Structuring PhD Programs:
More control, better outcomes?

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Abstract

In recent years, European PhD programs have gone through several changes with the aim to adopt more structured formats, making them to some extent more similar to those in the United States. However, there is limited evidence of the impact of these changes on doctoral outcomes. This is particularly concerning at a time when the sustainability of the science system is under scrutiny due to an oversupply of PhD graduates and the precariousness of academic research careers. This paper assesses the impact of a policy change in doctoral education introduced in Spain in 2011 (Royal Decree 99/2011), which, among other things, imposed a mandatory maximum duration for Spanish doctoral programs and increased controls at the institutional level. We rely on a unique dataset to follow the entire population of Spanish graduates from 2000 to 2020 and build four sets of variables concerning graduates' outcomes that may be influenced by the policy change: publication quantity and quality, size of the scientific network, research independence, and novelty of the research produced. To assess the impact of the Royal Decree 99/2011, we implement a difference-in-differences econometric approach on a matched sample of treated Spanish university departments and control French departments. Our analysis suggests that doctoral students who graduated shortly after the policy change and were, therefore, likely to have been in their doctoral program when the law was introduced experienced no effects on their outcomes. Conversely, the change in the law appears to have benefited the productivity of doctoral students who enrolled after its introduction. The shock also reshaped the publication and research collaboration patterns of early career researchers in Spain, notably by increasing the research independence of PhD graduates and tightening links with supervisors regarding the share of co-authored articles.

Keywords: PhD students, PhD program structuring, PhD productivity, Research independence, PhD duration

JEL codes: O30, I28, J24

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1. Introduction

The importance of PhD graduates in advancing the scientific knowledge frontier and contributing to technological innovation is receiving increasing attention from scholars (Larivière, 2012; Buenstorf and Heinisch, 2020; Corsini et al., 2022). Countries invest a relevant proportion of their total GDP in higher education systems (OECD, 2019) and, with the 2005 Bologna Process, they are asked to structure their doctoral programs based on the principle that recognizes doctoral candidates as professionals, that is, early-stage researchers (Bologna Process, 2005, Salzburg Principle IV).[1]

At issue is whether PhD graduates can fully utilize their educational achievements. Indeed, the growing number of new doctoral graduates and the limited capacity of both the academic and private sectors to incorporate them into the job market has led to a pessimistic outlook on the future of the PhD labour market (Cyranoski et al., 2011; Notman and Woolston, 2020, OECD 2021). In addition, the European doctoral programs have undergone a restructuring process in the last few decades, which has led them to converge with the U.S. doctoral programs in some dimensions (Dance, 2013; EUA, 2022). In this context of reform and precariousness of the labour market, empirical evidence is needed to support policymakers in designing effective training programs that maximize students' productivity and increase their employability (Stephan, 1996; Corsini et al., 2022).

The scientific literature has recently increased attention on factors affecting PhD students' productivity and careers, such as university quality, supervisor characteristics, peer effects, and funding availability (Waldinger, 2010; Pezzoni et al., 2016; Baruffaldi et al., 2016; Gaulé and Piacentini, 2018; Horta et al., 2018; Corsini et al., 2022; Wuestman et al., 2023). A number of studies have analyzed the impact of early career academic performance on time from PhD graduation to tenure (e.g. Cruz-Castro and Sanz-Menéndez, 2010; Sanz-Menéndez et al., 2013). Works going back to the 1970s have explored the role of early career factors on academic research productivity (e.g. Clemente, 1973; Long and McGinnis, 1981 and 1985, Stock et al., 2011). Some studies have described the time to PhD graduation in specific fields (e.g., Siegfried and Stock, 2001; Stock et al., 2011) and specific institutions or countries (e.g. Lassibille and Navarro, 2010; Caparrós-Ruiz, 2019), and age at PhD is often considered an indicator of research potential, showing mixed results (Sanz-Menéndez et al., 2013). However, none of them have empirically evaluated how regulatory changes in the structure of doctoral programs affect doctoral graduates.

[1] https://eua.eu/resources/publications/626:salzburg-2005-%E2%80%93-conclusions-and-recommendations.html

Increasing regulations from higher education institutions and authorities on the design of PhD programs and procedures lies in that supporting doctoral education necessitates substantial public investment; thus, more extended PhD programs demand more money from taxpayers to support stipends, research expenses, and faculty salaries. Therefore, policymakers, directors of PhD programs, and taxpayers are urged to understand the optimal design of doctoral training that maximizes students' productivity and, consequently, the social benefit return to society through scientific advancement. In addition, the working conditions of PhD students, who often spend several years in doctoral training with meagre chances of securing a permanent job, make PhD programs' requirements, such as the maximum length of the doctoral training or conditions on where and how to publish research results, of great interest to them. An Editorial article in Nature Medicine (Editorial, Nature Medicine 13, 2007) sheds light on the fact that obtaining a PhD in biomedical sciences in the U.S. can take twice as long as it does in the U.K. or Australia. The question it raises is whether U.S. PhDs are worth more in terms of research impact and career prospects or if having a speedier system would be more advantageous to PhD students and the system as a whole.

With this paper, we aim to contribute to this debate by answering the question: What is the effect of a law imposing stricter and homogeneous regulations on PhD programs at the national level in terms of, among other things, maximum duration?

Regarding how PhD length may relate to students' performances, scholars have mainly relied on selected samples of students from specific universities or disciplines or drawn data from surveys. The most common studies on this topic investigate the factors associated with the probability of time to degree and PhD completion. For example, studies on U.S. PhD programs have shown how funding affects PhD completion (Ehrenberg and Mavros, 1995), how institution-related factors, supervisor-related factors, and the dissertation topic influence the time to attainment of the doctorate (Wao and Onwuegbuzie, 2011), and, relying on increasing data availability and up-to-date linkage techniques, how the time US STEM students spend in graduate schools has shifted upwards over the last sixty years (Cheng, 2023). Recent studies of European and New Zealand doctoral programs also focus on time to degree completion and rely on case studies of specific universities or disciplines (Spronken-Smith et al., 2018; Skopek et al., 2020; Ábrahám et al., 2022).

As regards Spain, Lassibille and Navarro (2011) study the determinants of time to graduation of PhD students from one Spanish university over an eight-year period (ending in 2004) and find

that the time to completion is extremely sensitive to student abilities and those who receive funding finish faster. Caparrós-Ruiz (2019) uses the 2009 National Institute of Statistics (INE) Survey on doctoral holders to report descriptive evidence on the determinants of the time to the doctorate in Spain and the relationship between time to the doctorate and the probability of working as a researcher. He shows how graduates in STEM have a higher probability of completing their doctoral studies than non-STEM graduates and that funding is a significant factor for PhD completion. Moreover, he finds a negative correlation between the time to complete a doctorate and the likelihood of working as a researcher.

Unique to our work, we study the impact of a policy shock introduced in Spain in 2011 (Royal Decree 99/2011). The Decree introduced novel and centralized institutional controls on the design of PhD programs at Spanish universities, demanding the creation of doctoral schools, the implementation of monitoring mechanisms on the training and research activities performed by PhD students, the mandatory nature of the open archive of the full text of approved doctoral theses, and the requirement of having a majority of reviewers external to the university in defence committees. The Decree also imposed a maximum duration of three years for all Spanish doctoral programs that started after its introduction, whereas it imposed a strict five-year window -from the publication of the Decree in February 2011 to February 2016- to complete the doctoral program for students affected by the Decree during their training. It should be noted that in July 2023, one year was added to the maximum length of PhD studies, increasing it again from 3 to 4 years. This indicates the lack of consensus in policy about the optimal duration of PhD studies and the need for evidence.[2] In this same period, France did not experience significant changes in the legislation as stringent as Spain did concerning the design and duration of PhD programs. French legislation had started to implement the Bologna process recommendations earlier but without imposing such stringent rules.

We built a unique dataset to assess the impact of the Royal Decree 99/2011. We collected data for the entire populations of doctoral graduates in Spain and France over a temporal window of 21

[2] The justification for this new change, introduced in the Royal Decree 576/2023, which entered into force on 19 July 2023, is that "the duration of doctoral studies is adapted to the real needs of students. Thus, experience in recent years has shown that the maximum duration of doctoral studies can be extended for both full-time and part-time doctoral students, with the possibility of a one-year extension." Other changes introduced in July 2023: "Each thesis is required to have a minimum of two reports issued by doctors who are experts in the subject and external to the university, who may propose aspects for improvement. The examining board that assesses the doctoral thesis is expected to be made up of a majority of members external not only to the university where the thesis is defended, but also to the programme in which the doctoral student is enrolled, and it must be guaranteed that it will have a balanced composition between men and women."

years (2000-2020), including all institutions and disciplines. We accessed the Spanish Ministry of Science, Innovation and Universities' database (*TESEO*) and the French National Repository of Electronic Dissertations (*Theses.fr*) to collect all the doctoral theses defended at Spanish and French universities. We complemented thesis information with graduates' publication record data from the Elsevier Scopus database to track graduates' outcomes over time. We construct four sets of graduates' outcomes (graduates' publication quantity and quality, size of their scientific network, research independence, and novelty of the research produced) and estimate the effect of the Royal Decree 99/2011 at the university department-year level. We propose an econometric methodology to determine the causal relationship between the reform and graduates' outcomes, which relies on a difference-in-differences estimation on a matched sample of Spanish and French departments, thus using French departments as a control group. Additionally, our approach introduces a novel contribution to the possibility of tracking doctoral graduates' outcomes over time in Spain. By matching the Spanish National repository of doctoral theses with the Scopus publication data, we have overcome the limitations of the previously used INE Survey of doctoral holders, which ended in 2009 (Caparrós-Ruiz, 2019).

The rest of the paper is organized as follows: Section 2 describes the institutional framework in Spain and France and the critical change Spain underwent in 2011. Section 3 describes the data sources, while Section 4 explains our methodological approach and the construction of variables. Section 5 summarises the results, while Section 6 concludes.

2. Policy Framework

The Bologna process in 2005 laid the foundation for the doctoral training reforms in Europe through the Salzburg Principles. The recommendations provided, which recognize doctoral graduates as early-stage researchers who contribute to the creation of new knowledge, include that doctoral programs "should operate within an appropriate time duration (three to four years full-time as a rule)" in which doctoral students should be able to work on original research ideas.[3] The discussions held in Salzburg during the Bologna process did not reach a consensus about fixing a maximum duration for PhD programs, but nevertheless, the recommendation was issued.[4]

Spurred on by the recommendations of the Bologna process, European governments began to reform their PhD programs by designing "structured" programs (Dance, 2013 Nature; EUA, 2022).

[3] Recommendation VII of the Bologna process 2005, https://eua.eu/resources/publications/626:salzburg-2005-%E2%80%93-conclusions-and-recommendations.html

[4] The summary of the discussion can be found here: https://eua.eu/component/attachments/attachments.html?task=attachment&id=1881

The traditional European doctoral model, where students were used to following the footsteps of their supervisors and the PhD program consisted of an exclusive student-supervisor relationship, has been replaced by a model where students apply to a program that includes formal structures such as doctoral schools, courses, supervision agreements, external examiners, mobility options, publication requirements, and is regulated in terms of duration, monitoring procedures, quality assessment and research evaluation (Taylor, 2023). These changes led to a convergence of European doctoral programs toward U.S. programs, with the diffusion of the academic job market culture where doctoral schools aim at delivering internationally competitive graduates (Ábrahám et al., 2022).

However, the doctoral systems are still characterized by remarkable differences, both when comparing European and U.S. doctoral programs and within the European system. For example, in terms of completion time, European students take an average of 4 to 6 years to obtain a doctorate, while their U.S. counterparts take 6 to 10 years, depending on the cohort and discipline (Mather et al., 2024; Cheng, 2023; Ábrahám et al., 2022; Spronken-Smith et al., 2018; Dance, 2013; Schillebeeckx et al., 2013). Moreover, the system is characterized by time trends, as demonstrated by the latest Survey of Earned Doctorates from the U.S. National Science Foundation, which highlights a downward trend in the duration of U.S. doctoral programs in recent years (Survey of Earned Doctorates, 2023). Regulations controlling doctoral programmes, which may be driving these differences, lack empirical support for what is the best structure for a doctoral program. As a result, some countries have decided to adopt a heavy regulatory regime with the aim of improving the doctoral research system, as in the case of Spain.

The Spanish government introduced, in February 2011, the Royal Decree 99/2011 to regulate the Spanish doctoral programs. Article 3(2) of the Decree regulates the length of the PhD programs, imposing a "duration of a maximum of three years from admission to the programme until the submission of the doctoral thesis, with a maximum extension of 2 years".[5] Students who were undertaking their doctoral training when the Royal Decree was introduced had "5 years to present and defend their doctoral thesis", after which the students were "definitively withdrawn from the doctoral programme" in case the 5-year period "elapsed without the thesis being defended".[6] The Royal Decree 99/2011 also regulates the content of the doctoral thesis, stating that

[5] Royal Decree 99/2011: https://www.boe.es/buscar/act.php?id=BOE-A-2011-2541
[6] Transitory provision 2 of the Spanish Royal Decree 99/2011.

the doctoral thesis shall consist of an "original research work prepared by the candidate" and "prepare the doctoral candidate to work independently".[7]

While the maximum duration of the doctoral training had to be adopted by all Spanish universities without discretion, how to implement originality and independence in research work was left to the universities' decisions, which have to control the respect of these criteria through their doctoral schools.[8] These doctoral schools have to supervise the decisions and specific norms established by the academic commissions of the different doctoral programs across disciplines. As an example, the doctoral school of the Universidad Complutense de Madrid requires PhD theses that consist of a 'compendium of articles' to include papers where the PhD student is the 'leading author' and that have been published (or accepted) in high-quality journals, and be compatible in terms of copyright with the mandatory requirement of an open archive of the full text of the thesis in institutional electronic repositories, but it does not have any specific requirements on the publication format for the theses published as monographs, except for the general open access requisite.[9] In contrast, the doctoral school of the University of Malaga, which currently offers 24 doctoral programs, conditions the defence on having already published the results of the PhD thesis, and this applies to both PhD formats (monographs or collections of articles). The Universidad de Malaga norms of 2012 were very explicit about the requirements on publications in Article 19 on 'quality control of doctoral theses':[10] "The Academic Commission of each of the Doctoral Programs will establish, with the approval of the Doctoral School to which the program is affiliated, and of the Postgraduate Commission, minimum quality criteria for a doctoral thesis to initiate the evaluation and defence process. Generally, and respecting the ways of operation in the different branches of knowledge, it must be demanded that, during the process of preparing the doctoral thesis, the doctoral candidate has generated quality contributions directly related to their thesis work, whose total score is equal to or greater than 1 point according to the criteria used by the National Agency for Quality Assessment and Accreditation (ANECA) at the time of evaluating the Doctoral Programs with Mention towards Excellence. These publications are those that endorse the thesis work."[11]

[7] Article 13 of the Spanish Royal Decree 99/2011.
[8] Article 13 of the Spanish Royal Decree 99/2011.
[9] https://edoctorado.ucm.es/faq-doctorado
[10] https://www.uma.es/secretariageneral/normativa/propia/consejo/octubre_2012/anexo01.pdf
[11] And it follows: "A quality contribution is understood to be that publication or merit that can be evaluated with at least half (0.5) point according to the criteria used by the National Agency for Quality Assessment and Accreditation (ANECA) at the time of evaluating the Doctoral Programs with Mention towards Excellence. In those cases where the ANECA does not establish detailed scores below 1 point, it will be the Academic Commission of the Doctoral

These examples illustrate the trend towards increasing controls at the institutional level on the duration of PhD studies and the publication outlets and formats of PhD theses, even prior to the defence, that were applied by some Spanish universities following the Royal Decree of 2011. An exhaustive review of how each university doctoral school and every doctoral program within each university has implemented and changed the application of the national rules is beyond the scope of this paper. However, it will be the subject of follow-up research.

We expect this increased control to have different possible effects on graduates' outcomes. On the one hand, shorter doctoral programs may be detrimental to the training of independent researchers, as the rapid expansion of scientific knowledge in recent decades has led to an increasing 'burden of knowledge', which may require more time for proper training and to generate papers (Jones, 2010 and 2014). However, the increase in knowledge is balanced by the development of tools that allow researchers to share, access and manage information more easily (Washington, 2012). On the other hand, longer programs may trap students in uncertain periods of apprenticeship and low-paid positions, which may have a negative impact on their confidence and creativity (Daniels, 2015). In addition, the burden of knowledge, together with increasing phenomena in science such as the teamwork approaches, division of labour and standardization of tasks, may lead to a narrow specialization of students, with the risk of turning them into "support workers" for established scientists by acting as inexpensive temporary workforce (Milojević et al., 2018; Stephan, 2012; Wuchty et al., 2007; Milojević, 2014). If this happens, we expect to see an increase in graduates' networks but a decrease in their independence and first-author publications. The increase in the graduates' network could also be the consequence of strategic behaviour by supervisors who, in order to overcome the increased institutional control, push their students to join different projects and increase co-authorship to inflate their publication productivity. Strategic behaviour could be adopted by students themselves, who see joining different networks as a portfolio investment to increase their chances of getting a job, especially when regulation does not

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Program that defines the scores corresponding to the contributions of the area, which allow assigning to each contribution a value of 0.0, 0.5, 0.75, or 1.0 point. These evaluation criteria will be public and accessible from the website of the Doctoral Program. Requirements for contributions that are presented to endorse a thesis: a. That these contributions have been presented, published, or accepted for publication after the date of registration of the thesis project. b. That the contributions include the University of Málaga, through the affiliation of the director and/or the doctoral candidate. c. That the doctoral candidate is listed as the first or second author of all of them. Only in truly exceptional cases, the Postgraduate Commission of the University of Málaga may authorize that in a contribution that endorses a thesis, the doctoral candidate appears in a position after the second, in view of the justifications presented and with the approval of the Academic Commission of the Program.A single contribution from two or more authors may only endorse one thesis" https://www.uma.es/secretariageneral/normativa/propia/consejo/octubre_2012/anexo01.pdf

allow academic inbreeding, as is often the case in European university regulation. Previous literature also reports some empirical evidence on the relationship between structured PhD programs and doctoral outcomes. Ábrahám et al. (2022) show that a shorter PhD duration in economics is associated with less prestigious graduate placements. O'Carroll (2012) finds that structured programs are associated with increased candidates' scholarly output regarding the likelihood of publishing a paper and presenting their work at international meetings. Qualitative evidence, on the other hand, suggests that structured programmes may be associated with overly prescriptive quality and time controls that risk limiting doctoral candidates' creativity and increasing occupational stress due to productivity-based evaluation (Nature Research, 2022; EUA, 2022). Finally, Cyranovsky et al. (2011) report the testimony of a Chinese neuroscientist who claims that the low quality of Chinese PhD graduates is due to a lack of quality control in the system and the fact that the three-year duration of PhD programmes is too short to develop excellent research.

3. Data sources and study sample

We build our study sample by linking data from multiple sources. The primary data source is *TESEO*, the Spanish Ministry of Science, Innovation and Universities' database, which collects information on the doctoral theses defended in Spain since 1976. It includes information from more than 80 universities and doctoral centres in all disciplines in Spain. We select data on all the theses defended in Spain from 2000 to 2020 by directly interacting with the Ministry. For each thesis, we obtain information on the title and the summary (mainly in Spanish), the name of the doctoral program, the university and department where the thesis was defended, the graduate's and supervisors' names and surnames, the defence date, the names and surnames of the defence committee members, and information on the discipline. Discipline information relies on the UNESCO Thesaurus nomenclature for fields of science and technology.[12] We also collect the same type of data on dissertations for graduates from France in the same period, including all the French institutions. We retrieve these data from the *Theses.fr* database, the French National repository of doctoral dissertations, following the approach of Corsini et al. (2022).[13]

We retrieve data on publication records from Elsevier Scopus and link them to the graduates by a novel approach combining a name matching, based on combinations of doctoral graduates and Scopus authors' names, with a machine learning classifier, the Random Forest, for disambiguation

[12] https://vocabularies.unesco.org/browser/thesaurus/es/?clang=en
[13] https://theses.fr/

(Corsini et al., 2025). The name matching allows us to obtain high recall. The Random Forest disambiguates to increase precision. The Random Forest algorithm is trained and evaluated separately for Spain and France on two manually selected samples of 16,691 Spanish graduate-Scopus author pairs and 7,311 French graduate-Scopus author pairs, respectively. Both are split into 80% (training) and 20% (evaluation). Three research assistants were hired to act as manual annotators. To predict the most likely matches, the Random Forest relies on five features (or predictors) that we compute for all the graduate-Scopus author pairs: a dummy indicating the presence of the graduate's supervisor among the Scopus publication's co-authors; two dummies indicating whether the city and country where the thesis has been defended are the same as the city and country of the Scopus author's affiliation; a dummy indicating whether the thesis discipline is the same as the Scopus author's publication discipline; and a variable calculating the Levenshtein similarity between the graduate and the Scopus author's names. Our Random Forest algorithm performs with a precision of 92%, recall of 83%, and F1 statistics of 87% (Corsini et al., 2025). We also link the students' supervisors with their respective Scopus author I.D.s following a rule-based approach, which considers the field of research and university of affiliation of the supervisors and Scopus authors and the co-authorship network of the supervisors (Corsini et al., 2025).

We use additional data sources to attribute a gender to each graduate student and her supervisor, to create the outcome variable related to the novelty of the research produced, and to construct the control variable of the department funding. We attribute gender by elaborating on IBM-GNR and WIPO data (Miguelez et al., 2019; Lax-Martinez et al., 2016). Concerning the outcome variables, we construct the novelty of the research variable by leveraging the newly released data of Arts et al. (2023). These authors calculated novelty indicators for all scientific papers of Microsoft Academic Graph (now OpenAlex) up to December 2020. The novelty indicator we use is the *cosine_max* variable of the Arts et al. dataset, which is calculated as one minus the maximum pairwise cosine similarity between the focal paper and all prior papers published in the preceding five years. The similarity measure is based on articles' new words, bigrams, trigrams, and keywords. To link the *cosine_max* to the graduates' articles in our sample, we rely on the DOI. We cannot link the *cosine_max* to all our graduates' articles since not all the Scopus publications we collected have an available DOI. Finally, we collect information on

funding from the open data of the *Agencia Estatal de Investigación* (AEI) for Spain and the *Agence Nationale de la Recherche* (ANR) for France, the two main national research funding agencies.[14]

Our collected data on doctoral graduates consists of 193,027 PhD graduates in Spain who defended their thesis from 2000 to 2020, divided into 112,623 PhD graduates in STEM disciplines and 80,404 PhD graduates in non-STEM disciplines. Among them, 49% are linked to at least one Scopus publication (64% linked in STEM disciplines, in line with the result of Corsini et al., 2022, for French STEM graduates, and 28% linked in non-STEM disciplines).[15] Concerning the control group of French graduates, we collected the theses of 257,739 graduates who defended in France between 2000 and 2020, divided into 166,607 graduates in STEM disciplines and 91,132 graduates in non-STEM disciplines.

Figure A1.a of Appendix A depicts the number of theses defended in Spain by defence year for STEM and non-STEM disciplines. The peak observed in the years 2015-2017 is attributable to the Royal Decree 2011. Figure A1.b depicts the number of theses defended in France by defence year for STEM and non-STEM disciplines.

To build our final sample, we aggregate the students and their supervisors, along with their outcomes, at the university department-year level, which is the level of analysis we use in this paper. To do so, we define a department as the interaction between each university and 8 fields of study: Engineering, Life sciences, Mathematics, Physics, Medicine, Social sciences, Psychology, and Arts and Humanities. Information on the universities and fields is retrieved directly from the theses. We harmonized the UNESCO field classification used in TESEO with the OAI-PMH field classification used in Theses.fr. Building the dataset at the department level allows us to follow each treated and control department before and after the introduction of the Royal Decree 99/2011 and, thus, estimate its causal effect on the Spanish departments' doctoral outcomes. When selecting the departments, we only keep those universities where at least one doctoral thesis was defended in each year from 2000 to 2020 and discard universities that started (stopped) delivering doctoral diplomas after 2000 (before 2020). We end up with a study sample composed of 423 Spanish departments and 424 French departments, each of them followed over a 21-year period (2000-2020). Descriptive statistics are explained in Section 4.d and reported in Appendix B.

[14] https://www.aei.gob.es/ayudas-concedidas for Spain and https://anr.fr/en/funded-projects-and-impact/datasets-on-funded-projects/ for France.

[15] Appendix A plots the number of students linked to at least one Scopus publication in each defence year in STEM (Figure A2.a) and non-STEM disciplines (Figure A2.b).

4. Methodology and variables

Determining the impact of the Royal Decree 99/2011 on the doctoral outcomes of the Spanish departments would require observing the outcomes of such departments if the law was not implemented. Two main issues affect our study. Firstly, it is obviously not possible to observe simultaneously what would happen if a department were affected by the Decree and what would happen if it were not. In addition, all Spanish departments were affected by Royal Decree 99/2011 at the same time, so we cannot take advantage of the fact that some Spanish departments were not treated, or were treated late, to use them as a control group.

Therefore, our strategy consists of building an appropriate control group by drawing departments from French universities. Specifically, we collected information on French doctoral graduates who defended their theses in France from 2000 to 2020, considering all disciplines and all the French universities, and constructed the same variables at the department-year level for the French sample as done for Spain. To retrieve data on French graduates and their theses, we rely on *Theses.fr* database, following the approach of Corsini et al. (2022). The control group of French departments allows us to build a panel dataset at the department-year level, which includes the departments of both countries followed in the same period, and then to apply a difference-in-differences econometric specification to estimate the effect of the Royal Decree 99/2011 on the Spanish departments relative to the French ones.

The estimation model is presented in Equation (1). As described in Section 2, the Royal Decree 99/2011 is likely to differently affect the doctoral productivity of the students who were already undergoing their PhD training when the law was introduced and the students who instead started their PhD after the introduction of the Decree, because of the different constraints the law imposed on them. Thus, we decided to estimate the effect of the Decree in every year from 2011 to 2020. Specifically, we propose a difference-in-differences specification that includes interaction terms between being a treated department, i.e., a Spanish department, and each year of the six pre- and nine post-treatment periods. The interacted coefficients in the pre-treatment period allow us to discuss the parallel trends assumption in Section 5, while the interacted coefficients of the post-treatment period allow us to assess the impact of the Royal Decree 99/2011 on the Spanish departments in every year from 2011 and observe how this effect evolves over time.

We made four additional choices for our analyses. First, we chose 2005 as the starting year of the panel because it was the year of the Bologna process, which we assumed had established a common landscape for doctoral education in both Spain and France. Starting in 2005 also gives us

a sufficient time window to evaluate the parallel trends before the treatment. Second, since isolating the causal effect of the Royal Decree 99/2011 may still remain challenging because Spanish and French departments may be systematically different from each other and have different pre-existing trends in their outcomes confounding the estimation of the Decree's impact, we include a Coarsened Exact Matching (CEM) procedure to pair Spanish departments with similar French departments based on their observable characteristics before the introduction of the Decree. Matching is expected to improve the comparability between Spanish and French departments and, consequently, improve the identification of the Royal Decree 99/2011 impact. The matching procedure is described in Section 4.e. Third, for each regression, we run three different specifications of the model presented in Equation 1, first including no control variables, then including time-varying controls for department characteristics, and finally including both time-varying controls for department and supervisor characteristics. Time-varying controls are expected to further improve the identification of the Decree's impact on the Spanish departments. Fourth, we perform each analysis separately for STEM and non-STEM departments, as there are relevant differences in doctoral training and scholarly practices between STEM and non-STEM fields.

$$Department\ doctoral\ outcome_{it} = \sum_{\tau} \alpha_{\tau} Spanish\ department_{i} * 1_{\{\tau=t\}} + \beta X_{it} + \theta_{i} + \eta_{t} + \varepsilon_{it}$$

Equation (1)

In Equation 1, *i* indicates a given department and *t* a given year. $1_{\{.\}}$ is a dummy variable equal to one if the condition inside the brackets is verified and zero otherwise. X_{it} is the vector of time-variant control variables. θ_i represents the department fixed effects and η_t the year fixed effects. $\varepsilon_{i,t}$ is the idiosyncratic error term. The estimated parameters of our interest are $\hat{\alpha}_{\tau}$, which expresses, for each year *t,* the effect of the Royal Decree 99/2011 in that given year. Values of $\hat{\alpha}_{\tau}$ close to zero for all the years prior to the introduction of the Decree indicate that the parallel trends assumption between the Spanish and French departments is respected, while values of $\hat{\alpha}_{\tau}$ different from zero for the years after the introduction of the Decree indicate the existence of an effect of the law.

a. Outcome variables

As we are interested in the doctoral productivity of the departments, we consider four sets of department outcomes, which measure the average department student's publication quantity and quality, size of the scientific network, research independence, and novelty of the research produced. To create these variables, we first calculate each outcome for every student belonging to a department in year *t,* and then average it by the number of students who were enrolled in that department in the same year to obtain a measure at the department-year level. We focus on the student outcomes during the PhD period, which, in the absence of information on the PhD starting date, we consider to be the time window ranging from 3 years before the student defence date to 1 year after (Corsini et al., 2022). We include one year after the thesis defence in the PhD period to account for the time lags in the publication process, which is especially slow for social sciences (Powell, 2016). In other words, we track each student's outcome in each year of her PhD period, i.e., in each year between $t - 3$ and $t + 1$, where t is the student's thesis defence year. Then, we build a panel at the department-year level where, for each year *t,* we calculate the average productivity of all the students who were doing their PhD program that year. We attribute the student's outcomes produced in year *t* of her PhD period to the same department where the student defended her thesis. In so doing, we also assign the student's outcome produced in the year after the defence to the department of defence, regardless of a possible movement of the student after graduation, as we consider the outcomes in $t + 1$ as being produced through the knowledge acquired during the PhD program.

We measure the department student's publication quantity and quality with two variables that calculate, respectively, the average number of peer-reviewed articles published by a department student in year *t* (*Avg. number of publications per department student, t*) and the average number of 3-year normalized citations received by a department student's peer-reviewed article in the publication year *t* (*Avg. number of 3-year normalized citations received by a department student's publication, t*). [16] For example, assuming a department *i* composed of only two students, *a* and *b.* If the student *a* publishes 2 papers in 2015, one receiving 2.5 citations and the other receiving 1 citation, and the student *b* publishes 1 paper in the same year that receives 3 citations, the *Avg. number of publications per department student* in 2015 is calculated as ((1+1)+1)/2 = 1.5; while the *Avg. number of 3-year normalized citations received by a department student's publication* in 2015 is calculated as ((2.5+1)/2 + 3/1)/2 = 2.375.

[16] Citations received by the peer-review articles are normalized by publication year and discipline.

As for the size of the department student's scientific network, we calculate the average number of a department student's distinct co-authors in year *t* (*Avg. number of distinct co-authors per department student, t*), following the same approach explained before.

We use three variables based on the department students' publication behaviour to proxy for the average department student's research independence. First, we calculate the average share of peer-reviewed articles published by a department student as the first author in year *t* out of her total number of peer-reviewed articles published in the same year (*Avg. share of first-author publications per department student, t*). Second, we compute the average share of peer-reviewed articles published by a department student without the supervisor among the co-authors in year *t* out of the total number of peer-reviewed articles she published in the same year (*Avg. share of publications without the supervisor per department student, t*). Finally, we calculate the average share of peer-reviewed articles published by a department student as a single author in year *t* out of her total number of peer-reviewed articles published in the same year (*Avg. share of solo-author publications per department student, t*).

Concerning the novelty of the research produced, we rely on the *cosine_max* index produced by Arts et al. (2023), which measures the novelty of scientific papers. Specifically, for each peer-reviewed article published by a student, *cosine_max* gives the cosine dis-similarity between that article and the prior article from the entire population of articles published in the preceding five years that is closest in scientific content.[17] We assign the maximum value of *cosine_max* to each department student, corresponding to the most novel paper the student has published in year *t,* and then calculate the average maximum article semantic distance per department student in year *t* (*Avg. maximum article semantic distance per department student, t).*

b. Department characteristics

We calculate three variables to control for the time-variant characteristics of the departments. For each department, we first calculate the total number of PhD students enrolled in the PhD program in each year *t (N. of PhD students in the department, t)*. Second, we calculate the share of female PhD students per department out of the total number of PhD students enrolled in the PhD program in each year *t (Share of female PhD students in the department, t*). Third, we create a dummy variable which takes value one if a given department belongs to the top 20% of granted departments in its country, in the same field, in a given year *t (Top-20% granted department, t)*. To

[17] The dis-similarity is based on the article's new words, new bigrams, new trigrams, and keywords. For a comprehensive understanding, see Arts et al., 2023.

build this variable, we retrieve information on the main national individual research grants conceded in Spain and France by the AEI and the ANR, the *Proyectos I+D* grants and *ANR* grants, respectively. For each department in each year *t*, we first counted the total number of grants received by their affiliate researchers and then assigned the value one to the dummy *Top-20% granted department* if the total number of the department's grants falls into the top 20% of the distribution of grants received by all the departments in the same country, in the same field, and in the same year.

c. Supervisor characteristics

We add four time-variant variables controlling for department supervisors' characteristics. The productivity of the PhD students is related to the characteristics of their supervisors (Corsini et al., 2022), and the supervisors' characteristics and productivity might relate to the change in the doctoral policy introduced by the Spanish government as well. For instance, after the introduction of the Royal Decree 99/2011, department directors may encourage higher quality supervisors to supervise PhD students since students must satisfy more stringent criteria to obtain the PhD diploma. Hence, controlling for supervisors' characteristics helps us to reduce confounding effects and improve the identification of the Royal Decree 99/2011 impact on the departments' doctoral outcomes.

We control for the share of female supervisors out of the total number of department supervisors in each department-year (*Share of female supervisors in the department, t*).[18] To account for the academic age of the supervisors, we include a variable measuring the average seniority of the department supervisors in each *t* (*Avg. department supervisor seniority, t*). Finally, we include two variables controlling for the supervisors' publication productivity and scientific network size. To avoid mixing the productivity of the supervisors with that of their PhD students, given the common practice of co-authoring articles between students and supervisors, we lagged the supervisors' publication productivity and scientific network size variables by one year. Thus, we measure the average 3-year normalized citation-weighted publication productivity per department supervisors in year *t – 1 (Avg. 3-year normalized citation-weighted publications per department supervisor, t−1),* which accounts for both the quantity and quality of the supervisors' publication productivity by weighting the supervisors' articles by the citations they received. Finally, we measure the

[18] We do not include the number of supervisors in the department since it is highly correlated with the number of PhD students in the department.

average number of distinct co-authors per department supervisor in year *t – 1* (*Avg. number of distinct co-authors per department supervisor, t−1).*

d. Descriptive statistics

In Appendix B, we report the descriptive statistics of our study sample. Table B1 reports the statistics of the treated Spanish departments, while Table B2 shows the statistics of the control French departments.

Table B1 and Table B2 denote that, on average, Spanish departments have a higher doctoral student productivity in terms of average number of publications per department student (mean of 0.40 per year in Spain vs 0.30 in France), average number of 3-year normalized yearly citations received by a department student's publication (0.60 per year for Spain vs 0.55 per year for France), and average number of distinct co-authors per department student (2.61 per year for Spain vs 1.65 per year for France). The variables proxying for the research independence and the novelty of the research produced are instead very similar for the two countries' departments.

However, Spanish departments are, on average, smaller than French departments (86.38 PhD students per department-year in Spain vs 108.06 in France). Spanish departments are also more balanced in terms of student gender composition (47% of the PhD students in a Spanish department-year are female vs 40% in France).

The supervisors are, on average, slightly more senior and more productive in France than in Spain. The share of female department supervisors in France is lower than in Spain.

The descriptive statistics reported in Tables B1 and B2 show that the treated and control departments in our sample are systematically different in terms of average characteristics. This result supports our choice of using a matching procedure to obtain a final study sample that is balanced in the covariates, strengthening the parallel trends assumption and allowing us to mitigate the biases in the estimation of the Royal Decree 99/2011 effect.

e. Matching

To increase the comparability between the Spanish and French departments and mitigate violations of the assumption of parallel trends, we rely on a CEM procedure. Specifically, we select 11 observable department variables on which to match Spanish departments to similar French departments. The 11 variables consist of: 8 dummies corresponding to the eight fields in our sample, i.e., *Engineering, Life sciences, Mathematics, Medicine, Physics, Social sciences, Psychology*, and *Arts and humanities*, and 3 variables describing the department doctoral

productivity before the introduction of the Royal Decree 99/2011, i.e., between 2005 and 2010. The productivity variables consist of a yearly measure of the average department student's number of publications between 2005 and 2010 (*Average yearly number of publications per department student [2005-2010])*, the yearly average number of 3-year normalized citations received by a department student's publication between 2005 and 2010 (*Average yearly number of 3-year normalized citations received by a department student's publication [2005-2010]*), and the yearly average number of distinct co-authors per department student between 2005 and 2010 (*Average yearly number of distinct co-authors per department student [2005-2010]*). Differently from the outcome variables we use in the main model of Equation 1, in this case, we calculate a single value for each department doctoral outcome by averaging the yearly value of such outcome over the six years before the treatment, i.e., from 2005 to 2010.

When performing the CEM, we decided to adopt a conservative approach by forcing an exact matching on the fields in order to only pair departments that are exactly in the same field, and by asking for a 1-to-1 matching within each stratum created by the matching procedure. The 1-to-1 matching implies the nearest neighbour matching without replacement within each stratum, leading to a drop of treated (or control) departments that are not matched to any control (or treated) departments. This decision includes the cost of reducing the sample but allows us to increase the covariate balance between the treated and control groups and, thus, to increase the identification power of our estimates.

After the CEM procedure, we remain with 236 Spanish departments matched with 236 similar French departments. We lost 187 Spanish departments and 188 French departments that were too dissimilar to be included in the sample.

Table C1 in Appendix C reports the means, standardized mean differences, and variance ratios of the matching covariates before (Columns 1 to 4) and after (Columns 5 and 8) the CEM. After the matching, the standardized mean differences are close to zero for all the covariates, while the variance ratios are close to one for all the covariates. These results indicate that, in the final sample, we obtain covariates that are balanced in means and variability between the treated and control groups.

5. Results

a. Main results

Tables 1 to 7 report the OLS estimates of the model described in Equation 1. For our coefficient of interest, α, which measures the effect of the Royal Decree 99/2011, we report in the tables its estimated values only for the years after the treatment, i.e., from 2011 to 2020. The estimated values of α for the years prior to the treatment are discussed in the next section when checking for the parallel trends assumption.

Tables 1 to 7 report the results of the OLS estimates for each of the seven department outcomes considered. Each table reports the estimates divided by STEM and non-STEM departments and includes three different specifications of the model of Equation 1: first considering no control variables (Columns 1 and 4), then including time-varying controls for department characteristics (Columns 2 and 5), and finally including both time-varying controls for department and supervisor characteristics (Columns 3 and 6).

The results show that the Royal Decree 99/2011 significantly positively affected the Spanish department doctoral outcomes for both STEM and non-STEM departments in the period between 2017 and 2020. This period coincides with the end of the 5-year window given to students who were in their doctoral studies at the time of the Decree's introduction to complete their doctoral program.

Interestingly, we find a non-significant, and in some cases negative, effect of Royal Decree 99/2011 on Spanish departments in the years between 2011 and 2016. The negative effect seems to be more pronounced in non-STEM departments, especially concerning the quality, independence, and novelty of the department's doctoral productivity.

When controlling for department and supervisor characteristics, the result of the estimated effect of the Royal Decree 99/2011 does not change.

[Tables 1 to 7 about here]

b. Parallel trends

To make the identification of the Royal Decree 22/2011 impact valid, we check the existence of parallel trends in the outcomes of the Spanish and French departments before the law was introduced.

Our specification model of Equation 1 allows us to observe the estimated parameter of interest $\hat{\alpha}_\tau$ in all the years prior 2011, indicating the effect of the Decree in the period before the treatment. Values of $\hat{\alpha}_\tau$ close to zero for the years prior to 2011 would suggest there are no statistically significant differences in the department doctoral outcomes between Spanish and French departments prior to the treatment.

The results of the check for parallel trends assumption can be seen in figures 1 to 7 and tables 8 to 14. Figures 1 to 7 plot the values of $\hat{\alpha}_\tau$ before and after 2011, along with their 95% confidence interval. The figures show that, for all the seven dependent variables considered and both for STEM and non-STEM departments, almost all the estimated parameters of interest before 2011 are not statistically significant, with only a very few scattered exceptions which, in any case, do not denote different trends between Spanish and French departments in the period prior to the treatment.

The values of the estimated parameters $\hat{\alpha}_\tau$ before 2011 are also reported in Tables 8 to 14.[19]

[Figures 1 to 7 about here]

[Tables 8 to 14 about here]

6. Conclusion

Overall, the results of our analysis show that the Royal Decree 99/2011 significantly impacted the outcomes of the Spanish departments. We found a positive impact on almost all the measured outcomes between 2017 and 2020, for both STEM and non-STEM departments. Interestingly, we found a non-significant effect of the Royal Decree 99/2011 in the years between 2011 and 2016. The shock also reshaped the publication and research collaboration patterns of early career researchers in Spain, notably by increasing the apparent research independence of PhD graduates and tightening links with supervisors in terms of the share of co-authored articles.

The next step in our research is to investigate the possible mechanisms that drive the effects we have found. First speculation on the mechanisms may suggest that a policy implemented to re-design the PhD programs may have a negative effect on the students carrying out their PhD during the law's introduction and who have to adapt to the administrative changes of their

[19] The model specification used to estimate is that of Equation 1 but without the control variables. The inclusion of the control variables does not change the results.

program's conditions and rush to complete their thesis. The negative effect we found may be driven by the less research-oriented students who remain enrolled in the PhD program for several years, and when they are asked to defend the thesis, they rush to do it but without publishing any scientific outcome. In addition, the pronounced positive effects we found in the years after 2016 may be indicative of the beneficial effects of the Decree on students enrolled in doctoral programs after the Decree came into force. This positive effect may be driven by (i) the new conditions imposed by the law which encourage students to be more productive, or by (ii) a selection effect: either only motivated students decided to enrol in PhD programs characterized by more stringent rules in terms of duration and quality control, or supervisors started to select better students, or after the law the students who dropped out the PhD before defending increased and only the best students managed to complete it.[20]

[20] Recall that we cannot track students who have dropped out of the PhD program before the defence.

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Appendix A. EDT data and matching with Scopus.

Figure A1.a Graduates in Spain

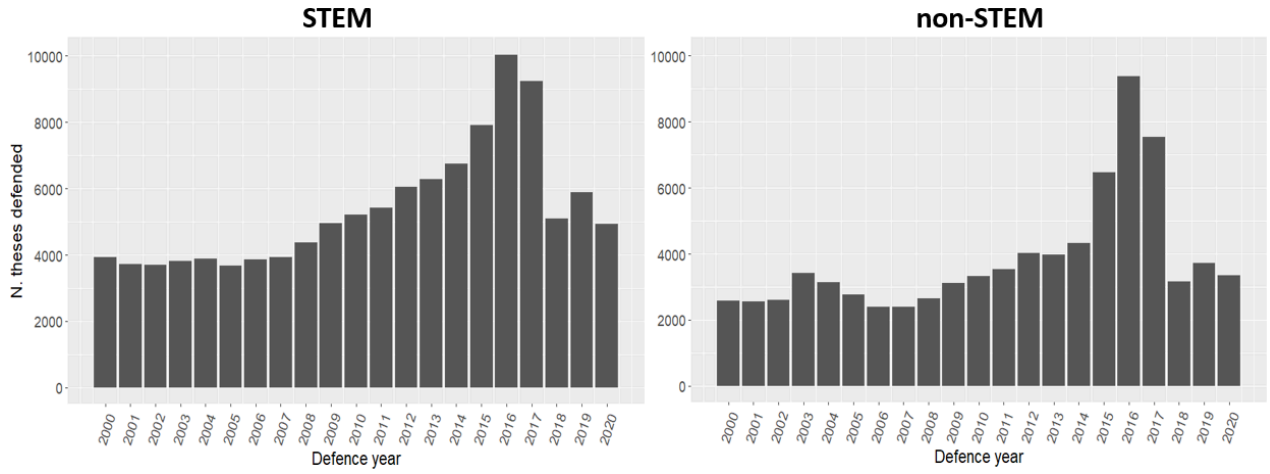
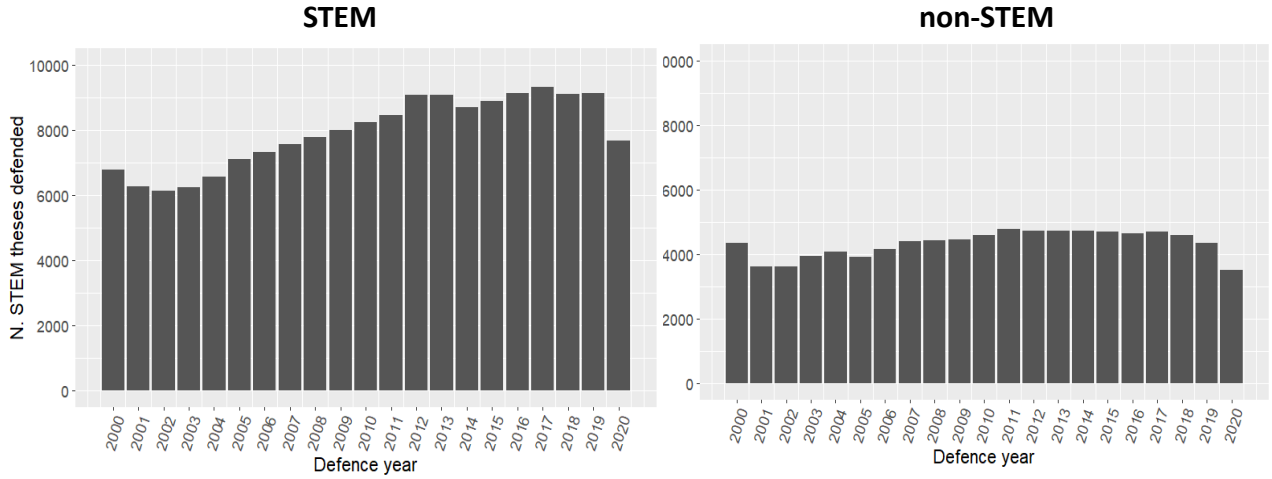


Figure A1.b Graduates in France



*Note: The decrease in the number of doctoral theses defended in 2020 is not due to a truncation of the data but to the COVID-19 pandemic, which affected the possibility of defending doctoral theses in both countries.

Figure A2. Number of graduates in Spain linked to a Scopus publication for STEM and non-STEM disciplines, by defence year.

Figure A2 in this appendix depicts, for each defence year, the number of graduates in Spain collected from Teseo who are linked and not linked to at least one Scopus publication in STEM (Figure A2.a) and non-STEM (Figure A2.b) disciplines, and their respective relative frequency.

Figure A2.a: STEM disciplines

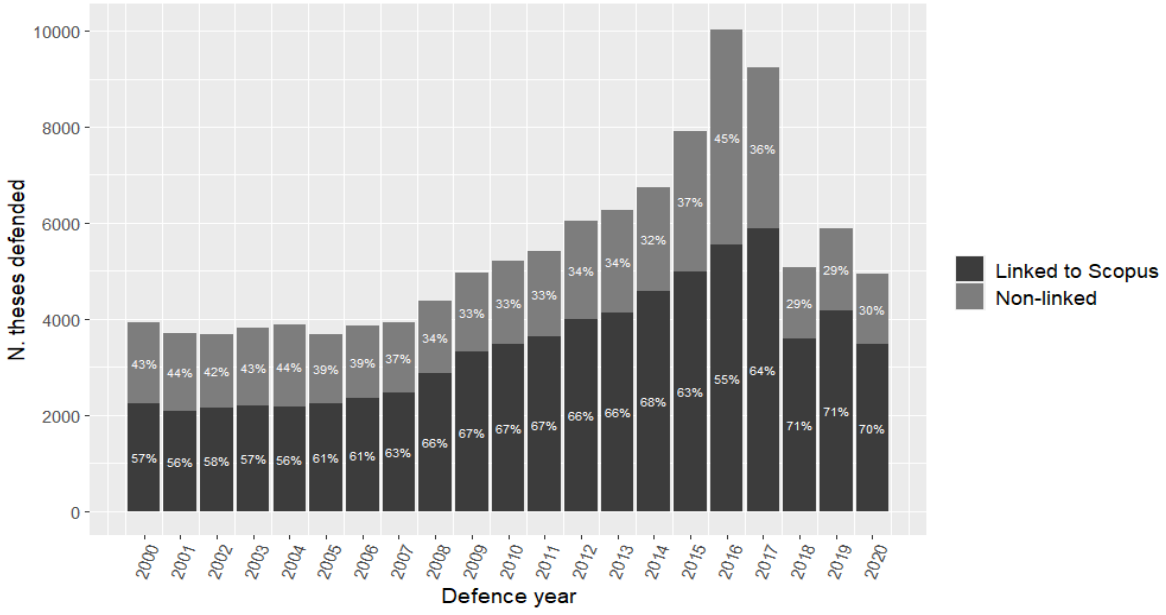
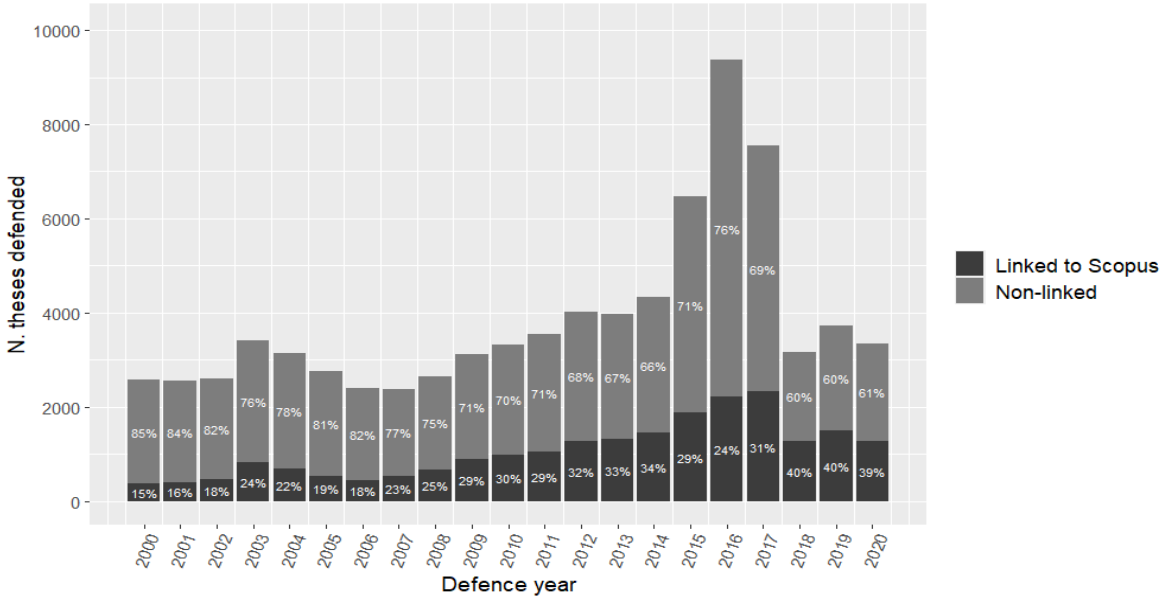


Figure A2.b: non-STEM disciplines



Appendix B. Descriptive statistics.

Table B1. Descriptive statistics of the Spanish departments before the Coarsened Exact Matching.

	N. of departments	N. of Observations: department-year	Mean per year	sd	min	max
Spanish departments						
Outcomes						
Avg. number of publications per department student, *t*	423	6,768	0.40	0.35	0.00	4.00
Avg. number of 3-year normalized citations received by a department student's publication, *t*	423	6,768	0.60	0.63	0.00	8.49
Avg. number of distinct co-authors per department student, *t*	423	6,768	2.61	8.42	0.00	398.79
Avg. share of first-author publications per department student, *t*	423	6,768	0.10	0.09	0.00	1.00
Avg. share of publications without the supervisor per department student, *t*	423	6,768	0.06	0.06	0.00	1.00
Avg. share of solo-author publications per department student, *t*	423	6,768	0.01	0.02	0.00	1.00
Avg. maximum article semantic distance per department student, *t*	423	6,768	0.08	0.07	0.00	0.63
Department characteristics						
N. of PhD students in the department, *t*	423	6,768	86.38	116.44	0.00	1451.00
Share of female PhD students in the department, *t*	423	6,768	0.47	0.18	0.00	1.00
Top-20% granted department, *t*	423	6,768	0.22	0.41	0.00	1.00
Supervisor characteristics						
Share of female supervisors in the deptartment, *t*	423	6,768	0.28	0.15	0.00	1.00
Avg. department supervisor seniority, *t*	423	6,768	11.22	4.55	0.00	24.00
Avg. 3-year normalized citation-weighted publications per department supervisor, *t−1*	423	6,768	8.74	9.81	0.00	145.57
Avg. number of distinct co-authors per department supervisor, *t−1*	423	6,768	15.08	32.21	0.00	807.00
Fields						
Engineering	53	848	.	.	.	.
Life sciences	53	848	.	.	.	.
Mathematics	53	848	.	.	.	.
Medicine	53	848	.	.	.	.
Physics	53	848	.	.	.	.
Social sciences	53	848	.	.	.	.
Psychology	52	832	.	.	.	.
Arts and humanities	53	848	.	.	.	.

Table B2. Descriptive statistics of the French departments before the Coarsened Exact Matching.

	N. of departments	N. of Observations: department-year	Mean per year	sd	min	max
French departments						
Outcomes						
Avg. number of publications per department student, *t*	424	6,784	0.30	0.31	0.00	4.50
Avg. number of 3-year normalized citations received by a department student's publication, *t*	424	6,784	0.55	0.93	0.00	49.87
Avg. number of distinct co-authors per department student, *t*	424	6,784	1.65	3.27	0.00	109.11
Avg. share of first-author publications per department student, *t*	424	6,784	0.11	0.12	0.00	1.00
Avg. share of publications without the supervisor per department student, *t*	424	6,784	0.05	0.07	0.00	1.00
Avg. share of solo-author publications per department student, *t*	424	6,784	0.01	0.02	0.00	1.00
Avg. maximum article semantic distance per department student, *t*	424	6,784	0.08	0.08	0.00	0.76
Department characteristics						
N. of PhD students in the department, *t*	424	6,784	108.06	176.15	0.00	1534.00
Share of female PhD students in the department, *t*	424	6,784	0.40	0.23	0.00	1.00
Top-20% granted department, *t*	424	6,784	0.16	0.36	0.00	1.00
Supervisor characteristics						
Share of female supervisors in the deptartment, *t*	424	6,784	0.24	0.18	0.00	1.00
Avg. department supervisor seniority, *t*	424	6,784	12.00	5.04	0.00	24.00
Avg. 3-year normalized citation-weighted publications per department supervisor, *t−1*	424	6,784	9.21	10.39	0.00	154.19
Avg. number of distinct co-authors per department supervisor, *t−1*	424	6,784	16.73	41.17	0.00	1614.00
Fields						
Engineering	55	880	.	.	.	.
Life sciences	55	880	.	.	.	.
Mathematics	57	912	.	.	.	.
Medicine	52	832	.	.	.	.
Physics	55	880	.	.	.	.
Social sciences	57	912	.	.	.	.
Psychology	39	624	.	.	.	.
Arts and humanities	54	864	.	.	.	.

Appendix C. Coarsened Exact Matching.

Table C1. Means, Standardized Mean Differences, and Variance Ratios of the matching covariates before (Columns 1 to 4) and after (Columns 5 and 8) the Coarsened Exact Matching.

	Sample before CEM				CEM sample			
	(1) Spanish departments	(2) French departments	(3) Std. Mean Difference	(4) Var. Ratio	(5) Spanish departments	(6) French departments	(7) Std. Mean Difference	(8) Var. Ratio
N. of departments	423	424			236	236		
Covariates								
Engineering	0.1253	0.1297	-0.0133	.	0.0975	0.0975	0.000	.
Life sciences	0.1253	0.1297	-0.0133	.	0.1144	0.1144	0.000	.
Mathematics	0.1253	0.1344	-0.0272	.	0.0720	0.0720	0.000	.
Medicine	0.1253	0.1226	0.0081	.	0.0763	0.0763	0.000	.
Physics	0.1253	0.1297	-0.0133	.	0.0720	0.0720	0.000	.
Social sciences	0.1253	0.1344	-0.0272	.	0.2161	0.2161	0.000	.
Psychology	0.1229	0.0920	0.1001	.	0.1314	0.1314	0.000	.
Arts and humanities	0.1253	0.1274	-0.0062	.	0.2203	0.2203	0.000	.
Average yearly number of publications per department student [2005-2010]	0.3146	0.2474	0.2753	1.3379	0.1771	0.1714	0.0233	1.0264
Average yearly number of 3-year normalized citations received by a department student's publication [2005-2010]	0.5044	0.4607	0.0915	1.0187	0.2734	0.2802	-0.0142	0.8869
Average yearly number of distinct co-authors per department student [2005-2010]	1.4035	1.1989	0.1126	1.0351	0.7016	0.6501	0.0283	1.0152

Tables and figures to be included in the main text.

Table 1. The effect of the Royal Decree 99/2011 on the average number of publications per Spanish department student, relative to French departments.

	STEM departments			Non-STEM departments		
	(1)	(2)	(3)	(4)	(5)	(6)
*(2011)*Spanish department*	-0.006	-0.006	-0.007	0.026**	0.025*	0.027**
	(0.032)	(0.033)	(0.033)	(0.013)	(0.013)	(0.013)
*(2012)*Spanish department*	0.041	0.042	0.036	0.007	0.0084	0.012
	(0.037)	(0.037)	(0.038)	(0.015)	(0.015)	(0.015)
*(2013)*Spanish department*	0.037	0.040	0.042	0.002	0.0031	0.008
	(0.032)	(0.033)	(0.032)	(0.012)	(0.013)	(0.013)
*(2014)*Spanish department*	-0.007	-0.004	-0.006	-0.017	-0.016	-0.011
	(0.033)	(0.034)	(0.033)	(0.017)	(0.016)	(0.016)
*(2015)*Spanish department*	0.029	0.031	0.032	-0.019	-0.020	-0.015
	(0.031)	(0.031)	(0.030)	(0.020)	(0.020)	(0.019)
*(2016)*Spanish department*	-0.011	-0.009	-0.005	-0.020	-0.021	-0.021
	(0.035)	(0.034)	(0.034)	(0.023)	(0.023)	(0.024)
*(2017)*Spanish department*	0.068**	0.069**	0.067*	0.015	0.013	0.012
	(0.034)	(0.034)	(0.035)	(0.018)	(0.018)	(0.019)
*(2018)*Spanish department*	0.15***	0.14***	0.13***	0.055***	0.053***	0.047**
	(0.042)	(0.042)	(0.041)	(0.020)	(0.020)	(0.020)
*(2019)*Spanish department*	0.28***	0.28***	0.24***	0.14***	0.14***	0.13***
	(0.048)	(0.048)	(0.046)	(0.028)	(0.028)	(0.026)
*(2020)*Spanish department*	0.15**	0.15**	0.100	0.19***	0.19***	0.18***
	(0.068)	(0.069)	(0.062)	(0.032)	(0.032)	(0.030)
N. of PhD students in the dept.		-0.001	-0.001		-0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female PhD students in the dept.		0.015	-0.060		0.082**	0.071**
		(0.034)	(0.047)		(0.034)	(0.033)
Top-20% granted department		0.001	-0.009		-0.004	-0.003
		(0.017)	(0.013)		(0.005)	(0.005)
Share of female supervisors in the dept.			0.035			-0.093**
			(0.063)			(0.037)
Avg. department supervisor seniority			0.012***			0.006***
			(0.003)			(0.002)
Avg. 3-year citation-weighted publications per department supervisor, t−1			0.004***			0.004**
			(0.001)			(0.002)
Avg. number of distinct co-authors per department supervisor, t−1			0.001			-0.001
			(0.001)			(0.001)
Department F.E.	YES	YES	YES	YES	YES	YES
Year F.E.	YES	YES	YES	YES	YES	YES
R^2	0.280	0.280	0.317	0.214	0.222	0.251
Number of departments	204	204	204	268	268	268
Observations	3,264	3,264	3,264	4,288	4,288	4,288

Notes: This table reports the estimated coefficients of the impact of the Royal Decree 99/2011 on the average number of publications per department student. The results of three different specifications of a linear regression model are displayed, both for STEM and non-STEM departments. Each observation corresponds to a department. In all regressions, each Spanish department is paired with the most similar French department using a Coarsen Exact Matching procedure. All specifications include department and year fixed effects. Columns (1) and (4) report the estimated coefficients of the interaction between being a Spanish department and each year of the post-treatment period of Equation 1. Columns (2) and (5) include time-variant department characteristics and columns (3) and (6) include time-variant supervisor characteristics. Robust standard errors, clustered at the department level, in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 2. The effect of the Royal Decree 99/2011 on the average number of 3-year normalized citations received by a Spanish department student's publication, relative to French departments.

	STEM departments			Non-STEM departments		
	(1)	(2)	(3)	(4)	(5)	(6)
*(2011)*Spanish department*	0.042	0.044	0.032	0.015	0.011	0.010
	(0.065)	(0.065)	(0.065)	(0.020)	(0.020)	(0.021)
*(2012)*Spanish department*	-0.066	-0.066	-0.089	-0.028	-0.027	-0.021
	(0.10)	(0.11)	(0.11)	(0.025)	(0.026)	(0.026)
*(2013)*Spanish department*	0.009	0.010	-0.005	-0.028	-0.029	-0.019
	(0.073)	(0.074)	(0.075)	(0.025)	(0.026)	(0.028)
*(2014)*Spanish department*	-0.091	-0.093	-0.11	-0.094	-0.096	-0.088
	(0.090)	(0.093)	(0.091)	(0.063)	(0.060)	(0.054)
*(2015)*Spanish department*	0.062	0.064	0.051	-0.036	-0.041	-0.031
	(0.072)	(0.074)	(0.073)	(0.033)	(0.032)	(0.028)
*(2016)*Spanish department*	-0.098	-0.097	-0.11	-0.21*	-0.21*	-0.22*
	(0.12)	(0.11)	(0.11)	(0.13)	(0.13)	(0.13)
*(2017)*Spanish department*	0.090	0.092	0.077	-0.032	-0.040	-0.053
	(0.076)	(0.076)	(0.078)	(0.040)	(0.040)	(0.041)
*(2018)*Spanish department*	0.092	0.091	0.040	0.059*	0.052	0.042
	(0.11)	(0.11)	(0.11)	(0.034)	(0.034)	(0.036)
*(2019)*Spanish department*	0.28**	0.27**	0.19*	0.15***	0.16***	0.14***
	(0.12)	(0.12)	(0.12)	(0.036)	(0.038)	(0.039)
*(2020)*Spanish department*	0.20*	0.19*	0.084	0.21**	0.21***	0.18**
	(0.10)	(0.10)	(0.10)	(0.081)	(0.080)	(0.082)
N. of PhD students in the dept.		0.001	0.001		0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female PhD students in the dept.		0.13	0.065		0.23	0.15
		(0.098)	(0.11)		(0.14)	(0.11)
Top-20% granted department		-0.016	-0.030		-0.018**	-0.016**
		(0.025)	(0.023)		(0.007)	(0.0072)
Share of female supervisors in the dept.			0.11			0.16
			(0.11)			(0.15)
Avg. department supervisor seniority			0.0067			0.0037
			(0.0082)			(0.0051)
Avg. 3-year citation-weighted publications per department supervisor, t−1			0.010***			0.015*
			(0.0024)			(0.0080)
Avg. number of distinct co-authors per department supervisor, t−1			-0.001			-0.001
			(0.001)			(0.001)
Department F.E.	YES	YES	YES	YES	YES	YES
Year F.E.	YES	YES	YES	YES	YES	YES
R^2	0.110	0.112	0.132	0.058	0.066	0.084
Number of departments	204	204	204	268	268	268
Observations	3,264	3,264	3,264	4,288	4,288	4,288

Notes: This table reports the estimated coefficients of the impact of the Royal Decree 99/2011 on the average number of 3-year normalized citations received by a department student's publication. The results of three different specifications of a linear regression model are displayed, both for STEM and non-STEM departments. Each observation corresponds to a department. In all regressions, each Spanish department is paired with the most similar French department using a Coarsen Exact Matching procedure. All specifications include department and year fixed effects. Columns (1) and (4) report the estimated coefficients of the interaction between being a Spanish department and each year of the post-treatment period of Equation 1. Columns (2) and (5) include time-variant department characteristics and columns (3) and (6) include time-variant supervisor characteristics. Robust standard errors, clustered at the department level, in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 3. The effect of the Royal Decree 99/2011 on the average number of distinct co-authors per Spanish department student, relative to French departments.

	STEM departments			Non-STEM departments		
	(1)	(2)	(3)	(4)	(5)	(6)
*(2011)*Spanish department*	-0.19	-0.18	-0.26	0.060	0.051	0.049
	(0.31)	(0.32)	(0.33)	(0.039)	(0.043)	(0.048)
*(2012)*Spanish department*	0.66	0.70*	0.59	-0.016	-0.030	-0.014
	(0.41)	(0.41)	(0.42)	(0.044)	(0.050)	(0.056)
*(2013)*Spanish department*	-0.19	-0.073	-0.17	-0.045	-0.082	-0.070
	(0.39)	(0.40)	(0.41)	(0.049)	(0.075)	(0.087)
*(2014)*Spanish department*	-0.22	-0.064	-0.22	-0.078	-0.14	-0.13
	(0.42)	(0.45)	(0.44)	(0.079)	(0.11)	(0.11)
*(2015)*Spanish department*	0.11	0.23	0.12	-0.089	-0.14	-0.13
	(0.55)	(0.57)	(0.56)	(0.087)	(0.11)	(0.11)
*(2016)*Spanish department*	0.26	0.40	0.44	0.38	0.33	0.33
	(0.48)	(0.49)	(0.48)	(0.40)	(0.41)	(0.41)
*(2017)*Spanish department*	-0.053	-0.026	-0.12	0.66*	0.63*	0.61*
	(1.17)	(1.17)	(1.16)	(0.36)	(0.37)	(0.36)
*(2018)*Spanish department*	2.68***	2.64***	2.43***	0.36	0.34	0.35
	(0.90)	(0.90)	(0.84)	(0.45)	(0.45)	(0.44)
*(2019)*Spanish department*	3.05***	3.01***	2.43***	0.78*	0.76*	0.77*
	(1.03)	(1.02)	(0.86)	(0.46)	(0.46)	(0.46)
*(2020)*Spanish department*	3.81**	3.76**	3.00*	1.52	1.50	1.49
	(1.78)	(1.78)	(1.53)	(1.06)	(1.04)	(1.07)
N. of PhD students in the dept.		-0.004**	-0.003**		0.001	0.001
		(0.002)	(0.001)		(0.001)	(0.001)
Share of female PhD students in the dept.		-0.100	-0.30		0.32	0.044
		(0.39)	(0.52)		(0.31)	(0.31)
Top-20% granted department		0.54	0.21		-0.22***	-0.21***
		(0.40)	(0.37)		(0.073)	(0.073)
Share of female supervisors in the dept.			0.029			0.93
			(0.50)			(0.62)
Avg. department supervisor seniority			0.020			0.006
			(0.039)			(0.024)
Avg. 3-year citation-weighted publications per department supervisor, t−1			0.062*			0.013
			(0.034)			(0.015)
Avg. number of distinct co-authors per department supervisor, t−1			0.024**			-0.001
			(0.010)			(0.001)
Department F.E.	YES	YES	YES	YES	YES	YES
Year F.E.	YES	YES	YES	YES	YES	YES
R^2	0.106	0.108	0.143	0.025	0.026	0.027
Number of departments	204	204	204	268	268	268
Observations	3,264	3,264	3,264	4,288	4,288	4,288

Notes: This table reports the estimated coefficients of the impact of the Royal Decree 99/2011 on the average number of distinct co-authors per department student. The results of three different specifications of a linear regression model are displayed, both for STEM and non-STEM departments. Each observation corresponds to a department. In all regressions, each Spanish department is paired with the most similar French department using a Coarsen Exact Matching procedure. All specifications include department and year fixed effects. Columns (1) and (4) report the estimated coefficients of the interaction between being a Spanish department and each year of the post-treatment period of Equation 1. Columns (2) and (5) include time-variant department characteristics and columns (3) and (6) include time-variant supervisor characteristics. Robust standard errors, clustered at the department level, in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 4. The effect of the Royal Decree 99/2011 on the average share of first-author publications per Spanish department student, relative to French departments.

	STEM departments			Non-STEM departments		
	(1)	(2)	(3)	(4)	(5)	(6)
*(2011)*Spanish department*	-0.015	-0.014	-0.014	0.007	0.007	0.007
	(0.013)	(0.013)	(0.013)	(0.006)	(0.006)	(0.007)
*(2012)*Spanish department*	-0.002	-0.002	-0.003	-0.003	-0.003	-0.001
	(0.014)	(0.014)	(0.014)	(0.006)	(0.006)	(0.006)
*(2013)*Spanish department*	-0.001	-0.001	0.001	-0.002	-0.001	0.001
	(0.013)	(0.013)	(0.013)	(0.005)	(0.006)	(0.006)
*(2014)*Spanish department*	-0.028	-0.029	-0.027	-0.013	-0.013	-0.011
	(0.018)	(0.018)	(0.018)	(0.011)	(0.010)	(0.009)
*(2015)*Spanish department*	0.014	0.014	0.015	-0.006	-0.006	-0.004
	(0.013)	(0.014)	(0.014)	(0.010)	(0.010)	(0.009)
*(2016)*Spanish department*	0.0068	0.007	0.008	-0.006	-0.006	-0.007
	(0.014)	(0.014)	(0.014)	(0.008)	(0.008)	(0.009)
*(2017)*Spanish department*	0.013	0.013	0.015	-0.004	-0.004	-0.006
	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)	(0.011)
*(2018)*Spanish department*	0.017	0.017	0.014	0.017**	0.017**	0.015*
	(0.014)	(0.014)	(0.014)	(0.008)	(0.008)	(0.008)
*(2019)*Spanish department*	0.024	0.024	0.018	0.036***	0.036***	0.032***
	(0.021)	(0.021)	(0.020)	(0.009)	(0.009)	(0.009)
*(2020)*Spanish department*	-0.013	-0.015	-0.027	0.039***	0.040***	0.034***
	(0.027)	(0.027)	(0.026)	(0.011)	(0.011)	(0.011)
N. of PhD students in the dept.		0.001	0.001		0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female PhD students in the dept.		0.041***	0.019		0.009	-0.001
		(0.015)	(0.018)		(0.021)	(0.015)
Top-20% granted department		-0.008*	-0.007		0.001	0.001
		(0.004)	(0.004)		(0.002)	(0.002)
Share of female supervisors in the dept.			-0.011			-0.006
			(0.022)			(0.014)
Avg. department supervisor seniority			0.005***			0.002**
			(0.001)			(0.001)
Avg. 3-year citation-weighted publications per department supervisor, t−1			0.001**			0.003
			(0.001)			(0.002)
Avg. number of distinct co-authors per department supervisor, t−1			-0.001			-0.001
			(0.001)			(0.001)
Department F.E.	YES	YES	YES	YES	YES	YES
Year F.E.	YES	YES	YES	YES	YES	YES
R^2	0.213	0.219	0.238	0.147	0.148	0.178
Number of departments	204	204	204	268	268	268
Observations	3,264	3,264	3,264	4,288	4,288	4,288

Notes: This table reports the estimated coefficients of the impact of the Royal Decree 99/2011 2011 on the average share of first-author publications per department student. The results of three different specifications of a linear regression model are displayed, both for STEM and non-STEM departments. Each observation corresponds to a department. In all regressions, each Spanish department is paired with the most similar French department using a Coarsen Exact Matching procedure. All specifications include department and year fixed effects. Columns (1) and (4) report the estimated coefficients of the interaction between being a Spanish department and each year of the post-treatment period of Equation 1. Columns (2) and (5) include time-variant department characteristics and columns (3) and (6) include time-variant supervisor characteristics. Robust standard errors, clustered at the department level, in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 5. The effect of the Royal Decree 99/2011 on the average share of publications without the supervisor per Spanish department student, relative to French departments.

	STEM departments			Non-STEM departments		
	(1)	(2)	(3)	(4)	(5)	(6)
*(2011)*Spanish department*	0.007	0.007	0.007	0.001	0.001	0.001
	(0.008)	(0.008)	(0.008)	(0.004)	(0.004)	(0.004)
*(2012)*Spanish department*	0.007	0.006	0.006	0.001	0.001	0.001
	(0.009)	(0.009)	(0.009)	(0.004)	(0.004)	(0.004)
*(2013)*Spanish department*	0.007	0.007	0.008	-0.003	-0.002	-0.002
	(0.008)	(0.008)	(0.008)	(0.004)	(0.004)	(0.004)
*(2014)*Spanish department*	0.008	0.008	0.008	-0.010*	-0.008	-0.008
	(0.008)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)
*(2015)*Spanish department*	0.015	0.015	0.016	-0.012*	-0.010	-0.010
	(0.010)	(0.010)	(0.010)	(0.006)	(0.006)	(0.006)
*(2016)*Spanish department*	-0.003	-0.002	-0.001	-0.006	-0.005	-0.006
	(0.013)	(0.013)	(0.013)	(0.011)	(0.011)	(0.011)
*(2017)*Spanish department*	0.015	0.015	0.015	-0.001	-0.001	-0.001
	(0.009)	(0.009)	(0.009)	(0.005)	(0.005)	(0.005)
*(2018)*Spanish department*	0.037***	0.037***	0.035***	0.004	0.004	0.004
	(0.013)	(0.013)	(0.013)	(0.005)	(0.005)	(0.005)
*(2019)*Spanish department*	0.047***	0.047***	0.043***	0.011**	0.012**	0.012**
	(0.013)	(0.013)	(0.013)	(0.006)	(0.006)	(0.006)
*(2020)*Spanish department*	0.063***	0.062***	0.057***	0.031***	0.032***	0.031***
	(0.018)	(0.018)	(0.017)	(0.006)	(0.006)	(0.006)
N. of PhD students in the dept.		0.001	0.001		-0.001**	-0.001**
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female PhD students in the dept.		0.031*	0.015		0.013	0.010
		(0.017)	(0.014)		(0.011)	(0.010)
Top-20% granted department		-0.001	-0.001		-0.001	-0.001
		(0.003)	(0.003)		(0.001)	(0.001)
Share of female supervisors in the dept.			0.013			0.004
			(0.018)			(0.012)
Avg. department supervisor seniority			0.002**			0.001
			(0.001)			(0.001)
Avg. 3-year citation-weighted publications per department supervisor, t−1			0.001			0.001
			(0.001)			(0.001)
Avg. number of distinct co-authors per department supervisor, t−1			0.001			-0.001
			(0.001)			(0.001)
Department F.E.	YES	YES	YES	YES	YES	YES
Year F.E.	YES	YES	YES	YES	YES	YES
R^2	0.090	0.098	0.109	0.062	0.065	0.067
Number of departments	204	204	204	268	268	268
Observations	3,264	3,264	3,264	4,288	4,288	4,288

Notes: This table reports the estimated coefficients of the impact of the Royal Decree 99/2011 on the average share of publications without the supervisor per department student. The results of three different specifications of a linear regression model are displayed, both for STEM and non-STEM departments. Each observation corresponds to a department. In all regressions, each Spanish department is paired with the most similar French department using a Coarsen Exact Matching procedure. All specifications include department and year fixed effects. Columns (1) and (4) report the estimated coefficients of the interaction between being a Spanish department and each year of the post-treatment period of Equation 1. Columns (2) and (5) include time-variant department characteristics and columns (3) and (6) include time-variant supervisor characteristics. Robust standard errors, clustered at the department level, in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 6. The effect of the Royal Decree 99/2011 on the average share of solo-author publications per Spanish department student, relative to French departments.

	STEM departments			Non-STEM departments		
	(1)	(2)	(3)	(4)	(5)	(6)
*(2011)*Spanish department*	0.001	0.001	0.001	0.006*	0.006*	0.006*
	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)
*(2012)*Spanish department*	0.001	0.001	0.001	0.004	0.005	0.005
	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)
*(2013)*Spanish department*	0.001	0.001	0.001	0.007**	0.008**	0.008**
	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.003)
*(2014)*Spanish department*	0.001	0.001	0.001	0.005	0.006*	0.006*
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
*(2015)*Spanish department*	0.001	0.001	0.001	0.005	0.006*	0.006*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
*(2016)*Spanish department*	0.003**	0.004**	0.004**	0.009***	0.010***	0.010***
	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
*(2017)*Spanish department*	0.002**	0.002**	0.002**	0.010***	0.010***	0.011***
	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)	(0.004)
*(2018)*Spanish department*	0.003***	0.003***	0.003**	0.012***	0.013***	0.013***
	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)	(0.004)
*(2019)*Spanish department*	0.003**	0.003*	0.003*	0.021***	0.022***	0.022***
	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)	(0.004)
*(2020)*Spanish department*	0.004**	0.003**	0.003	0.023***	0.023***	0.023***
	(0.002)	(0.002)	(0.002)	(0.005)	(0.005)	(0.005)
N. of PhD students in the dept.		0.001	0.001		-0.001***	-0.001***
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female PhD students in the dept.		0.003	0.005		-0.001	0.002
		(0.003)	(0.004)		(0.004)	(0.004)
Top-20% granted department		0.001	0.001		0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female supervisors in the dept.			-0.007			-0.007*
			(0.005)			(0.004)
Avg. department supervisor seniority			0.001			0.001
			(0.001)			(0.001)
Avg. 3-year citation-weighted publications per department supervisor, t−1			0.001			-0.001
			(0.001)			(0.001)
Avg. number of distinct co-authors per department supervisor, t−1			0.001			0.001
			(0.001)			(0.001)
Department F.E.	YES	YES	YES	YES	YES	YES
Year F.E.	YES	YES	YES	YES	YES	YES
R^2	0.011	0.012	0.015	0.086	0.089	0.092
Number of departments	204	204	204	268	268	268
Observations	3,264	3,264	3,264	4,288	4,288	4,288

Notes: This table reports the estimated coefficients of the impact of the Royal Decree 99/2011 on the average share of solo-author publications per department student. The results of three different specifications of a linear regression model are displayed, both for STEM and non-STEM departments. Each observation corresponds to a department. In all regressions, each Spanish department is paired with the most similar French department using a Coarsen Exact Matching procedure. All specifications include department and year fixed effects. Columns (1) and (4) report the estimated coefficients of the interaction between being a Spanish department and each year of the post-treatment period of Equation 1. Columns (2) and (5) include time-variant department characteristics and columns (3) and (6) include time-variant supervisor characteristics. Robust standard errors, clustered at the department level, in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 7. The effect of the Royal Decree 99/2011 on the average maximum article semantic distance per Spanish department student, relative to French departments.

	STEM departments			Non-STEM departments		
	(1)	(2)	(3)	(4)	(5)	(6)
*(2011)*Spanish department*	-0.002	-0.002	-0.002	0.006**	0.006*	0.006**
	(0.008)	(0.009)	(0.008)	(0.003)	(0.003)	(0.003)
*(2012)*Spanish department*	0.003	0.003	0.002	-0.001	-0.001	0.001
	(0.009)	(0.009)	(0.009)	(0.003)	(0.003)	(0.003)
*(2013)*Spanish department*	0.006	0.007	0.008	-0.002	-0.002	-0.001
	(0.008)	(0.008)	(0.008)	(0.003)	(0.003)	(0.003)
*(2014)*Spanish department*	-0.004	-0.004	-0.004	-0.004	-0.004	-0.003
	(0.009)	(0.009)	(0.009)	(0.005)	(0.004)	(0.004)
*(2015)*Spanish department*	0.005	0.006	0.006	-0.006	-0.006	-0.005
	(0.009)	(0.009)	(0.009)	(0.005)	(0.004)	(0.004)
*(2016)*Spanish department*	-0.004	-0.003	-0.003	-0.011*	-0.012*	-0.012*
	(0.009)	(0.009)	(0.009)	(0.006)	(0.006)	(0.006)
*(2017)*Spanish department*	0.021**	0.021**	0.021**	-0.003	-0.003	-0.004
	(0.009)	(0.009)	(0.009)	(0.005)	(0.005)	(0.005)
*(2018)*Spanish department*	0.029***	0.029***	0.025**	0.007*	0.006	0.005
	(0.011)	(0.011)	(0.010)	(0.004)	(0.004)	(0.004)
*(2019)*Spanish department*	0.036***	0.036***	0.028**	0.019***	0.020***	0.017***
	(0.013)	(0.013)	(0.013)	(0.006)	(0.006)	(0.006)
*(2020)*Spanish department*	0.022	0.021	0.008	0.023***	0.024***	0.021***
	(0.014)	(0.014)	(0.013)	(0.007)	(0.006)	(0.006)
N. of PhD students in the dept.		0.001	0.001		0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Share of female PhD students in the dept.		0.022**	0.001		0.026**	0.020**
		(0.011)	(0.012)		(0.011)	(0.010)
Top-20% granted department		-0.004	-0.005*		-0.002*	-0.001
		(0.003)	(0.002)		(0.001)	(0.001)
Share of female supervisors in the dept.			0.005			-0.011
			(0.013)			(0.010)
Avg. department supervisor seniority			0.004***			0.001***
			(0.001)			(0.001)
Avg. 3-year citation-weighted publications per department supervisor, t−1			0.001***			0.001**
			(0.001)			(0.001)
Avg. number of distinct co-authors per department supervisor, t−1			0.001			-0.001*
			(0.001)			(0.001)
Department F.E.	YES	YES	YES	YES	YES	YES
Year F.E.	YES	YES	YES	YES	YES	YES
R^2	0.252	0.256	0.296	0.140	0.154	0.190
Number of departments	204	204	204	268	268	268
Observations	3,264	3,264	3,264	4,288	4,288	4,288

Notes: This table reports the estimated coefficients of the impact of the Royal Decree 99/2011 on the average maximum article semantic distance per department student. The results of three different specifications of a linear regression model are displayed, both for STEM and non-STEM departments. Each observation corresponds to a department. In all regressions, each Spanish department is paired with the most similar French department using a Coarsen Exact Matching procedure. All specifications include department and year fixed effects. Columns (1) and (4) report the estimated coefficients of the interaction between being a Spanish department and each year of the post-treatment period of Equation 1. Columns (2) and (5) include time-variant department characteristics and columns (3) and (6) include time-variant supervisor characteristics. Robust standard errors, clustered at the department level, in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Figure 1.

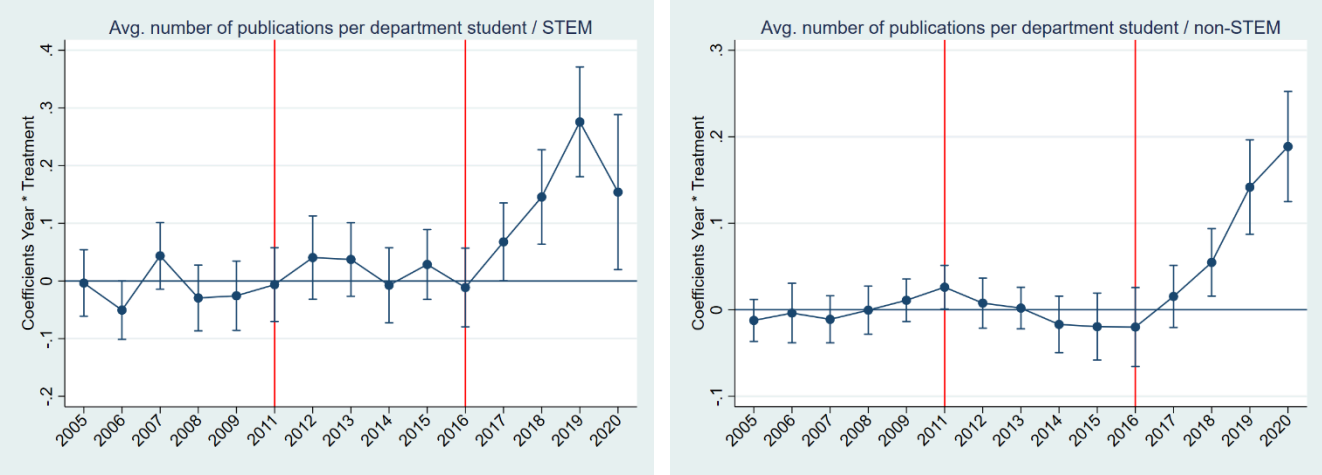


Table 8.

	STEM departments	**Non-STEM departments**
	(1)	(2)
*(2005)*Spanish department*	-0.004	-0.012
	(0.029)	(0.012)
*(2006)*Spanish department*	-0.050*	-0.004
	(0.026)	(0.017)
*(2007)*Spanish department*	0.043	-0.011
	(0.029)	(0.014)
*(2008)*Spanish department*	-0.030	-0.001
	(0.029)	(0.014)
*(2009)*Spanish department*	-0.026	0.011
	(0.030)	(0.012)
Department F.E.	YES	YES
Year F.E.	YES	YES
R2	0.280	0.214
Number of departments	204	268
Observations	3,264	4,288

Notes: Figure E1 and Table E1 report the estimated coefficients of the interaction between being a Spanish department and each year of the pre-treatment period of Equation 1, without including control variables, for the STEM and non-STEM departments. The reference category is the year 2010 interacted with being a Spanish department. The dependent variable is the average number of publications per department student.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Figure 2.

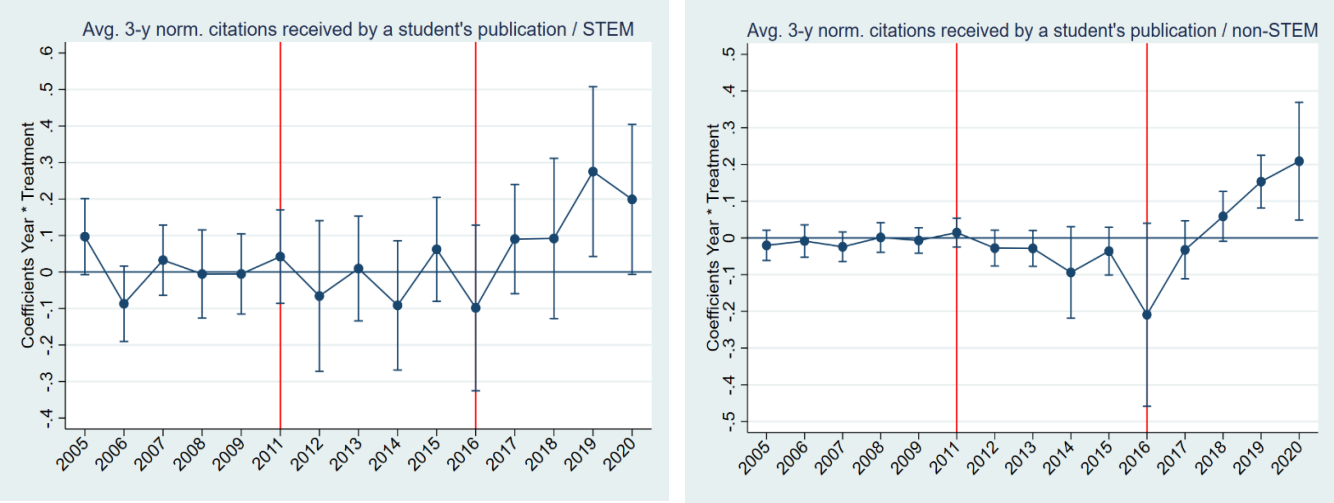


Table 9.

	STEM departments	Non-STEM departments
	(1)	(2)
*(2005)*Spanish department*	0.097*	-0.020
	(0.053)	(0.021)
*(2006)*Spanish department*	-0.087*	-0.008
	(0.052)	(0.022)
*(2007)*Spanish department*	0.033	-0.024
	(0.049)	(0.020)
*(2008)*Spanish department*	-0.005	0.001
	(0.061)	(0.020)
*(2009)*Spanish department*	-0.005	-0.007
	(0.056)	(0.018)
Department F.E.	YES	YES
Year F.E.	YES	YES
R2	0.109	0.058
Number of departments	204	268
Observations	3,264	4,288

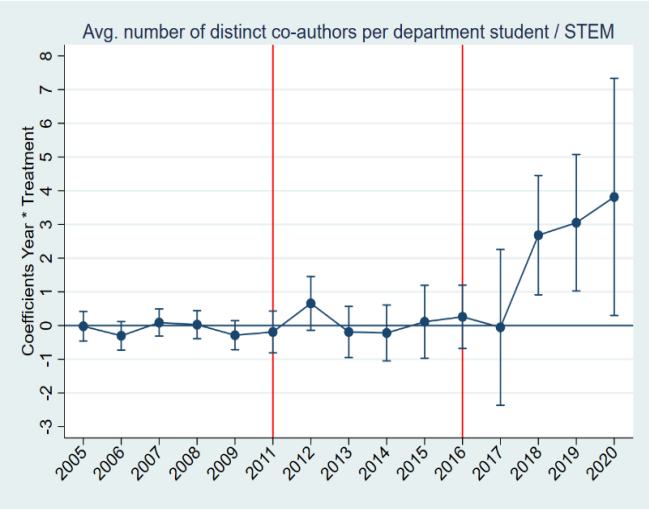
Notes: Figure E2 and Table E2 report the estimated coefficients of the interaction between being a Spanish department and each year of the pre-treatment period of Equation 1, without including control variables, for the STEM and non-STEM departments. The reference category is the year 2010 interacted with being a Spanish department. The dependent variable is the average number of 3-year normalized citations received by a department student's publication.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Figure 3.



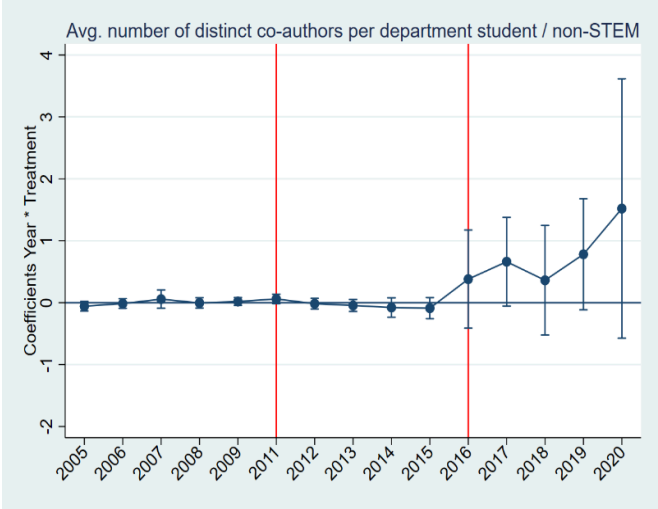


Table 10.

	STEM departments	**Non-STEM departments**
	(1)	(2)
*(2005)*Spanish department*	-0.020	-0.057
	(0.223)	(0.039)
*(2006)*Spanish department*	-0.303	-0.014
	(0.214)	(0.040)
*(2007)*Spanish department*	0.089	0.057
	(0.204)	(0.075)
*(2008)*Spanish department*	0.026	-0.004
	(0.210)	(0.043)
*(2009)*Spanish department*	-0.287	0.019
	(0.219)	(0.032)
Department F.E.	YES	YES
Year F.E.	YES	YES
R2	0.106	0.025
Number of departments	204	268
Observations	3,264	4,288

Notes: Figure E3 and Table E3 report the estimated coefficients of the interaction between being a Spanish department and each year of the pre-treatment period of Equation 1, without including control variables, for the STEM and non-STEM departments. The reference category is the year 2010 interacted with being a Spanish department. The dependent variable is the average number of distinct co-authors per department student.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Figure 4.

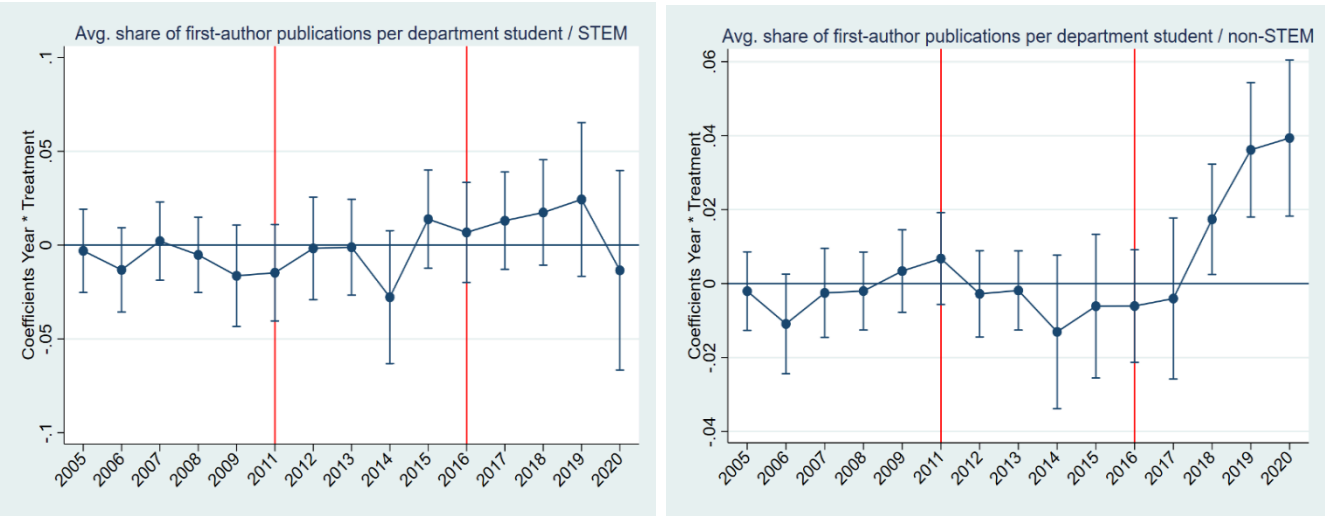


Table 11.

	STEM departments	Non-STEM departments
	(1)	(2)
*(2005)*Spanish department*	-0.003	-0.002
	(0.011)	(0.005)
*(2006)*Spanish department*	-0.013	-0.011
	(0.011)	(0.007)
*(2007)*Spanish department*	0.002	-0.003
	(0.011)	(0.006)
*(2008)*Spanish department*	-0.005	-0.002
	(0.010)	(0.005)
*(2009)*Spanish department*	-0.016	0.003
	(0.014)	(0.006)
Department F.E.	YES	YES
Year F.E.	YES	YES
R2	0.213	0.147
Number of departments	204	268
Observations	3,264	4,288

Notes: Figure E4 and Table E4 report the estimated coefficients of the interaction between being a Spanish department and each year of the pre-treatment period of Equation 1, without including control variables, for the STEM and non-STEM departments. The reference category is the year 2010 interacted with being a Spanish department. The dependent variable is the average share of first-author publications per department student.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Figure 5.

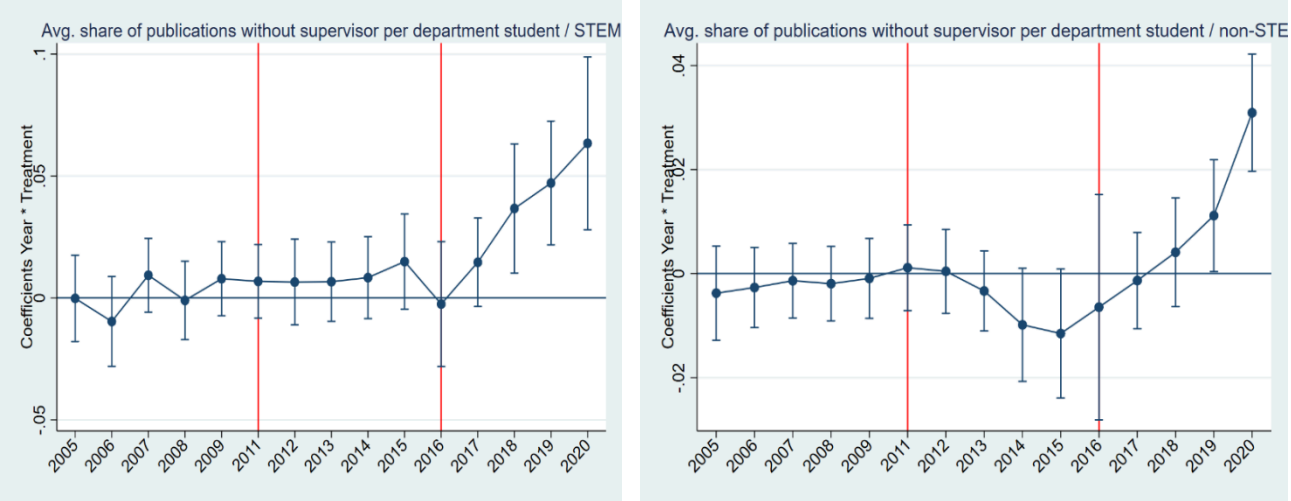


Table 12.

	STEM departments	**Non-STEM departments**
	(1)	(2)
*(2005)*Spanish department*	-0.001	-0.004
	(0.009)	(0.005)
*(2006)*Spanish department*	-0.010	-0.003
	(0.009)	(0.004)
*(2007)*Spanish department*	0.009	-0.001
	(0.008)	(0.004)
*(2008)*Spanish department*	-0.001	-0.002
	(0.008)	(0.004)
*(2009)*Spanish department*	0.008	-0.001
	(0.008)	(0.004)
Department F.E.	YES	YES
Year F.E.	YES	YES
R2	0.090	0.062
Number of departments	204	268
Observations	3,264	4,288

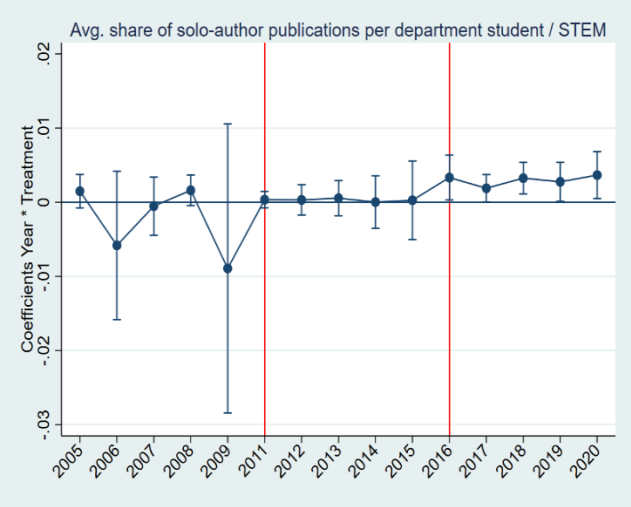
Notes: Figure E5 and Table E5 report the estimated coefficients of the interaction between being a Spanish department and each year of the pre-treatment period of Equation 1, without including control variables, for the STEM and non-STEM departments. The reference category is the year 2010 interacted with being a Spanish department. The dependent variable is the average share of publications without the supervisor per department student.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Figure 6.



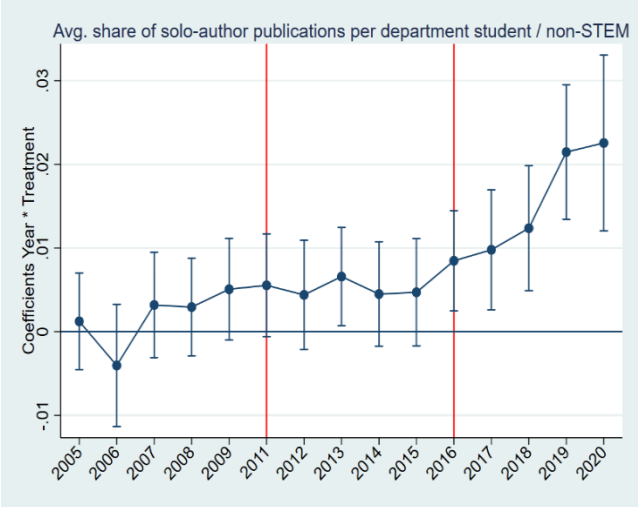


Table 13.

	STEM departments	**Non-STEM departments**
	(1)	(2)
*(2005)*Spanish department*	0.002	0.001
	(0.001)	(0.003)
*(2006)*Spanish department*	-0.006	-0.004
	(0.005)	(0.004)
*(2007)*Spanish department*	-0.001	0.003
	(0.002)	(0.003)
*(2008)*Spanish department*	0.002	0.003
	(0.001)	(0.003)
*(2009)*Spanish department*	-0.009	0.005
	(0.010)	(0.003)
Department F.E.	YES	YES
Year F.E.	YES	YES
R2	0.011	0.086
Number of departments	204	268
Observations	3,264	4,288

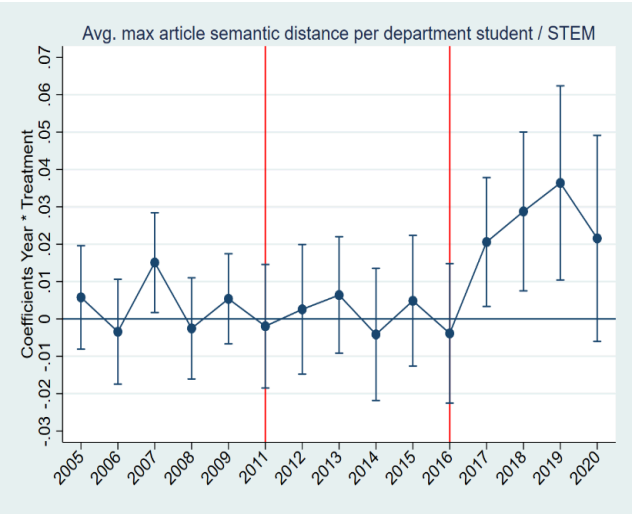
Notes: Figure E6 and Table E6 report the estimated coefficients of the interaction between being a Spanish department and each year of the pre-treatment period of Equation 1, without including control variables, for the STEM and non-STEM departments. The reference category is the year 2010 interacted with being a Spanish department. The dependent variable is the average share of solo-author publications per department student.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Figure 7.



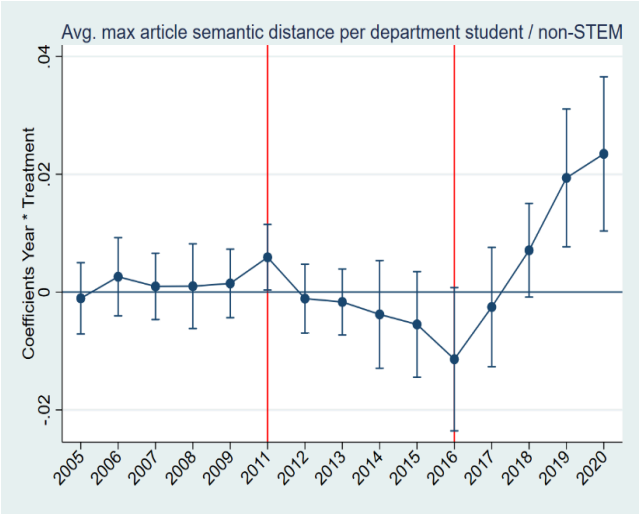


Table 14.

	STEM departments	**Non-STEM departments**
	(1)	(2)
*(2005)*Spanish department*	0.006	-0.001
	(0.007)	(0.003)
*(2006)*Spanish department*	-0.003	0.003
	(0.007)	(0.003)
*(2007)*Spanish department*	0.015**	0.001
	(0.007)	(0.003)
*(2008)*Spanish department*	-0.003	0.001
	(0.007)	(0.004)
*(2009)*Spanish department*	0.005	0.002
	(0.006)	(0.003)
Department F.E.	YES	YES
Year F.E.	YES	YES
R2	0.252	0.140
Number of departments	204	268
Observations	3,264	4,288

Notes: Figure E7 and Table E7 report the estimated coefficients of the interaction between being a Spanish department and each year of the pre-treatment period of Equation 1, without including control variables, for the STEM and non-STEM departments. The reference category is the year 2010 interacted with being a Spanish department. The dependent variable is the average maximum article semantic distance per department student.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.