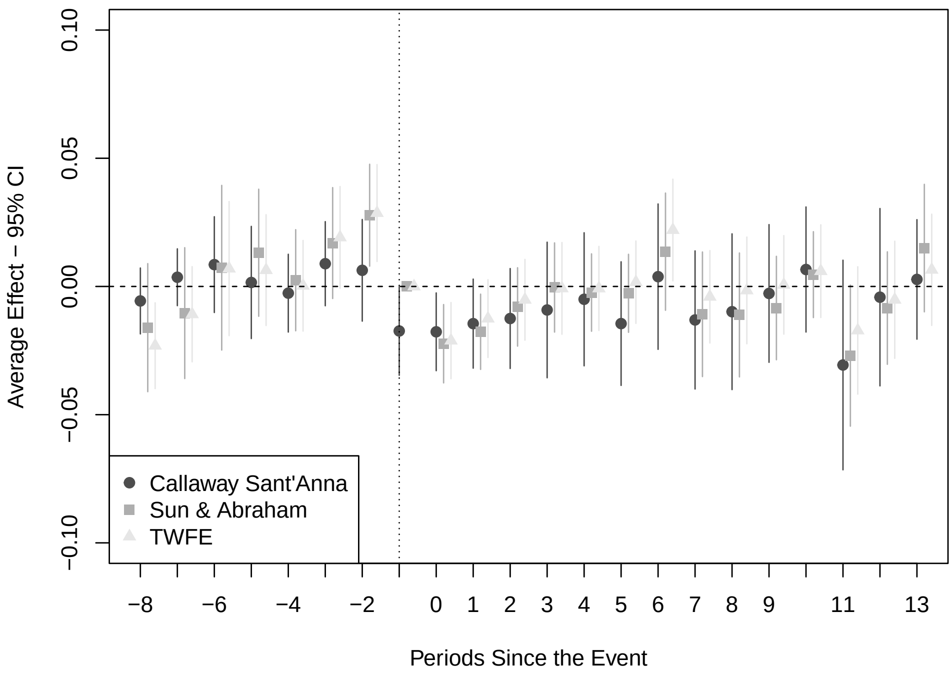

Figure 8: EFFECTS OF GOVERNMENT CUTS OF PHD SCHOLARSHIPS ON STUDENTS PRODUCTIVITY BASED ON DISTANCE FROM/TO CUTS INTRODUCTION

Notes: The figure shows the overlays of the event-study plots constructed using three different estimators: (1) a dynamic version of the TWFE model, (2) Sun and Abraham (2021), and (3) Callaway and Sant'Anna (2021). The outcome variable is equal to the probability that a student with a female name associated with a surname new to the system graduates and zero otherwise. In estimations (1) and (2) the baseline period is -1 and they include control variables and standard errors clustered at the student level. The controls used are: students' quality expressed as average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. Estimation (3) uses doubly robust estimation and the baseline control group is the not yet treated one.

Productivity and Quality of Research Results – In this paragraph, I concentrate on the scientific production of graduates in terms of quantity and quality. Table 7 shows that severe scholarship cuts reduce the number of papers produced by students by 2 pp, corresponding to a 45% reduction in student productivity. Looking at the event study in Figure 8, it appears that the effect concentrates on the first years after the government cut of scholarship appropriation. Table 8 shows that a government reduction of PhD scholarships reduces the average quality of research by 1 pp, a decrease of 59%. In terms of the dynamics of the effect, in Figure 9 the effect is mostly concentrated in a year after the event. In terms of research production, the average effect of the cut of government scholarships is mostly negative both in terms of quantity and quality. However, the dynamic of the event suggests that the effects are heterogeneous and concentrated in the short run.

Table 8: BASELINE RESULTS – STUDENT PUBLICATION QUALITY

	Average Quality of Papers' Published in Year t			
	(1)	(2)	(3)	(4)
PhD Scholarship Cuts	−0.002	−0.002	−0.013***	−0.012***
	(0.004)	(0.004)	(0.004)	(0.004)
Observations	68,944	68,944	68,944	68,944
N Students	10,083	10,083	10,083	10,083
N Advisors	3,639	3,639	3,639	3,639
Year fixed effects	✓	✓	✓	✓
University fixed effects	✓		✓	
Group-scholarship-cuts fixed effects		✓		
Group-scholarship-cuts linear time trends				✓
Field dummy			✓	✓
Controls			✓	✓

Note: This table explores the effect of government cuts of funded PhD scholarships on students' publication quality. Specifically, it presents estimates of coefficient β from equation (1) with my variable representing the average Scimago journal ranking of papers published by the PhD student in year t as the outcome variable. Column 1 estimates equation (1) without controls with university fixed effects; column 2 estimates equation (1) including instead cut-expansion groups fixed effects; column 3 includes student, advisor, university-specific controls, and scientific fields dummies to the previous specification in column 1; column 4, instead of fixed effects controls for cut-expansion groups linear time-trends. My controls consist of the advisor's gender (the associated probability that her/his name is a male name), the advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, the advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. University-specific controls are the total millions (HUF) of national research funding grants won, the total number of PhD enrolled, and the total number of papers produced indexed in Scopus. Standard errors in parentheses are clustered at the student level. Significance codes: *p<0.1; **p<0.05; ***p<0.01

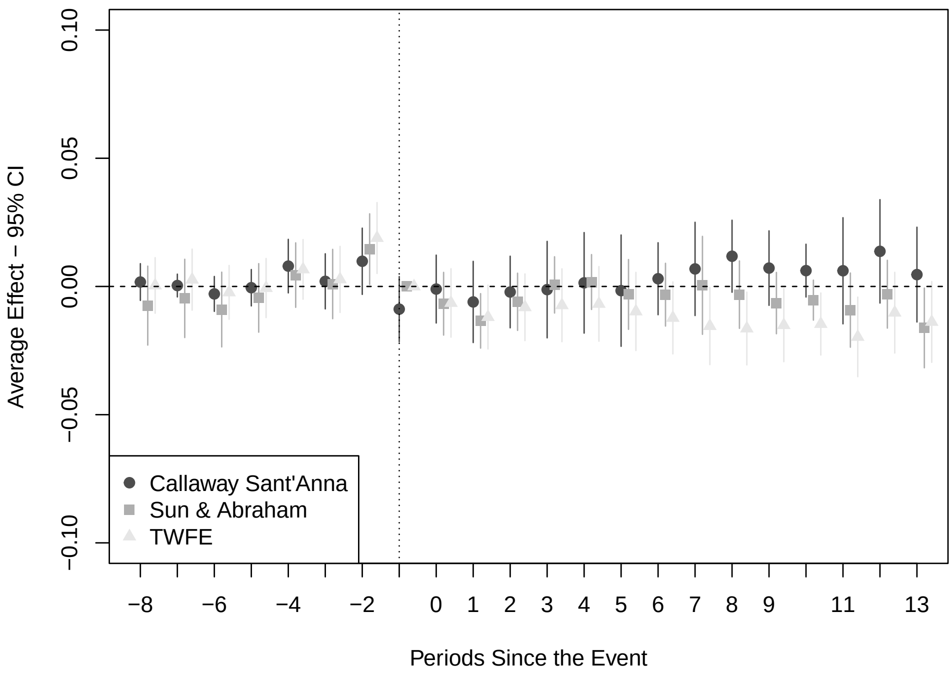

Figure 9: EFFECTS OF GOVERNMENT CUTS OF PHD SCHOLARSHIPS ON STUDENTS PAPER QUALITY BASED ON DISTANCE FROM/TO CUTS INTRODUCTION

Notes: The figure shows the overlays of the event-study plots constructed using three different estimators: (1) a dynamic version of the TWFE model, (2) Sun and Abraham (2021), and (3) Callaway and Sant'Anna (2021). The outcome variable is equal to the average quality of papers an advisor published in year t. Quality is proxied with the Scimago journal ranking associated with each paper's journal in the publication year. In estimations (1) and (2) the baseline period is -1 and they include control variables and standard errors clustered at the student level. The controls used are: students' quality expressed as average Scimago journal ranking of her/his previous publications, student's productivity measure as the number of papers weighted the number of co-authors per publication, advisor's gender (the associated probability that her/his name is a male name), advisor's quality expressed by the average Scimago journal ranking of her/his previous publications, advisor's productivity expressed as the number of previous publications weighed by the number of co-authors per publication, and the number of students supervised by the advisor in the previous 3 years including the actual one. Estimation (3) uses doubly robust estimation and the baseline control group is the not yet treated one.

6 Discussion

In this paper, I have examined the individual-level consequences of government cuts reducing the number of PhD scholarships on entry rates, graduation probability, and research performance.

My work sheds light on how such cuts operate at the individual level and in particular have highlighted three crucial considerations. First, my findings have shown that scholarship cuts have sizeable and long-lasting effects on the entry rates of female and non-traditional students. The entry rates of those students decrease between 0.2 and 2 pp. It appears that a reduction in government scholarships discourages those students from pursuing a doctorate or drastically reduces their chances of being selected for such programs. Moreover, once I accounted for the dynamic over time I found that the effect grows over time and government scholarship cuts reduce female entry rates more heavily in the medium-long run. This highlights, that female enrolment in STEM might depend on network effects linked to the number of previously enrolled female students. A similar mechanism has been underlined in the literature which examines the role of gender homophily in higher education (Rossello, 2021; Main, 2014). Overall, the contraction of doctoral scholarships might hinder social mobility. Given the importance of education on job attainment (Spilerman and Lunde, 1991; Mertens and Röbken, 2013), the persistent reduction of the entry rate of female and non-traditional students might hinder their ability to reach the top of the socio-economic ladder in the future and surely their chances to enter academia as professors.

Second, besides this distressing result, I found that doctoral programs become more efficient after the scholarship cut. In particular, graduation probability increases substantially between 0.4 and 2 pp, particularly for female students. However, the dynamic over time is an inverted U-shape and the effect appears only in the medium run. This observation suggests that students are more likely to complete their doctorates but they do not reduce their time to graduation. The increased efficiency of doctoral programs in relation to scholarship cuts might relate to a selection effect of doctoral candidates or to the quality/quantity of the supervision received. For example, a selection effect might operate on the quality of candidates selected, allowing only the higher achieving students to enter doctoral training while those with lower achievement are excluded. In contrast, the effect might be irrespective of the selected candidates but linked to the quality of supervision. In fact, scholarship cuts are likely to reduce the number of doctoral students per cohort and this might imply that those who enter find better supervision and less competition for advisor's time. Past research in higher education has shown a substantial positive impact of reduced class sizes and students' attainment (De Paola et al., 2013). Globally my results have shown that there exists a trade-off between inclusion and efficiency exacerbated by the after-shock dynamics of entry rates and graduation of female and non-traditional students. In fact, I found that government cuts to PhD scholarships have an ambiguous effect on students' attainments and potential unintended and long-lasting consequences in terms of inclusion. On the one hand, the reduction of scholarships increases the chance of completing the PhD, but at the same time, this positive effect is counterbalanced by a reduction of a similar amount of entry rates for female and non-traditional students. This trade-off is particularly relevant for the literature that examines gender or racial imbalances in science and higher education because it highlights a potential regression of the progress made in terms of equal representation of female and non-traditional students made in the last decades. Indeed, most higher education systems saw a contraction in government appropriation after the great recession and this dynamically might cause university systems to go back in terms of their demographic composition.

The third consideration refers to the effect of scholarship cuts on the research output of doctoral students. I found that both the quantity and quality of the research are negatively affected. This is not surprising given the importance that funding has for Science (Stephan, 2010; Franzoni et al., 2022). Indeed it appears that size matters. Most of the scientific research in STEM is lab-based and organised around large scientific teams. PhD candidates are at the forefront of those teams and often are those who run the lab experiments in the first place. A lower number of PhD scholarships reduces sizes and improves the efficiency of doctoral programs but it reduces the scientific capacity of a department reducing scientific productivity as well as quality. Looking at the dynamics over time, the effect is mostly in the short run. Both students' productivity and quality of research drop immediately after the cuts and then they recover. The latter might suggest that research teams might adapt to smaller groups, increasing, perhaps, their external collaboration.

7 Conclusion

Over the last two decades, university systems experienced substantial changes. A reduction of government appropriation linked to the reduced public support for public funding to universities and university marketization which culminated in austerity measures during the Great Recession. However, at the same time, enrolment has increased, peripheral university systems formalized doctoral programs, and number of doctoral graduates increased (Mangematin, 2000). These changes and transformations make the evaluation of budget cuts to higher education difficult to be identified. To overcome this issue, in this paper, I have considered the staggered cuts of PhD scholarships made by Orbán to expand his political influence over the university system. While past research has highlighted the general tendency of authoritarian regimes to exert control over the size and composition of the student body in higher education (Bautista et al., 2022; Grüttner and Connelly, 2005), in the case of Hungary, the cuts were mostly unexpected and staggered. Moreover, the political objective of Orbán's government ensures that cuts were exogenous to the economic cycle and to the scientific activity of universities. I provided a causal estimation of the impact of scholarship cuts on Science using a generalized difference-in-differences approach. My results highlight an important trade-off. While the government's reduction of PhD scholarships might improve efficiency by increasing the graduation probability of students; it does so at the expense of the inclusion of females and non-traditional PhD students, as well as, the quantity and quality of the scientific production. Future research is needed to understand the mechanisms behind this trade-off and examine more closely the complex dynamics of enrolments, graduation, and scientific production after the shock.

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Table 9: VARIABLE DESCRIPTION

Variable	Description	Categories	Percent/Mean (SD)
	Dependent Variables:		
Enrolment:			
A female name enters PhD training	Probability that a female name enters PhD in year t		0.067 (0.245)
A new surname enters PhD training	Dummy equal to 1 if the student that enters in year t has a new surname and zero otherwise	No	91%
		Yes	9%
Graduation:			
A student graduates as PhD	Probability that the student graduates in year t. It is equal to the number of years since enrolment over the total years of enrolment for students who graduate and zero otherwise		0.270 (0.390)
A female name graduates as PhD	Probability that a female name graduates in year t and zero otherwise		0.119 (0.291)
A new surname graduates as PhD	Probability that the student that graduates in year t has a new surname and zero otherwise		0.131 (0.303)
Research Quantity and Quality:			
Student productivity	The number of papers published in year t by the student weighted by the number of co-authors		0.044 (0.309)
Average quality of papers published	The average Scimago journal ranking of papers published by the PhD student in year t		0.017 (0.203)
	Treatment-Related Variables:		
PhD scholarship cut	Dummy variable equal to one if the university saw a cut in PhD scholarship greater than the 3rd quartile of the distribution of scholarship cuts	No	54%
		Yes	46%
Group-scholarship-cuts	The group cohorts when the first severe scholarship cuts occur	Never	35%
		2010	16%
		2013	23%
		2016	0.03%
		2018	15%
		2021	13%
Universities	22 Universities where 6 are the largest	DE	16%
		SZTE	15%
		PTE	13%
		ELTE	11%
		BME	10%
		MATE/SZIE	8%
		Small Uni. $< 5\%$	27%
	Student's Controls:		
Student productivity average	Average number of papers weighted by the number of co-authors per publication		0.099 (0.562)
Student quality average	Quality expressed as average Scimago journal ranking of her/his previous publications,		0.033 (0.231)
	Advisor's Controls:		
Probability that the Advisor is Male	Probability that the advisor's name is masculine		0.777 (0.398)
Advisor productivity average	Average number of papers weighted by the number of co-authors per publication		1.484 (1.239)
Advisor quality average	Quality expressed as average Scimago journal ranking of her/his previous publications,		1.098 (1.350)
Number of students supervised	number of students supervised by the advisor in the previous 3 years including the actual one.		0.646 (1.036)
	University Controls:		
Number of PhDs	Number of PhDs students enrolled in year t by the university		921 (546)
Funds for research	Total millions (HUF) of national research funding grants won or existing at year t in the university		586 (456)
Scientific Production Quantity	Number of papers in SCOPUS published by the university in year t		839 (495)