Can Money Buy Scientific Leadership? The Impact of Excellence Programs on German and French Universities

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Abstract

German and French governments have had, quasi simultaneously, this ambitious goal to push forward national champions on the global higher education and research market via, as they called it, "excellence programs". We develop a difference-in-difference approach to identify the impact of such non standard research policy on selected universities. Our identification strategy builds upon matching those entities to European universities and upon controlling for a number of potential confounding factors via regression adjustment. We find that excellence programs have an overall positive effect on scientific outcomes that we precisely estimate. Interestingly, impact does not concentrate on top cited papers but is larger on the internationalization of research and on collaborations with industry. Additional evidence from event studies supports the idea that excellence policy essentially preserved treated universities from loosing their scientific competitive edge.

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1 Introduction

It is generally admitted that great science does not only proceed from great people but also from well designed institutions as long emphasized by social science scholars (Merton, 1968; Dasgupta and David, 1994; Aghion et al., 2010, among many others). Most of today's elite universities, founded in the middle ages, the renaissance period or the age of enlightenment, have specific institutional designs and campus culture that are deeply rooted in their history. Having recalled that, it seems like "mission impossible" to create (or recreate) great and successful universities with ad-hoc science policy programs and (public) money. Conceptually, however, nothing prevents clever and deep pocket states to improve the design of institutions and attract great research communities that would significantly improve their ranking in an essentially stable top scientific hierarchy. In this paper we provide a study aiming at measuring the ex-post impact of two national programs sharing such ambitious objectives.

When global university rankings emerged in the mid 2000's, German and French governments discovered that they did not have national universities listed on the top of those rankings. This came as a relative surprise since those governments expected the performances of their best universities to be more aligned with their historic leadership in science and technology, national research capacity and current global economic strength. Factors that are common to the two countries may however to some extent explain the mixed performances of their top universities, such as the importance of national research institutes, egalitarian views on higher education and the absence of significant tuition fees. Other factors are more specific to each country, such as the weakness of French universities as autonomous and strategic institutions since the revolution, or the fact higher education is essentially a local state competence in Germany.

As a response, both German and French governments quasi simultaneously launched policy programs targeted to foster the performances of their top universities: the "Zukunftskonzepte" program of the German "Exzellenzinitiative" and the French "Initiative d'Excellence" (IdEx). Those two programs are very similar in their design (competitive selection by an independent international committee of a limited number of universities) and explicitly aim at fostering differentiation in their respective national systems of higher education and research. Both target the stimulation of institutional experiments and innovations as a mean to ultimately favor the emergence of national champions in the global market for higher education and research. We seize the opportunity of those two quasi-simultaneous national experiences to measure how efficient such policies were on the treated institutions.

Results may not only be of interest for the involved governments, but also for our understanding of science policy. Most previous quantitative studies of the impact of science policies (see Stephan, 2015 and references therein) have studied funding programs that are more "conventional" in the sense they do not aim the structural change of the targeted entities. Are unconventional science policies targeting national champions and supporting projects aiming at improving institutional design a reliable avenue? Answers to this question are of paramount interest for numerous governments willing to take an active part in the increasing globalization of higher education and research. Though no other European country launched a similar program, a number of other governments in other regions of the world have recently did so, in particular in Asia, such as China, South Korea or Taiwan.[1]

To the best of our knowledge, the impact of such excellence programs has never been identified in a dedicated empirical study. We acknowledge that a number of case studies have well documented the specifics of each program (Shin, 2009; Zhang, Patton and Kenney, 2013; Exzellenzinitiative, 2016; Fu, Baker and Zhang, 2018), and sometimes have carefully studied differentiation within the country. However, because the selection of universities in far from random, simply using non selected entities as controls leads to confound the treatment impact with the selection effect–the very reasons why committees picked up some universities and not others. To avoid this issue, one needs to find a sufficient number of non-treated universities that are similar to the treated ones, but typically such reliable control entities are not available within the country.[2] In the present study, we have assembled a dataset of European universities to consistently match treated universities with similar non treated universities, potentially beyond France and Germany. We combine data from the CWTS Leiden Ranking, the EUMIDA-ETER projects (Lepori, 2023) and Eurostat to compile a 12-year panel dataset of 255 European universities.

Another threat to the identification of excellence policy impact is that university performances may be directly influenced by a number of factors which would also be correlated with the treatment. Typically, if German, French or other European governments develop research policies simultaneously or posterior to the treatment, such as an increase of government spending in higher education and research or a change in the fees universities can charge students, the estimator would be biased as it would confound the effects of the excellence policy and of the unobserved policy. Fortunately our data contain not only bibliometric indexes, but also structural and financial yearly information that are essential to control for contextual factors of scientific performances. We control for university fixed effects, yearly university spending (to account for the variation over time of other sources of funding), country-year fixed effect accounting for any country specific yearly shock and any national trend, and regional R&D.

We find that excellence policy has a positive direct impact on treated universities

[1] There are other science policies labeled as excellence programs. But those programs target smaller communities of researchers working in the same location and on a common theme of field, not universities (Möller, Schmidt and Hornbostel, 2016; Langfeldt et al., 2015; Carayol, Henry and Lanoe, 2023).

[2] In other words, the within country population of non treated universities is not sufficiently dense within the vicinity of treated entities in the space of relevant characteristics.

which is particularly robust on scientific outcome variables such as the number of published scientific articles, the number of internationally coauthored articles and the number of collaborations with private companies. The impact on the number of top cited scientific papers are positive but not significant. Impacts range from 7 to 13 % increases depending on the outcome variable. One Million euros in excellence policy leads to 22.5 more scientific articles (that means a paper costs less than fifty thousand euros), among which 19 are out of an international collaboration, 2.5 are produced in collaboration with industry, 3.7 are top 10% cited papers and .6 are top 1% cited papers. Expressed in percentage points, the impact of those excellence programs is actually very similar on the number of articles and on the numbers of top quality papers (top 1% and top 10%). This suggests those excellence programs impact does not concentrate on top quality outcomes, within treated universities. Effects are however larger on international collaborations and on collaborations with industry which are specific goals of those programs.

These results stand holding constant the yearly national context of operation and thus actually do not say much on how the relative position of treated and non treated German and French universities evolve vis-à-vis their European competitors. In this respect, we propose a dedicated extension. We run event studies of both selected and non selected French and German universities showing that treated units barely maintain their scientific edge over the funding period whereas non selected universities essentially lose edge against their own peer institutions. Overall, the results are consistent with the idea that excellence policy prevented most treated universities from losing their scientific competitive edge, whereas the competitive position of non-selected universities in those countries have essentially waned both in their national and in the European contexts. One explanation could be that, simultaneously to running excellence programs, French and German governments did not undertake the more systemic reforms that would have helped both their "average" university to remain competitive and their leading institutions to more significantly rise in the European and global contexts.

This paper is related to the literature on the impact of funding policies in science. A number of articles have studied the impact and design of project funding in science (Azoulay, Graff-Zivin and Manso, 2011; Jacob and Lefgren, 2011; Carayol and Lanoe, 2019; Banal-Estanol, Macho-Stadler and Perez-Castrillo, 2019). Carayol, Henry and Lanoe (2023) studied the impact of "research clusters" competitive funding. Payne (2002) has looked into the impact of earmarked funding of US universities by which universities receive federal funding along a non peer reviewed process (Savage, 1999). To our knowledge our study is the first ex-post impact analysis of competitive funding undertaken at the university level, such as the excellence science policy having an international dimension. Zhang, Patton and Kenney (2013) and Fu, Baker and Zhang (2018) look at the impact of university excellence programs in China and Taiwan but only use non selected national universities as controls and actually both find publication outputs to raise more among controls than among selected universities. Buenstorf and Koenig (2020) recently specifically studies the impact of the German program on the subsequent arrival of other sources of funding, but not on the outcomes.

The remaining of the paper is organized as follows. The next section discusses the specifics of the excellence programs in the two countries. The third section presents the methodology and the data. The fourth section exposes the results on the impact of excellence funding and discusses the results. The fifth section discusses potential limitations of the study and some robustness checks. The sixth section proposes an extension studying the evolution selected and non selected French and German scientific performances over the period. The last section concludes.

2 Higher education and research institutions and excellence policies in France and Germany

Excellence programs have been been developed in a number of European countries (Denmark, Germany, Spain, France...) but to our knowledge, only France and Germany have run programs at the university level. They have done so because policy makers in both countries realized they had relatively “weak universities” with respect to the size and quality of their research and innovation base. This is a slightly different standing point as compared to Asian countries which have seen excellence programs more as a way to achieve closing the gap with leading developed countries. There are however interesting historical and structural characteristics to the two national research systems. Accordingly, the two university level excellence programs, have slight differences that are worth being detailed. We thus briefly discuss the two national systems and excellence programs sequentially.

2.1 The German academic research system and the Zukunftskonzepte program

Though Germany counts more than three hundred higher education institutions and the Humboldtian model of research universities is born in Germany, a large part of German academic research is actually performed outside universities. Germany counts a number of research institutes associated with various societies such as the Max Planck Society (focusing on basic research), the Fraunhofer Gesellschaft (focused on applied and contractual research), the Helmholtz Association, or the Leibnitz society. For instance, in year 2011, universities only performed 45 % of academic research (13.4 billion euros). At the federal level, the main funding source of research is the German Research Foundation

(DFG - Deutsche Forschungsgemeinschaft), which provides both institutional and project funding to university and non-university research entities.

German universities are public and usually have strong connections with the local states (the länder of the Federal German Republic) which provide funding for teaching and research. Universities are usually seen as “natural” destinations for the local states students. German universities are often criticized for being bureaucratic and moderately autonomous. Besides they have a low (and even decreasing) ratio of staff per students. German universities are often known for their very low ratio of tenured personnel among research staff which mainly make a living with short terms employment contracts.

The Federal government together with the länder jointly launched the “Exzellentzinitiative” to promote differentiation in the university system with the objective to produce world-class research universities that would be attractive to international students. The funding program started in year 2006, had a second important funding phase in 2011, and has been renewed for a third phase very recently (2020). The selection process is not managed directly by the federal nor by local states’ governments, but instead by the German Research Council and the German Science Council. The program includes three main lines of funding: clusters of excellence on specific disciplines, graduate schools and institutional strategies. We here focus on the latter program which is the most prestigious, called “Zukunftskonzepte” and which targets a limited number of universities to expand their scientific excellence and compete as national champions in the global market for higher education and research. In the first phase of funding, three universities were selected in 2006 and then six more in 2007. In this research article we focus on the second phase launched in 2009 because it is quasi simultaneous with the first French excellence program (see below). The basic idea of the selection stage of this program was to emulate competition between non funded universities of the first stage and universities already funded in the first phase. The selection process went through several stages. Twenty two new applicant universities showed up, out of which seven were selected to compete with the eleven incumbent universities. At the end of this selection process late 2011 early 2012, seven entrant universities were selected together with four incumbents of the first stage (see Table 2). In total, 2.4 Billion euros have been awarded for this second stage of the exzellenzinitiative, to be divided between the three specific programs.

2.2 French academic research system and the Initiative d’Excellence program

As the German one, the French higher education and academic research system is quite developed overall, but its universities initially showed modest performances in global rankings. Some historians trace back the weakness of French universities to the fact they were closed down in the revolutionary times as royal regime institutions. Though universities were later reintroduced, they never reemerged as original institutions with significant leadership. Their constituting faculties kept strong power and professors were in effect civil servants whose career is essentially regulated by national disciplinary-based bodies (Conseil National des Universités). Besides French universities were never granted the right to select their undergraduate incoming students whereas higher education schools (mostly non PhD granting) could do so and were simultaneously better funded by the State. A reform was introduced in the late sixties which slightly reinforced the power of university president but its remained limited overall and the reform eventually lead to the dis-aggregation of all city-wide universities along political and/or disciplinary differences, leading to lots of small and often specialized universities.

After the Second World War, the goal to increase national research capacity has been essentially addressed via national research institutes such as the comprehensive Centre National de la Recherche Scientifique (CNRS) and other national institutes having specific goals (INRAE for agriculture and environment, INSERM for health and medicine, INRIA for computer science, CEA for atomic research). Those institutes offer tenured research positions with no teaching obligations, and are thus very attractive for brilliant minds willing to develop their research agenda. In the meantime, universities hardly propose attracting salaries and reduced teaching load to their top professors that would align with those proposed in top research universities worldwide.

On the basis of a bi-partisan report written by two former prime ministers, the French presidency launched in year 2009 a large scale investment plan to stimulate research and productivity. This program has been administered by a newly created institution (Commissariat Général à l'Investissement) placed under the direct authority of the Prime Minister. The idea was to pilot structural change that needed to be administered outside the direct control of the ministry of higher education and research. This funding has been preserved by three French presidents who all came from different aisles of the political spectrum, and by all their prime ministers. More than twenty billion euros were allocated to research and higher education. In this paper we focus on one specific program named "Initiatives d'Excellence" (IdEx) granted of a total budget of 6.3 billion euros. The main goal of this program, as for its German counterpart, was to sustain the emergence of a limited number of so called "world class universities", that is national champions in the global market of higher education and research. Out of seventeen projects submitted to the international committee, three were selected early in year 2011 (the University of Bordeaux, the University of Strasbourg, and Paris Sciences et Lettres) and five more early 2012 (Sorbonne University, University of Paris, University Paris-Saclay, Aix-Marseille University and Toulouse University). Later, posterior to year 2016, the excellence funding of some of the selected research sites have eventually been finally confirmed, whereas some were terminated. We call this program IdEx 1 because some other university sites were also selected and funded later on the basis of a second and also a third call. However, within the period 2012-2016 all and only those eight research sites were directly treated by the IdEx program. See Table 1 for details on the selected entities.

There are two important specifics of the IdEx program that depart from the German Zukunftskonzepte program. First, most of the time the IdEx grant was supporting the merge of several preexisting universities and higher educations schools into an original university. See Table A3 in the Online Appendix for details on those merges.[3] Second, the grants allocated to each site (.8 Billion euros each in average) were to constitute financial endowments of each university. In practice, those funds are managed by a financial agency placed under the authority of the parliament. Each university receives the yearly returns from placing those funds on non-risky assets on the financial market (about 3% rate of return).

3 Data and methodology

3.1 Empirical strategy and Data

To assess the effect of the excellence policy, we would have to be able to observe simultaneously for each university what would have happened if it had been a recipient of the policy, and if it had not. Naturally, we can observe only one of the two situations: it is not possible to know what would have happened for a university that was not a recipient of the policy if it had finally been a *university of excellence*, and for a recipient university if it had finally not been a *university of excellence*.

A first, somewhat naive proposition to evaluate the effect of the measures put in place would be to directly compare the universities benefiting from the policy (to be referred to as *treated universities*) with those that were not selected or did not apply (*untreated universities*). This approach comes up against the fact that being a beneficiary of the excellence policy is probably not the result of a random experiment, since the most dynamic and prestigious universities may particularly prone to apply and to be selected. The risk of such a comparison would be to attribute to the effect of the measure what is due to the particularities of the beneficiaries of the policy.

To neutralize this potential *selection effect*, it is necessary to control for observable differences between beneficiaries and non-beneficiaries at the time of treatment. This requires to constitute for each treated university a *control group* containing one or more

[3]Most of those merges did work out, but at different points in time. Some did merge but reached a legal form where each merging entity kept their moral personality (as for Paris Sciences et Lettres). Some entities eventually did not merge despite the prospects, like the Ecole Polytechnique which never formally entered the new Université Paris-Saclay, leading to the creation a new distinct entity, namely the Institut Polytechnique de Paris.

untreated universities comparable to the treated one on a number of observable characteristics that are assumed to capture all of the determinants of the selection. A risk is to omit characteristics that influence selection, which would make the control group inappropriate and ultimately not allow the causal effect of the policy to be identified.

In order to construct relevant control groups, we need to find relevant data on treated and non-treated universities. We first use bibliometric data from the CWTS Leiden Ranking, a database published annually since 2011 by the *Center for Science and Technology Studies* of the University of Leiden (Netherlands). It provides a set of indicators calculated from the Web of Science for a sample of almost 1,200 universities worldwide and updated annually since 2011.

To complete these bibliometric indicators, we use structural and financial data coming from two projects: ETER (European Tertiary Education Register) and its predecessor, EUMIDA (EUropean MIcroDAta). Both projects were contracted by the European Commission with the aim to collect information on higher education institutions in Europe (Lepori, 2023). Last updated in 2017, the EUMIDA-ETER database constitutes an unbalanced panel of about 3,000 academic institutions from 37 countries covering the years 2008 and 2011 to 2016. We select indicators related to education (number of graduates according to the ISCED level) and funding (revenues and expenses). We focus on personnel expenditures of each university, a variable globally well-documented in the dataset except for France for which we complete the missing values with the data from the French administration[4] and annual reports of French engineering schools. In order to neutralize the numerous changes in the institutional perimeter of French universities that have occurred in recent years (Table A3), a preliminary work on the data was carried out to recalculate the different indicators of the current institutions for the pre-merger periods.[5]

We then obtain a sample of 74 French and German universities, of which 18 benefited from the excellence policy. Concerning France, we consider as treated the French universities selected within the framework of the IdEx 1 policy only, because the period that we observe after the treatment (2013-2017) corresponds to the situation where only the universities selected within the framework of IdEx 1 are effectively "*treated*" (11 universities, see Table 1). Concerning Germany, we must take some precautions since there have been three successive phases of the Zukunftskonzept program. The first one predates the IdEx 1 program but may have time-lagged effects. The second one is almost simultaneous while the third one is too recent to interfere with our data. We therefore naturally focus on universities that did not benefit from program 1 but were selected under program 2. Thus we exclude from the sample the universities that benefited from the Zukunftskonzept 1

[4]https://data.enseignementsup-recherche.gouv.fr/explore/dataset/fr-esr-operateurs-indicateurs-financiers/information/?sort=uai.

[5]We were not able to reconstitute the financial indicators of the *Institut Polytechnique de Paris*, so we exclude it from our sample.

program, whether they were treated by the Zukunftskonzept 2 program or not. At the end, we consider 7 German universities treated by the Zukunftskonzept 2 program in our study (Table 2).

Up to this point, our sample is still clearly unsatisfactory. First, the number of observations is too limited to find a correct control group for each treated university. Second, there is an important selection effect, that we highlight in Figure 1. We represent French and German universities (treated and non-treated) according to their number of papers published in the top 10% and their personnel expenditures. One can note that all the universities in the upper right corner are treated, which confirms the presumption of a selection effect and above all makes our sample of universities inoperative in finding controls for these treated universities.

We address this concern by including in the dataset other universities from the following European countries: Austria, Belgium, Italy, the Netherlands, Portugal, Spain, the United Kingdom, Denmark, Ireland, Sweden, Switzerland, Finland and Norway. Since we have no financial data in the EUMIDA-ETER database in 2009 and 2010 for those European universities, we estimate the missing values with linear interpolation and/or by applying the growth rates of public funding for universities calculated at the country level according to the European University Association (EUA),[6] except for United Kingdom.[7] We plot in Figure 2 the same graph as Figure 1 including this time those European institutions, and observe that there exist some institutions with similar values for these two observable characteristics which should ease the construction of a control group for each treated university. Nevertheless, this representation remains very illustrative. Indeed, it is in the hyperplane of all the dimensions relevant to the selection that we would like to have data points of control universities close to the treated ones. By now, our sample of 255 European universities seems to have enough richness and compactness to allow us to constitute satisfactory control groups for the treated universities.[8]

Last but not least we were also able to collect data on the spendings associated to the excellence programs. Selected French universities for the IdEx program basically spent each year a fixed 3% of the endowment which can be easily calculated. When several universities that did not yet merge over the considered period joined forces in one IdEx project, amounts are split according to the relative importance of each entity. Concerning Germany, we use public information posted on the DFG website to have a precise view of the spendings of each Zukunftskonzept project for years 2014-2016, which we average and project on other post treatment years. We apply PPP rates to account for the difference

[6] https://eua.eu/101-projects/586-public-funding-observatory.html

[7] In contrast to other European countries, the United Kingdom has reduced public funding, while tuition fees have risen sharply. It would not be relevant to estimate the evolution of staff costs based on the growth rate of public funding in the United Kingdom.

[8] To the best of our knowledge, no other country than France and Germany in the sample considered has implemented an excellence policy at the university level.

across the two countries.

3.2 Matching

We need to determine the variables that are relevant to the selection and observable so that we can match universities that are beneficiaries and non-beneficiaries of the excellence policy. One underlying assumption is that, once we have controlled for this set of observable characteristics, treatment status of universities is random (referred to as the *Conditional Independence Assumption* in the literature). As it is impossible to formally test its validity, this assumption, though strong, is commonly used in the literature (Azoulay, Graff-Zivin and Manso, 2011) and also in our paper.

Matching variables are selected considering both previous literature and data availability. The correlation matrix between the different variables is given in Table 3. The number of publications is strongly correlated with the number of publications belonging to the 10% most frequently cited (0.98), the number of PhD graduates (0.81) or the university expenditure in PPP (0.86). These variables are indicative of the size of the university. In order to avoid having several variables with redundant information, and given that the number of publications is better documented than these other variables, we keep the number of articles as a criterion for matching universities. We will also include the proportion of research articles published in the top 10%: this is moderately correlated with the number of articles (0.54) and will allow us to differentiate the universities according to a research quality dimension.

Since CWTS data are also available by discipline,[9] we select the weight of the natural sciences (excluding the physical sciences) and health sciences[10] for the matching: this is generally the dominant discipline of each university, and when it is not the case, the main discipline is *Physical sciences and engineering*. Since the correlation between these two disciplines is strongly negative (-0.80), we keep the first one for the matching, allowing to reflect the specialization of the universities. We also include the weight of the discipline *Social sciences and humanities*: this variable is almost uncorrelated with the others and will allow us to discern the institutions specialized in social sciences. Finally, we also retain the multidisciplinary degree of the scientific production of universities measured as the inverse of the Herfindahl-Hirschmann index calculated on the weights of the disciplines of the published articles.

Several matching methods can be applied to match treated and control universities, like the Mahalanobis, the Propensity Score or the Coarsened Exact Matching. In this

[9]The disciplines considered are *Biomedical and health sciences*, *Life and earth sciences*, *Mathematics and Computer Science*, *Physical sciences and engineering* and *Social sciences and humanities*

[10]we add the weight of the discipline *Biomedical and health Sciences* to that of the discipline *Life and earth sciences*.

paper we select the Coarsened Exact Matching (CEM) procedure (Iacus, King and Porro, 2012) for several reasons. First it allows to choose the balance between the treated and control groups *ex ante* contrary to other matching methods where balance is discovered *ex post*. CEM thus prevents to repeat processes of matching and balance checking as is the case with other matching methods, where any change in the algorithm has unpredictable consequences on balance on any or all variables. Second, Iacus, King and Porro (2012) argue that CEM is better than the other existing matching methods to reduce imbalance, model dependence, estimation error, bias, variance, mean square error, and other criteria.

In practice, the procedure divides the empirical distribution of each variable into bins. Treated and untreated universities belonging to the same bins in the multivariate space are matched. When a treated university is matched with one or more non-treated universities in such a bin, we refer to this group as a *stratum*. Only matched entities are considered and the weight of controls is a function of the relative number of treated and controls in their stratum relative to the total number of treated and controls in the sample. As with any matching method, CEM involves finding the right compromise between increasing the chances of finding one or more counterfactuals for each university treated and improving the accuracy of the matching. Indeed, the more coarsening we are for a given variable, the more universities in the control group we have, but the more they likely differ from the treated. With 255 universities in the panel, achieving both a good quality matching and at the same time maintaining a sufficient number of observations requires care.

To match universities, we consider data from year 2012, that is when the policy is starting to be implemented but has not produced any effect yet. From the empirical distribution of the variables retained for the CEM (see Figure A1), Table 4 indicates the division into bins that we chose for each of them. Concerning the weight of the Humanities and Social Sciences, the objective is essentially to distinguish institutions highly specialized in this field from others, because publications in these disciplines are relatively poorly taken into account by the Web of Science. Then we match treated and non-treated universities if they belong to the same bin on the five observable characteristics selected. The 255 universities in the sample could be allocated into any of the 160 bins, each of one containing either recipient universities only, non-recipient universities only, universities of both types, or none. Only the groups containing universities of both types will be considered later. These are the strata mentioned above.

Because the sample of universities is small and excellence policies in both countries share many commonalities, we consider universities benefiting from excellence policies both in France and Germany as being treated by a single policy.[11] We use CEM according to the procedure described previously to get a control group of untreated universities that are similar to the 18 beneficiaries (11 French and 7 German ones). Then we analyze

[11]We also study the effects of those policy at the national level (France and Germany separately) in Section 6.

the quality of the matching stage in two ways. We first run t-tests between treated and control universities before and after matching (Tables 5 and 6). These t-tests show that the differences between treated and control universities are significantly reduced after the matching stage. Second, we calculate the multivariate $\mathcal{L}_1$ distance before and after matching to further measure imbalance reduction thanks to the CEM procedure. We observe a reduction of the multivariate $\mathcal{L}_1$ distance (see Table A30 and A31), which, even if moderate, qualifies our CEM procedure to be a satisfactory matching method (see Iacus, King and Porro (2012), page 7). We are satisfied with the matching performed for two other reasons: (i) the sample is made up of 101 universities (18 treated and 83 control universities) which constitutes a sufficient number of observations to estimate the causal effect of the policy in the second stage; and (ii) all treated universities have at least one counterfactual.

3.3 Models

Conditional on the first stage exact matching, we estimate the causal effect of excellence policy on the treated relying on the following specification:

$$y_{it} = \alpha \text{ Treated}_i \times \text{ Post}_t + \beta X_{it} + \gamma_{ct} + \theta_i + \eta_t + \varepsilon_{it}, \tag{1}$$

where y_{it} is an indicator of university i publication outcomes in year t. Dummy variable Treated$_i$ equals one for French and German treated universities and zero otherwise. Dummy variable Post$_t$ is equal to one in the post treatment period ($t > 2012$) and zero otherwise ($t < 2012$).[12] θ_i represents the university fixed effect that accounts for all time-invariant characteristics (including treatment status), and η_t is a year fixed effect. We include control variables at the university or at the regional level (X_{it}). As the scientific outcomes are also very much affected by the national context (including of course national science policies), we also include country-year fixed effects (γ_{ct}).

Our main goal is to consistently estimate parameter α which captures the impact of excellence policy in the post treatment period as long as the selection effect has been sorted out thanks to the first (matching) stage. Technically, this first stage is taken into account by weighting each observation of second stage regressions. Weights equal one for treated entities and $(m^C/m^T) \times (m_i^T/m_i^C)$ for control ones, with m^C and m^T the number of control and treated universities in the sample, and m_i^T and m_i^C the number of treated and control units specifically in university i's stratum.

When estimating the average impact of excellence treatment, we are in fact looking at heterogeneous treatments just because excellence projects have varying magnitudes across

[12]Treatment year 2012 is never considered. Besides, since the effects of excellence policy may be time-lagged, we consider several time windows for the post-treatment period. Our preferred specification retains the idea of a delay in the appearance of effects ($t > 2014$).

universities. To account for such treatment heterogeneity, we rely upon the following specification:

$$y_{it} = \alpha \, \text{Euros-Treatment}_{it} + \beta X_{it} + \gamma_{ct} + \theta_i + \eta_t + \varepsilon_{it}, \tag{2}$$

where Euros-Treatment$_{it}$ is the spending (expressed in Million euros) of university i and year t thanks to excellence programs. This variable is of course non null only when Treated$_i \times$Post$_t$ equals one. Thanks to this specification we can also more directly estimate the returns of euros spent thanks to excellence programs.

Identification relies on the common trend hypothesis, according to which treated units would have had similar trends after treatment as controls in the absence of treatment. This assumption is of course not verifiable as the counterfactual is not available. It is however possible to test a distinct but quite similar hypothesis, that is treated and controls have had similar pre-treatment trends. We estimate the impact of treatment on performances before treatment (rather than after). We use a specification close to Equation 1, but we substitute the dummy variable Before$_t$ to the dummy Post$_t$, where the dummy Before$_t$ equals one before the implementation of the policy ($t \leq 2012$) and 0 otherwise:

$$y_{it} = \alpha \, \text{Treated}_i \times \; \text{Before}_t + \beta X_{it} + \gamma_{ct} + \theta_i + \eta_t + \varepsilon_{it}. \tag{3}$$

This aims at testing a "theoretical" effect of the policy on the treated entities in the period preceding its implementation. The absence of a pre-treatment trend differential is verified if the coefficient α is close to 0 (no effect). If the value is significantly different from 0, then the treated and control universities are on different trajectories before the implementation of the policy.

We also use an alternative econometric specification that allows us to compare treatment effects for each post-treatment year and pre-treatment (placebo) years. The specification is as follows:

$$y_{it} = \sum_{\tau} \alpha_\tau \text{Treated}_i \times \; \mathbb{1}_{\{\tau = t\}} + \beta X_{it} + \gamma_{ct} + \theta_i + \eta_t + \varepsilon_{it}, \tag{4}$$

with $\mathbb{1}_{\{.\}}$ a dummy equal to 1 if the condition into brackets is verified and zero otherwise. The estimated parameter $\hat{\alpha}_t$ for each year t considered indicates the effect of the treatment that year (purely theoretical "effect" for years prior to the treatment). We are expecting $\hat{\alpha}_t$ values close to zero when the year t is prior to the treatment year (which will indicate that there is no differentiated trend between treated and controls prior to treatment). If at the same time we observe $\hat{\alpha}_t$ values significantly different from zero and clearly "oriented" when t is a post-treatment year, this will underline the existence of a causal effect of the excellence program.

3.4 Variables

We now present the variables involved in the regressions.

Dependent variables To estimate the causal effect of this policy, we consider a set of indicators reflecting the excellence of universities. The first one is the total number of articles as excellence policies have this objective to sustain the research capacity of targeted entities. We also consider the number of publications that belong to the top 10% most cited compared with other publications in the same field and year. This measurement allows us to take into account both quantity and quality of the institution's research: it is thus a performance measure in the top qualitative segment of research outcomes. We also consider the exclusive top 1% segment. Table A5 provides descriptive statistics for the treated universities. If there is a great variety in the size of selected institutions (a 10 ratio between the minimum and the maximum number of papers), we note that the shares of papers that belong to the top cited segments are on average higher than the threshold (1%, or 10%), which confirms that the universities selected for this policy are already performing well in research.

Both French and German excellence programs have this goal to foster the internationalisation of targeted universities. We thus consider the number of international collaborations defined as the university's publications co-authored with foreign countries. Being a beneficiary of excellence policy could also have a signal effect on the quality of the institution's research, and thus would increase the number of collaborations with international partners.

We also look at the number of papers that have been co-authored with one or more industrial organizations, that are defined as *all private sector for profit business enterprises, covering all manufacturing and services sectors, including research institutes and other corporate R&D laboratories that are fully funded or owned by for profit business enterprises*. This variable does not reflect, strictly speaking, the excellence of universities. However the excellence policy could modify the number of collaborations with the private sector in two opposing ways. On the one hand, being a beneficiary of the excellence policy may have a signal effect on the research of the institution, which would enhance the attractiveness of these institutions to the private sector. On the other hand, these additional financial resources may deter researchers from researching financial support from the private sector and eventually decrease the number of collaborations with industrial organizations. Before the implementation of the policy, around 7% of the papers are co-authored between a future treated university and the private sector (Table A5).

Control Variables We control for personnel expenditures of universities[13] because financial resources of higher education institutions might change over time and be correlated with treatment status. Even if an university has not benefited from the excellence policy, it may have obtained additional funding from other institutional partners, private companies, research funding agencies, or additional state or local government endowments (e.g. regions). The correlation matrix (Table 3) indicates a strong correlation between the financial variables and scientific outcomes. Without controlling for universities funding, the estimated causal effect of excellence policy may be biased. We consider personnel expenditures rather than other financial variables for several reasons. First, as higher education institutions may spend more money than they receive, we prefer to consider expenditure variables that may better reflect their financial effort for research than revenues variables. Second, among all the expenditure variables, we may focus on those that are more related to scientific outcomes. Last but not least, the variable must be either well-documented in the original database, or at least it is possible to easily fill missing observations. Since personnel expenditures meet all these different criteria and constitute a very large part of the universities budget, we choose this variable and express it in purchasing power parity.

Another potential source of bias in estimating the causal effect of excellence policy could come from regional economic dynamism. Collaborations with firms in particular may for instance be affected by the local dynamics of private research activity. Besides, this variable may be correlated with the explanatory variable of interest ($\text{Treated}_i \times Post_t$). For instance, economic activity in those regions that host treated universities may have been stronger after 2012, potentially leading to some endogeneity issues (correlation of variable $\text{Treated}_i \times Post_t$ with the error term) that would bias upwards our estimates of the causal effect of excellence policies. In order to avoid this problem, we need regional level data that are representative of research intensity and that can explain collaborations with universities. We use research and development expenditures (public and private) as well as the number of researchers at the regional level (nuts 2) available on Eurostat.[14]

4 Main results: The impact of excellence policy

In this section we present the second stage regressions that should allow us to estimate excellence policy impact on treated universities.

[13]Except those spendings that are directly related to the excellence policy we are interested in. We assume three fourth of excellence fundings are dedicated to human resources (which is consistent with our knowledge of the program) and those amounts are subtracted to yearly HR spendings.

[14]https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_e_gerdreg
https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_p_persreg&lang=en

Pretrends For the identification of treatment effects to be valid, the parallel trends assumption between the treated in the absence of treatment and the controls needs to be valid. It is of course impossible to test the validity of this assumption, but we can check if trends were parallel before treatment thanks to placebo tests that are presented in Table A32. We observe that the coefficients associated with the variable $\text{Treated}_i \times \text{Before}_t$ are very close to 0 and are insignificant in all regressions. This suggests an overall absence of pre-trend: French and German universities treated by their respective national excellence programs had globally similar trajectories to their controls prior to the implementation of the policy. This is reassuring regarding the estimation of the joint effect of the excellence policy at the binational level. We can also test for the existence or absence of differentiated pre-trends using Equation (4). Estimated parameters $\hat{\alpha}_t$ for each year considered, as well as their 95% confidence interval are represented in Figures 3 – 5. In those graphs, we can verify the absence of significantly different pre-trends. We also observe in those graphs that there are no significant yearly effects of excellence programs before year 2015.

Main results

Table 7 reports the estimated values of coefficient α associated with $\text{Treated}_i \times \text{Post}_t$ in Equation (1). Correctly identified, this parameter gives the *average effect* of the policy on the beneficiaries in the yearly number of papers in each category (total, top 1%, top 10%, international collaborations and industrial collaborations). As we observed in Figures 3 – 5 that there is no inflexion in the magnitude of the coefficients over years 2013 and 2014, those programs likely do not have really have any recordable impact in the first years posterior to 2012. We thus do not consider those two years in the regressions leading to Table 7. We observe in column (3) that benefiting from an excellence policy translates into an estimated 189 additional research articles per year for treated universities. Columns (1) and (2) indicate that 25 papers (respectively 4) are among the 10% (respectively 1%) most frequently cited in their research field. It is also estimated that 155 articles process from international collaborations and 23 from collaborations with the private sector (columns (4) and (5) of the table).

To ease the interpretation of the results, we may relate them to the average performance of the universities benefiting from an excellence policy. Relative to year 2012 average outcomes, this gives an increase of 6.7% for research articles, 6% for research articles in the top 10%, 7.6% for research articles in the top 1%, 10.2% for articles in international collaboration and 12.7% for articles in collaboration with the private sector. Those results are significant for the number of papers, the number of papers from international collaborations and the number of papers in collaboration with industry. However, we cannot exclude that the coefficients associated with the number of papers in the top

10% or top 1% are not different from 0. This may be due to the limited number of observations which is inherent to the design of the policy itself.

Interestingly, when we consider the estimates of the returns of euros spent (see Table A36), all effects are positive and significant. We estimate that one Million euros in excellence policy leads to 22.5 more scientific articles (that means a paper funded this way costs less than fifty thousand euros), among which 19 are out of an international collaboration, 2.5 are produced in collaboration with industry, 3.7 are top 10% cited papers and .6 are top 1% cited papers.

How efficient is excellence policy ?

To appreciate the relative efficiency of the program we are in need of comparison points in the form of returns to other science funding programs. There are however a limited number of results available from the literature. Maybe the most comparable results are provided by Payne (2002) which finds that an additional Million of 1996 dollars in earmarked funding raises the number of articles of US universities by 21 or 22, which translates approximately into 18 to 19 articles per year 2012 Million euros.[15] This is below but close to our estimates of excellence programs impact.

We may also compare our results obtained for individual level funding schemes. For instance Jacob and Lefgren (2011) estimate that NIH N01 funds ($1.7 Million in average) are associated with only about 1.2 additional publications. Those numbers are significantly below our own results but the authors acknowledge that their estimates are likely biased downward due to a replacement effect (unfunded individuals may by more likely to obtain other funds that the authors can not observe and account for).

Is the policy really targeting Excellence ?

As the main policy goal or the funding programs we study is to improve scientific excellence, it is thus very interesting to compare estimated impacts for different segments of scientific outcomes "quality". In this respect, and this is perhaps one of the largest surprises of our results, excellence programs impact is actually very similar on the number of articles and on the numbers of top quality papers (top 1% and top 10%). A previous study (Azoulay, Graff-Zivin and Manso, 2011) on the evaluation of a funding program targeting individual scholars report a 2.5 larger impact on the top 1% cited papers than on the total numbers of papers. We may thus conclude that funding at the university

[15] $1 Million in 1996 is equivalent to $1.476 Million in 2012 according to US IPC rates. Since $1 Million in 2012 roughly corresponds to €.844 (respectively .787) Million adjusted in PPP in France (respectively Germany), the impact of an additional Million of dollars in the US in 1996 (22 papers) can be converted into an impact of 17.8 papers in France and 19.1 in Germany, per Million of 2012 euros.

level, even if labelled "excellence programs", has more diluted effects. Its impact is not concentrated on top quality outcomes within the university, as compared to funding at the individual researcher level.

Internationalization of research and collaborations with industry

We have seen above that the elasticity of the policy is larger on the number of papers in international collaborations than on all scientific papers. More precisely, it is 52% larger. This suggests the excellence policy at the university level is well designed to support the goal of internationalizing research.

The impact of excellence policy on collaborations with companies is even larger: it is twice the impact on the number of papers. Again, this supports the idea that excellence policy is well aligned with the goal of increasing collaborations with industry. More precisely, the positive demand effect for collaborating with universities (companies being increasingly willing to collaborate with universities when they exhibit the prestigious excellence label) clearly dominates the negative supply effect (universities being less willing to collaborate with companies because excellence funding may raise their opportunity costs). In other words excellence funding has a crowding in rather than a crowding out effect on partnering with private commercial entities.

5 Potential limitations and robustness checks

In this section we discuss potential limitations of our study and multiple related robustness checks that we conduct. They concern the matching procedure, estimating impact at the bi-national level, the financial data that we use and other potential limitations.

Matching

The matching procedure uses control universities from other countries than France and Germany because there are not a sufficient number of comparable universities to the treated in those two countries. A potential weakness of this method could be that those controls coming from other national university systems would be affected by uncontrolled effects, posterior to the treatment date. To deal with such potential threat to identification we have included country×year fixed effects in all regressions which fully control for all differences between university systems over time. This should in principle absorb any yearly variation at the national level. To go even further, we also have conducted robustness checks by excluding, at matching stage, all universities from UK whose university system may be considered as distinct from continental ones. Universities from continental

Europe only are then matched using again the CEM method. Results of similar regressions as those presented in Subsection 3.3 for this sample are exposed in the Online Appendix. In a nutshell, the estimated values of coefficient α associated with Treated $\times$ Post are qualitatively similar than our main results obtained when UK universities are included in the sample.[16] This is also the case when we consider the estimates of the returns of euros spent.

Another critique of our matching procedure could address the high residual difference between matched and control entities: the multivariate $\mathcal{L}_1$ distance equals 0.92 after the CEM procedure. Note however that such remaining differences are easily explained by the use of continuous variable at the matching stage, a limited number of universities and an underlying asymmetric size distribution of universities. Moreover, according to Iacus, King and Porro (2012), the matching is successful when one records a decrease in the $\mathcal{L}_1$ measurement, which applies to our study. We could further slightly matching by strengthening matching conditions but this would be at the expense of excluding more treated and control universities, in particular the largest ones. We believe we have reached the best trade-off so that both balancing conditions are met and sample size and composition is acceptable.

Estimating impact at the bi-national level

We have so far estimated the joint effect of the excellence policy at the bi-national level only. One could however be worried that the effects of those policies could in fact be very different in France and in Germany as those are two distinct policies deployed in two countries. The impact measured at the bi-national level could then be a questionable weighted average of potentially very different impacts. To verify this, we run the same regressions as before on each country separately. First stage regressions are also performed specifically considering only one country's selected universities as treated. Selected universities from the other country are then excluded from the sample. The results are presented in the Online Appendix (Tables A35 and A37).

We find that the effects in the two national programs are very comparable. At the first sight, impact seems to be greater for Germany than for France on the number of papers and number of papers in international collaboration, but this difference is likely due to a positive "pre-trend" observed only on treated German institutions. Indeed, looking at the placebo tests performed for the IdEx case (Table A33), we observe that the coefficients associated with the variable $\text{Treated}_i \times \text{Before}_t$ are small and insignificant in

[16]Estimated effects are only slightly higher for the number of papers and the number of papers in the top 10%, and lower for the three other variables. Note, the 10% level significance for the number of papers co-authored with a private partner is lost and significance for papers published with an international partner is now at the 10% level (instead of at 5%). Looking at the placebo tests, all the coefficients associated with the variable Treated $\times$ Pre-Period are insignificant in all regressions.

all regressions.[17] Those same placebo tests on the Zukunftskonzept program (Table A34) return estimates that are still insignificant, but negative and larger in absolute value in the same columns (4) and (5). This suggests that the effects of the Zukunftskonzept program on these two explained variables (number of papers and number of papers in international collaboration) may have been overestimated, and to a greater extent than the IdEx program was underestimated. This could lead to the conclusion that IdEx program effects are larger than Zukunftskonzept program ones[18] but these results should however be taken with caution as differences are not significant.

Financial data

We are also constrained by the availability of financial data on universities that are comparable across countries and over time. Consequently we may miss some important factors of scientific outcomes. For instance we would like to include the costs of equipment in addition to personnel expenditures in our regressions since they take a large part in research expenditures in STEM. However, such variable is not available in the EUMIDA-ETER database. To the best of our knowledge, there is no database at the European level that includes a variable measuring the universities' cost of equipment. We have investigated if such data exist at the national level for at least some countries with little success. Looking at France, *equipment costs* data are not available in the financial database of French universities. Regarding Germany, we have found one single paper Ahn, Clermont and Langner (2022) that uses financial data from German universities. The data unfortunately are only for year 2010. One table of that paper presents Pearson correlations among the different types of universities' expenditures by fields, including personnel expenditures, equipment expenditures and total expenditures. Equipment expenditures and personnel expenditures are extremely correlated in Engineering (0.935) and Natural Sciences (0.856), and highly correlated in Mathematics, Social Sciences and Humanities (more than 0.7). This supports the idea that costs of equipment are very correlated with human resources and thus not controlling for it specifically is not of a big concern for our study.

[17]Coefficients tend to be positive in columns (4) and (5), which would indicate that the treatment effect may have been slightly underestimated.

[18]That is further supported by regressions estimating the returns of euros spent in those two countries: a Million euros in the French IdEx program brings 27.9 more papers, 24 in international collaboration, 2.8 papers in collaborations with industry, 4.5 papers in the top 10%, .9 papers in the top 1%, against respectively 24, 17.9, 2.3, 2.7 and .4 papers for the Zukunftskonzept (see Tables A36 and A38 in the Online Appendix).

Other potential limitations

Another limitation of our study arises from the existence of several phases of the Exzellenzinitiative. We would have liked to measure the effects of the second phase of the program considering all the 11 German treated universities, but it has been necessary to exclude from the sample the 4 universities that were also selected in the first phase of the program. Consequently our average treatment effect on the treated of the second phase of the German program is estimated considering 7 out of 11 treated universities, which limits the scope of those results.

To the best of our knowledge, no other European country than France and Germany have implemented an excellence policy at the university level in our sample, some have led other excellence policies at the researcher or team levels. Those funds are in principle taken into account in the second stage regressions, as we have included the personnel expenditures of the university.If, for some reason, those additional funding are not perfectly captured in the data, and if, simultaneously, other countries have supported their universities in a larger extent, then we may underestimate the impact of excellence programs in France and Germany. But note France and Germany also ran excellence policies at the team level.

6 Extension: The evolution of the competitive position of treated and untreated French and German universities

In this supplementary section, we examine the evolution of the competitive positions of the national universities in our sample, depending on whether they were selected by the program or not. Unlike in the previous section, we do not estimate causal effects. We only follow the competitive position of entities over time. To do so, we use the following very simple econometric specification (always considering the weights from the first stage):

$$y_{it} = \sum_{\tau} \beta_\tau \text{Treated}_i \times \mathbb{1}_{\{\tau=t\}} + \theta_i + \varepsilon_{it}, \tag{5}$$

with β_t the change in the competitive position of the treated institutions (relative to their controls) in year t compared to the same competitive position observed in the reference year (2012).

To appreciate the simultaneous evolution of the competitive positions of the non-selected national universities, we repeat the same operation on the latter. That is, we retain the following specification:

$$y_{it} = \sum_{\tau} \beta_\tau \text{Non-selected}_i \times \mathbb{1}_{\{\tau=t\}} + \theta_i + \varepsilon_{it}. \tag{6}$$

The dummy Non-selected$_i$ is equal to 1 if i is a French or German university and has not been selected (0 otherwise). Of course, the weights used for regressions (5) and (6) come from a first step in which we considered these universities as having been (very theoretically) "treated", allowing us to compare them with the other universities in their own comparison stratum.

In both equations, we control only for individual fixed effects (and thus all other time-invariant factor effects) and for year fixed effects as there is no attempt to identify any causal effect here.

The coefficients and their 95% confidence intervals are shown in Figure 7. The main finding is that the treated entities see their competitive position globally maintained after the treatment (for some indicators, the evolution would even be slightly negative). On the contrary, the trend is clearly declining for the national entities that were not selected. Looking at France and Germany separately, we have very similar findings, even more contrasting for the German situation than for the French one.

The different results are consistent with the idea that the excellence programs have helped the selected universities to maintain their overall competitiveness compared to their competitors, while the French and German untreated universities are losing ground in their own league. To understand this phenomenon, we need to look more closely at university funding. More specifically, we study the evolution of the human resources expenditures of the different universities in the sample, which are the most reliable and complete at the European level.

In Figure 8 we consider human resources funds in the post treatment period supported by excellence programs considered both with and without excellence funds[19] and those that were not, and show similar figures for their controls outside France and Germany. Taking year 2012 funds as the baseline, it is clear from the figure that excellence programs have allowed the treated universities to maintain human resources spending with respect to their control universities. We also see that without such funds, they would have had very similar expenses than non selected entities. In the meantime, non-selected universities have also had access to more funding than their own controls, which does not explain why those universities are losing ground in their own league.

[19]As we ignore how exactly those funds have been spent, we assume 75% of those funds accrue to human resources Notes and uniform yearly spending of excellence funding.

7 Conclusion

In this paper we estimate the impact of excellence policies conducted at the university level, based on recent German and French experiences. We find that this policy had a positive direct impact on scientific articles, international collaborations and collaborations with private companies. We estimate that one Million euros spent via such excellence policy leads to 22.5 more scientific articles, of which 19 in an international collaboration, and 2.5 in collaboration with industry. We also find that the impact does not concentrate on top cited articles, though they are larger in percentage terms on international collaborations and on collaborations with industry which are explicit goals of those excellence programs. Comparisons with previous studies on other funding schemes seems to support the idea that such funding scheme are efficient on scientific outcomes, international collaborations and collaborations with industry but less so at fostering excellence.

In the meantime, universities treated via this policy have essentially maintained (rather than significantly increased) their competitive edge in the post treatment period whereas other national universities have lost some ground in their respective leagues. As the funding of non treated national universities remains comparable with respect to those of their controls, we hypothesize that, simultaneously to running excellence programs, French and German governments may have not undertaken some needed more generic reforms. It could well also be that the impacts of recent institutional changes are by nature lagged and thus not yet observable. We thus leave this issue as an essentially open question for further investigations and discussions.

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Tables and Figures

Institution	Status	Sample
Aix-Marseille Université	IdEx 1	Yes
Institut national polytechnique de Toulouse	IdEx 1	Yes
Institut Polytechnique de Paris	IdEx 1	No
Paris Sciences et Lettres (PSL)	IdEx 1	Yes
Sorbonne Université	IdEx 1	Yes
Université de Bordeaux	IdEx 1	Yes
Université de Paris	IdEx 1	Yes
Université de Strasbourg	IdEx 1	Yes
Université de Versailles-Saint-Quentin-en-Yvelines (UVSQ)	IdEx 1	Yes
Université Paris-Saclay	IdEx 1	Yes
Université Sorbonne Paris Nord	IdEx 1	Yes
Université Toulouse III - Paul Sabatier	IdEx 1	Yes

Table 1: French universities supported by Idex 1 program, and inclusion status in the sample

Institution	Status	Sample
Eberhard Karls University of Tübingen	Zukunftskonzept 2	Yes
Freie Universität Berlin	Zukunftskonzept 2	No
Heidelberg University	Zukunftskonzept 2	No
Humboldt-Universität zu Berlin	Zukunftskonzept 2	Yes
Ludwig-Maximilians-Universität München	Zukunftskonzept 2	Yes
RWTH Aachen University	Zukunftskonzept 2	No
Technical University of Munich	Zukunftskonzept 2	Yes
Technische Universität Dresden	Zukunftskonzept 2	Yes
University of Bremen	Zukunftskonzept 2	Yes
University of Cologne	Zukunftskonzept 2	Yes
University of Konstanz	Zukunftskonzept 2	No

Table 2: German universities supported by Zukunftskonzept 2 program, and inclusion status in the sample

Table 3: Cross-correlation table

	Variables	1	2	3	4	5	6	7	8	9	10	11
1	Number papers	1.00										
2	Number papers top 10\ %	0.98	1.00									
3	% papers top 10%	0.54	0.64	1.00								
4	Number international collab.	0.99	0.98	0.58	1.00							
5	Number collab. private sector	0.93	0.93	0.56	0.94	1.00						
6	Sh. Natural sciences - Health	0.28	0.28	0.09	0.27	0.25	1.00					
7	Sh. Social sciences	-0.17	-0.11	0.17	-0.16	-0.20	-0.26	1.00				
8	Sh. Physics	-0.14	-0.16	-0.13	-0.13	-0.09	-0.80	-0.34	1.00			
9	Number graduates ISCED 7	0.49	0.43	0.17	0.45	0.35	0.03	-0.02	-0.03	1.00		
10	Number graduates ISCED 8	0.81	0.80	0.46	0.79	0.73	0.12	-0.13	0.01	0.37	1.00	
11	Personnel expenditure	0.86	0.84	0.47	0.84	0.81	0.17	-0.11	-0.07	0.54	0.78	1.00

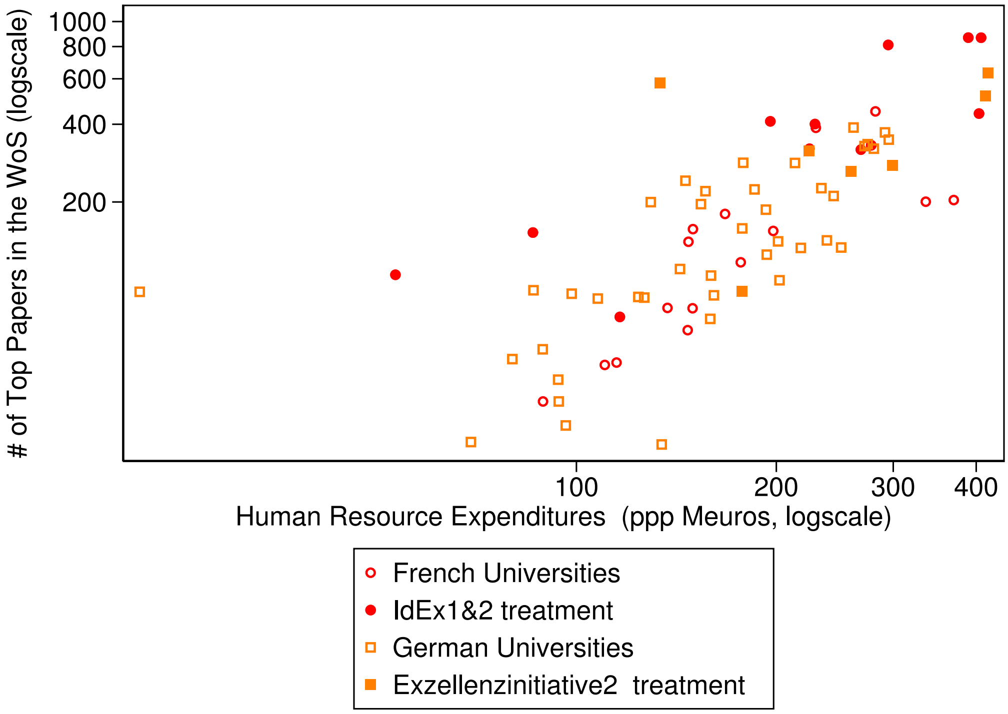

Figure 1: Total human resources spending and top-10% papers of French and German universities listed in the CWTS ranking, and their excellence treatment status (year 2012 data).

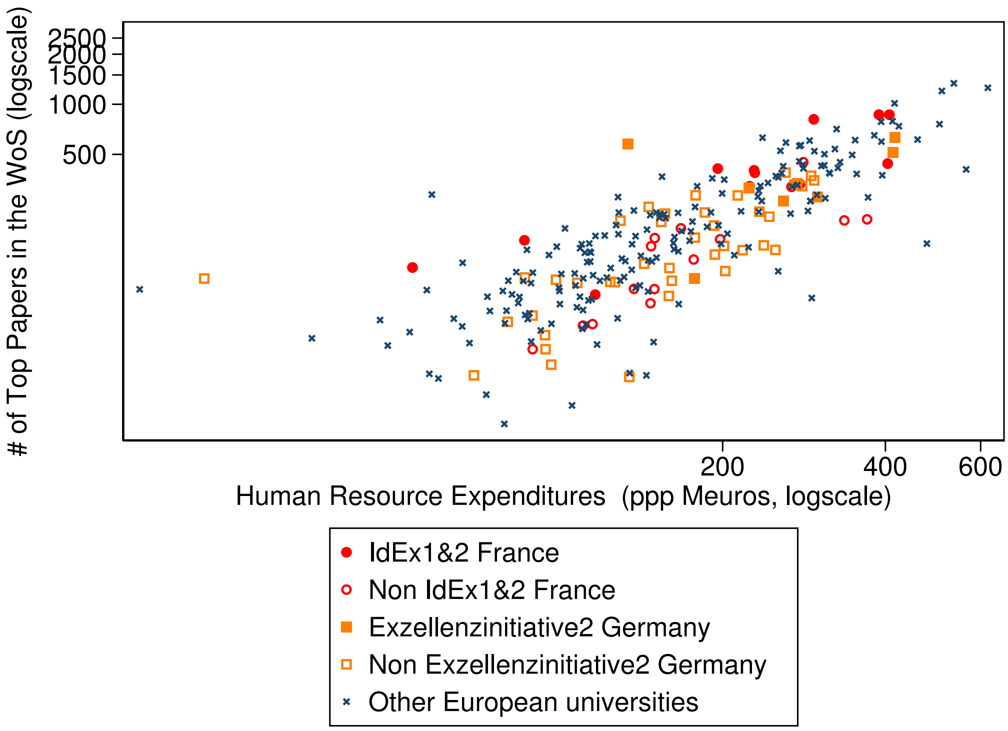

Figure 2: Total human resources spending and number of top 10% papers in our sample of European universities listed in the CWTS ranking (year 2012 data).

Variable	Bins
Number papers	[0 ; 1310] (60% of universities) [1310 ; 2248] (20% of universities) [2248 ; 3225] (10% of universities) [3225 ; 5412] (9% of universities) [5412 ; 9662] (1% of universities)
Quality of publications	[0 ; 9.7] (40% of universities) [9.7 ; 11.8] (30% of universities) [11.8 ; 13.9] (20% of universities) [13.9 ; 21] (10% of universities)
Sh. Natural Sciences - Health	[0 ; 67.09] (80% of universities) [67.09 ; 98.15] (20% of universities)
Sh. Social Sciences	[0 ; 19.47] (90% of universities) [19.47 ; 75.86] (10% of universities)
Multidisciplinarity	[1 ; 3.81] (80% of universities) [3.81 ; 4.85] (20% of universities)

Table 4: Cutoff points for the variables used in the Coarsened Exact Matching

	Treatment group		Control Group		Difference t-test	
	mean	sd	mean	sd	diff	p
Number papers	2803.39	1567.56	1511.17	1199.95	-1292.22	(0.00)
% papers top 10%	11.85	1.55	11.07	2.46	-0.78	(0.06)
Sh. Natural sciences - Health	53.11	12.91	51.71	19.91	-1.40	(0.68)
Sh. Social sciences	4.45	2.81	11.29	10.27	6.83	(0.00)
Multidisciplinarity	3.05	0.50	3.14	0.75	0.08	(0.53)
Observations	18		237		255	

Table 5: Difference t-test between treated universities (IdEx + Zukunftskonzept) and control universities at time of treatment before coarsened exact matching

	Treatment group		Control Group		Difference t-test	
	mean	sd	mean	sd	diff	p
Number papers	2803.39	1567.56	2400.16	1284.09	-403.23	(0.49)
% papers top 10%	11.85	1.55	11.89	2.00	0.04	(0.98)
Sh. Natural sciences - Health	53.11	12.91	54.68	20.60	1.57	(0.86)
Sh. Social sciences	4.45	2.81	7.86	5.02	3.41	(0.01)
Multidisciplinarity	3.05	0.50	2.91	0.72	-0.15	(0.65)
Observations	18		83		101	

Table 6: Difference t-test between treated universities (IdEx + Zukunftskonzept) and control universities at time of treatment after coarsened exact matching

	(1)	(2)	(3)	(4)	(5)
	Top 10%	Top 1%	Papers	International	Private
Treated × Post	24.984	4.152	188.923*	155.521**	23.719**
	(16.596)	(2.692)	(97.226)	(75.393)	(9.042)
Observations	775	775	872	872	872
Adjusted R^2	.97	.96	.98	.97	.97

Table 7: Regression results of excellence treatment.

*Notes: This table reports the estimated coefficients of the interaction between being selected into the excellence program and the post treatment period of Equation 1. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Industry
Euros-Treatment_it	3.674***	0.592**	22.554***	18.916***	2.503***
	(1.349)	(0.238)	(6.903)	(5.715)	(0.652)
Observations	775	775	872	872	872
Adjusted R^2	.97	.96	.98	.98	.97

Table 8: Regression results of excellence treatment, expressed in Million euros.

*Notes: This table reports the estimated coefficients of the annual spendings in excellence funding expressed in Million euros a expressed in Equation 2. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

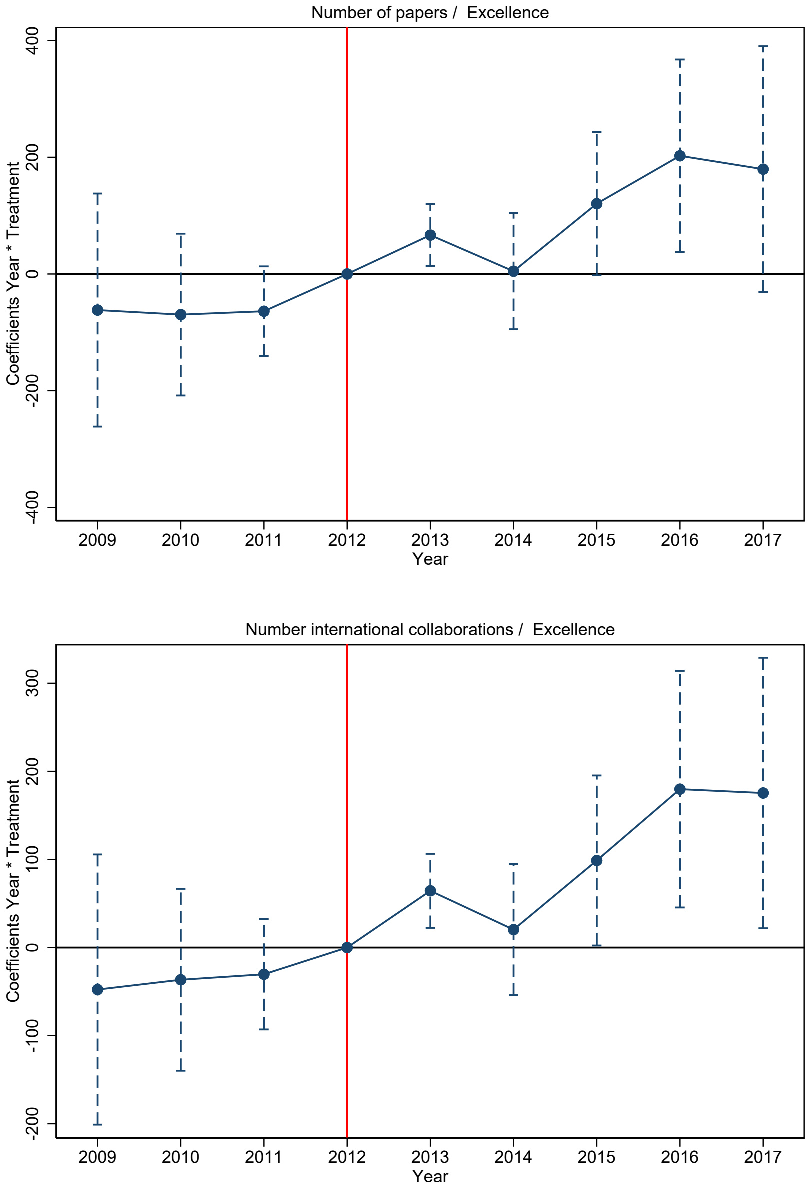

Figure 3: Annual average effect of the excellence programs on the beneficiary universities.

Note: Graphs represent the estimation of parameters α_t from Equation (4) when explained variables are the number of articles (top graph) and the number of articles in an international collaboration (bottom graph). The estimated coefficient for year 2012 (α_{2012}) is in reference. Vertical dotted lines give 95% confidence intervals when standard errors are clustered at the university level.

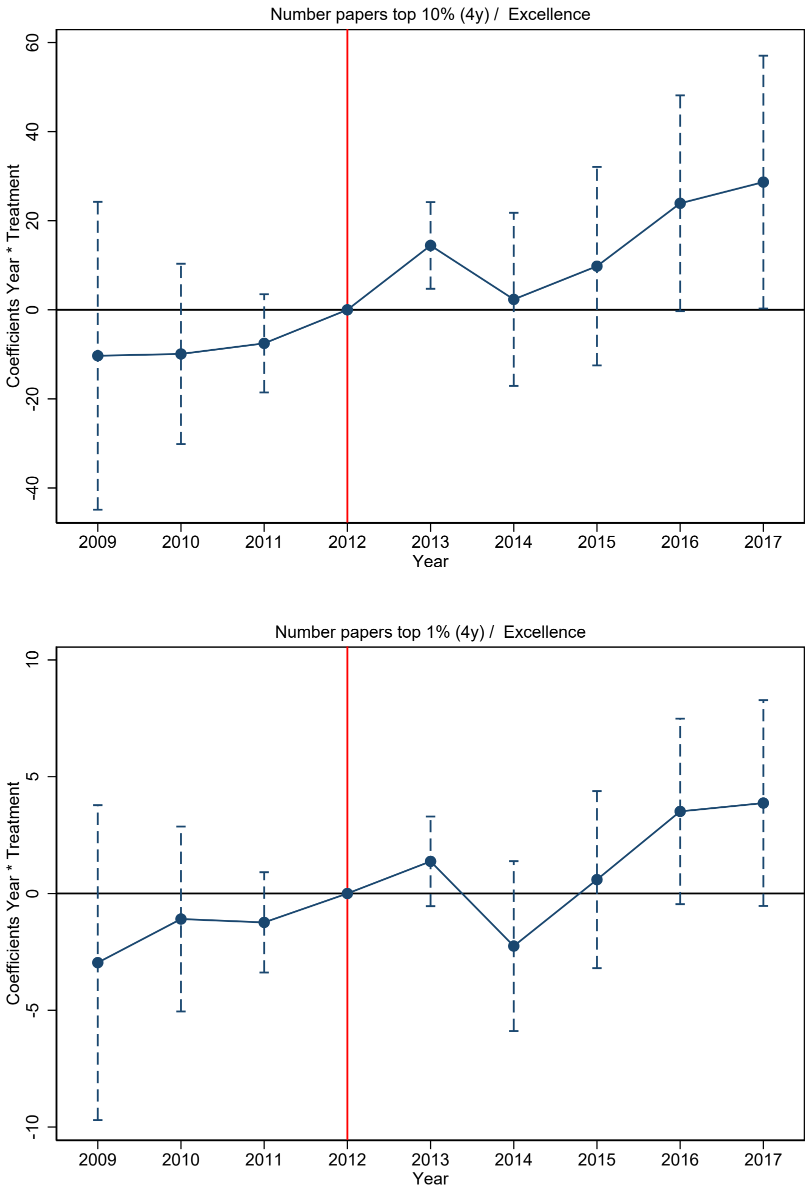

Figure 4: Annual average effect of the excellence programs on the beneficiary universities.

Note: Graphs represent estimated parameters α_t from Equation (4) when explained variables are the number of top 10% (top graph) and top 1% (bottom graph) articles. The estimated coefficient for year 2012 (α_{2012}) is in reference. Vertical dotted lines give 95% confidence intervals when standard errors are clustered at the university level.

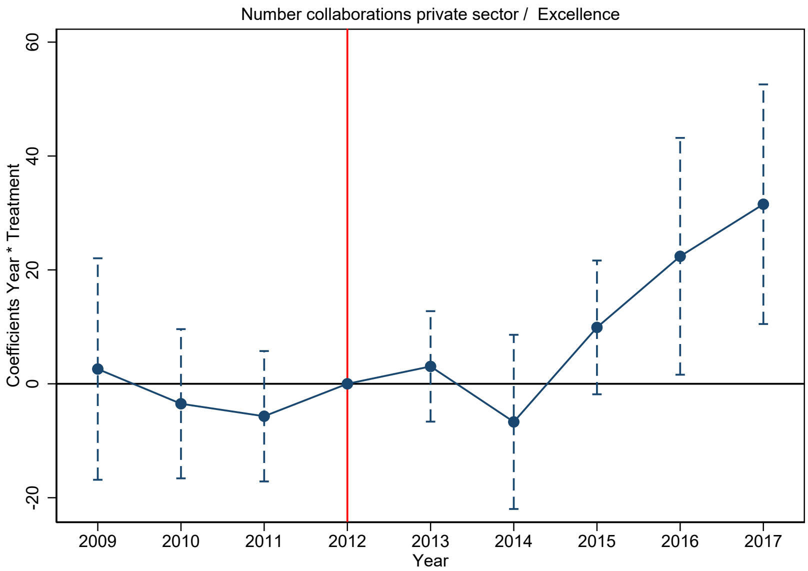

Figure 5: Annual average effect of the excellence programs on the beneficiary universities.

Note: Graphs represent estimated parameters α_t from Equation (4) when explained variables are the number of articles coauthored with a company. The estimated coefficient for year 2012 (α_{2012}) is in reference. Vertical dotted lines give 95% confidence intervals when standard errors are clustered at the university level.

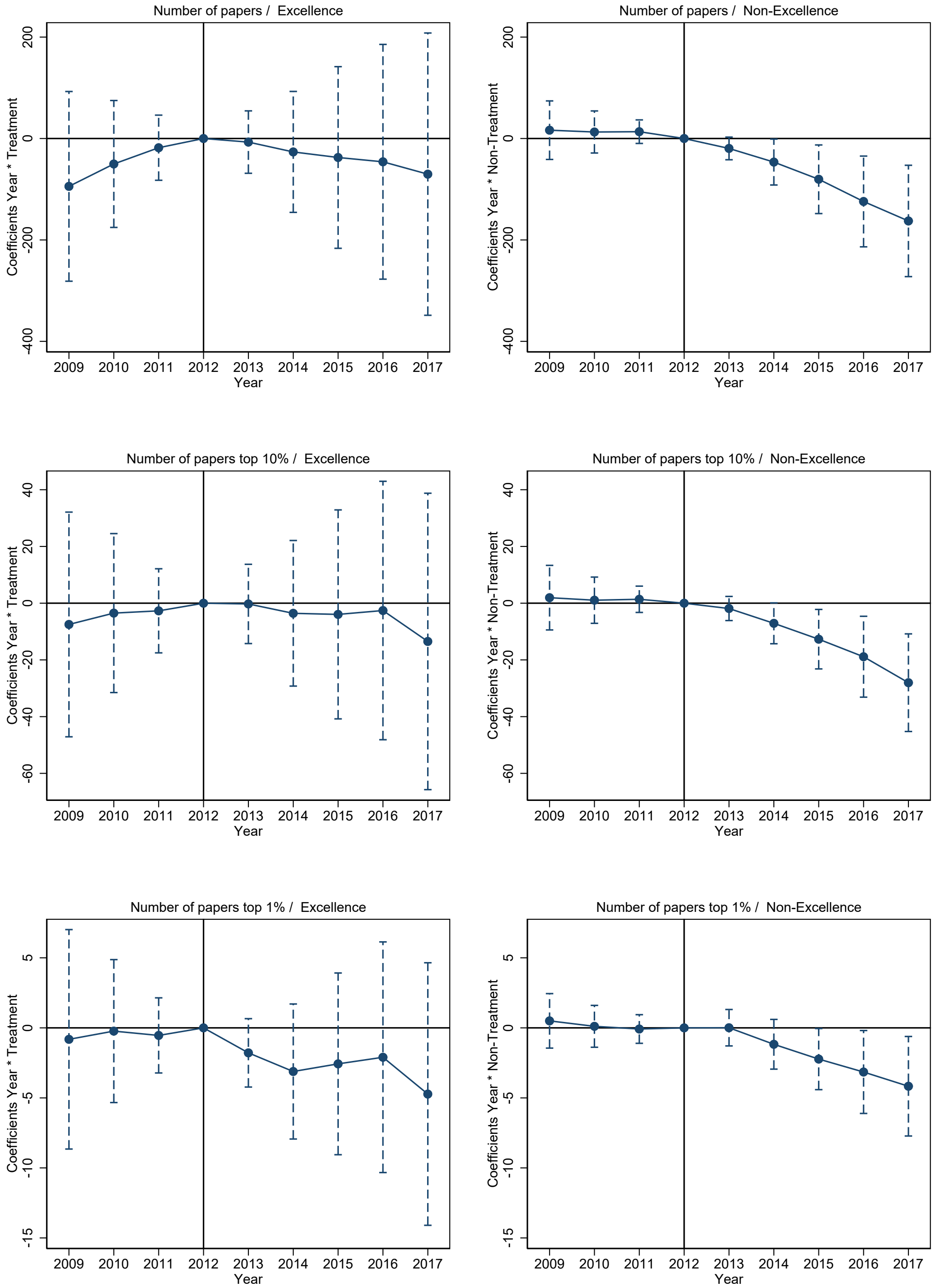

Figure 6: Event studies of treated (left) and non treated (right) universities in France and Germany.

Note: Graphs represent estimated parameters β_t in Equation (5) for left panels (event studies for selected entities) and in Equation (6) for right panels (event studies on non-selected national entities). The explained variables are the number of articles (top graphs), the number of top 10% papers (middle graph) and the number of top 1% papers (bottom graphs). The coefficient of year 2012 (β_{2012}) is taken into reference (variations are relatives to that year). Vertical dotted lines give 95% confidence intervals when standard errors are clustered at the university level.

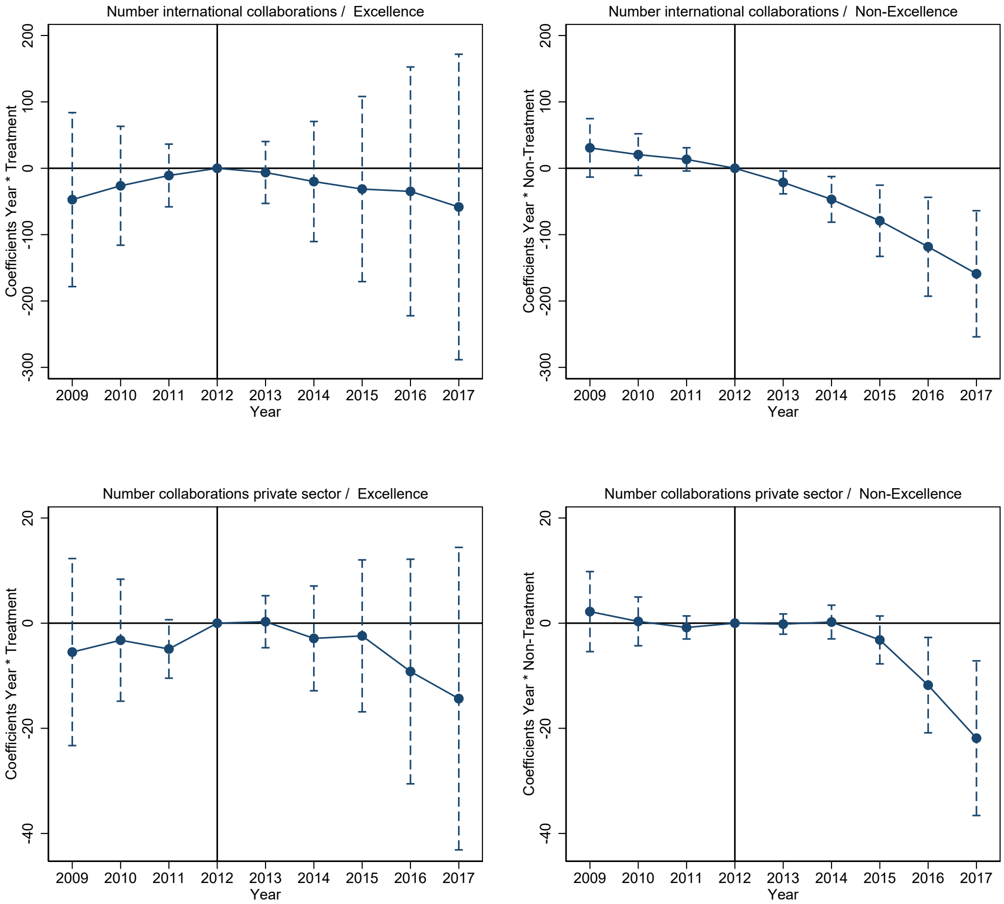

Figure 7: Event studies of treated (left) and non treated (right) universities in France and Germany.

Note: Graphs represent estimated parameters β_t in Equation (5) for left panels (event studies for selected entities) and in Equation (6) for right panels (event studies on non-selected national entities). The explained variables are the number of articles in an international collaboration (top graphs) and the number of collaborations with a company (bottom graphs). The coefficient of year 2012 (β_{2012}) is taken into reference (variations are relatives to that year). Vertical dotted lines give 95% confidence intervals when standard errors are clustered at the university level.

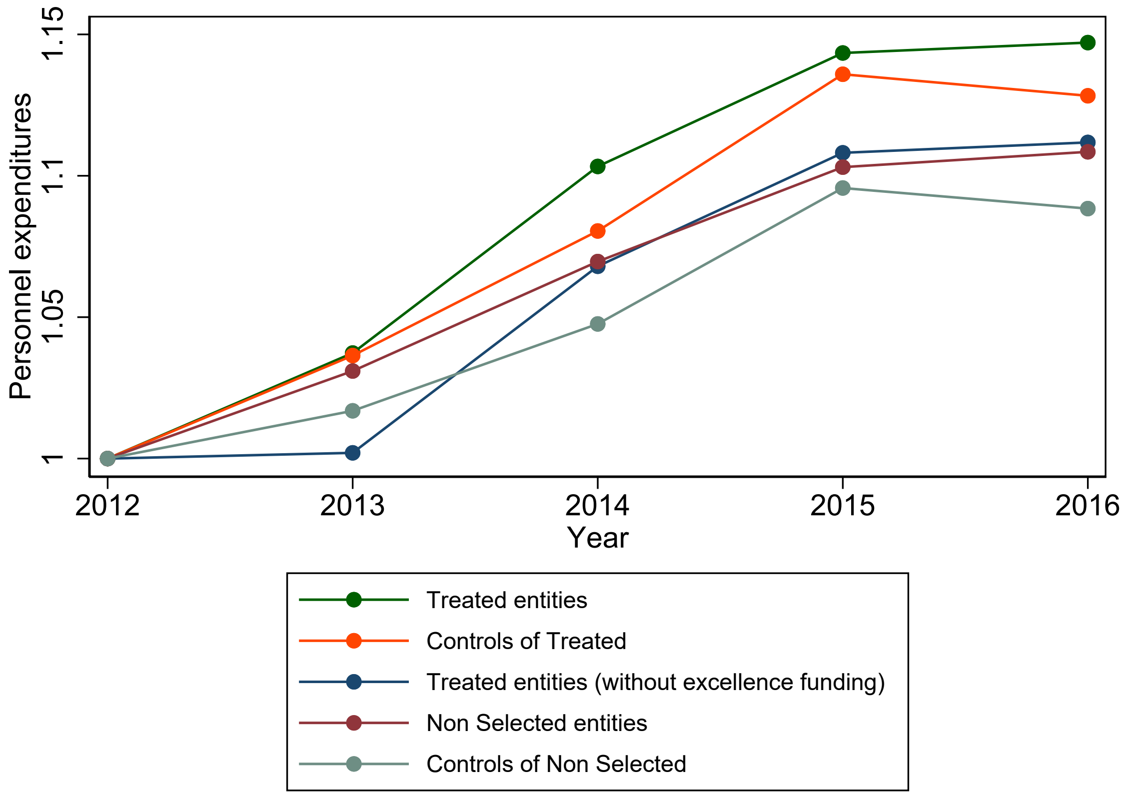

Figure 8: Evolution of personnel expenditures of French and German universities selected or not by excellence programs, as well as their respective controls. The expenses of the selected universities are shown with and without excellence funding.

Notes: We assume 75% of the excellence funding goes to human resources and uniform yearly spending of excellence funding. French and German universities are excluded from the control sample.

Online Appendix

Supplementary descriptive statistics

University name	IdEx Treatment
Aix-Marseille University	IdEx
Institut Polytechnique de Paris	IdEx
Institut National Polytechnique de Toulouse	IdEx
Sorbonne University	IdEx
University of Bordeaux	IdEx
University of Strasbourg	IdEx
Université Paris Sciences et Lettres	IdEx
Université Paris-Saclay	IdEx
Université Sorbonne Paris Nord	IdEx
Université Toulouse III - Paul Sabatier	IdEx
Université de Paris	IdEx
Université de Versailles Saint-Quentin-en-Yvelines	IdEx
Claude Bernard Lyon 1 University	Non IdEx
University of Burgundy	Non IdEx
University of Caen Normandy	Non IdEx
University of Lille	Non IdEx
University of Montpellier	Non IdEx
University of Orléans	Non IdEx
University of Poitiers	Non IdEx
University of Rennes 1	Non IdEx
University of Western Brittany	Non IdEx
Université Cote d'Azur	Non IdEx
Université Grenoble Alpes	Non IdEx
Université Paris-Est Créteil Val de Marne	Non IdEx

Table A1: French universities in the CWTS ranking and IdEx 1 treatment.

University name	Exzellenz Treatment
Eberhard Karls University of Tübingen	Zukunftskonzept
Freie Universität Berlin	Zukunftskonzept
Heidelberg University	Zukunftskonzept
Humboldt-Universität zu Berlin	Zukunftskonzept
Ludwig-Maximilians-Universität München	Zukunftskonzept
RWTH Aachen University	Zukunftskonzept
Technical University of Munich	Zukunftskonzept
Technische Universität Dresden	Zukunftskonzept
University of Bremen	Zukunftskonzept
University of Cologne	Zukunftskonzept
University of Konstanz	Zukunftskonzept
Bielefeld University	Non Zukunftskonzept
Carl von Ossietzky University of Oldenburg	Non Zukunftskonzept
Chemnitz University of Technology	Non Zukunftskonzept
Friedrich Schiller University Jena	Non Zukunftskonzept
Friedrich-Alexander-Universität Erlangen-Nürnberg	Non Zukunftskonzept
Georg-August-Universität Göttingen	Non Zukunftskonzept
Goethe University Frankfurt	Non Zukunftskonzept
Gottfried Wilhelm Leibniz Universität Hannover	Non Zukunftskonzept
Hannover Medical School	Non Zukunftskonzept
Heinrich Heine University Düsseldorf	Non Zukunftskonzept
Johannes Gutenberg University Mainz	Non Zukunftskonzept
Julius-Maximilians-Universität Würzburg	Non Zukunftskonzept
Justus Liebig University Giessen	Non Zukunftskonzept
Karlsruhe Institute of Technology	Non Zukunftskonzept
Kiel University	Non Zukunftskonzept
Leipzig University	Non Zukunftskonzept
Martin Luther University Halle-Wittenberg	Non Zukunftskonzept
Otto von Guericke University Magdeburg	Non Zukunftskonzept
Paderborn University	Non Zukunftskonzept
Philipps-Universität Marburg	Non Zukunftskonzept
Ruhr-Universität Bochum	Non Zukunftskonzept
Saarland University	Non Zukunftskonzept
TU Dortmund University	Non Zukunftskonzept
Technische Universität Bergakademie Freiberg	Non Zukunftskonzept
Technische Universität Berlin	Non Zukunftskonzept
Technische Universität Braunschweig	Non Zukunftskonzept
Technische Universität Darmstadt	Non Zukunftskonzept
Technische Universität Kaiserslautern	Non Zukunftskonzept
Ulm University	Non Zukunftskonzept
University of Bayreuth	Non Zukunftskonzept
University of Bonn	Non Zukunftskonzept
University of Duisburg-Essen	Non Zukunftskonzept
University of Freiburg	Non Zukunftskonzept
University of Greifswald	Non Zukunftskonzept
University of Hohenheim	Non Zukunftskonzept
University of Kassel	Non Zukunftskonzept
University of Münster	Non Zukunftskonzept
University of Potsdam	Non Zukunftskonzept
University of Rostock	Non Zukunftskonzept
University of Stuttgart	Non Zukunftskonzept
Universität Hamburg	Non Zukunftskonzept
Universität Regensburg	Non Zukunftskonzept
Universität zu Lübeck	Non Zukunftskonzept

Table A2: German universities in the CWTS ranking and Zukunftskonzept 2 treatment.

Year	Merged entity	Originating institutions
2013	Université de Bordeaux	Université Bordeaux I Sciences et Technologies Université Bordeaux Segalen Université Montesquieu Bordeaux IV
2014	Université de Montpellier	Université Montpellier I Université Montpellier II
2015	Université Grenoble-Alpes	Université Grenoble I Joseph Fourier Université Grenoble II Pierre Mendès-France Université Grenoble III Stendhal
2016	Université Clermont-Auvergne	Université Clermont-Ferrand I Auvergne Université Clermont-Ferrand II Blaise Pascal
2017	Université Grenoble-Alpes	Université Grenoble I Joseph Fourier Université Grenoble II Pierre Mendès-France Université Grenoble III Stendhal
2017	Université Sorbonne	Université Paris IV Paris-Sorbonne Université Paris VI Pierre et Marie Curie
2017	Université de Lille	Université Lille I Sciences et Technologies Université Lille II Droit et Santé Université Lille III Sciences humaine et sociales
2019	Institut Polytechnique de Paris	Ecole Polytechnique Télécom SudParis Télécom Paris ENSAE ENSTA
2019	Université Côte d'Azur	Université de Nice Sophia Antipolis
2019	Université Paris Saclay	Université Paris XI Paris-Sud Université d'Evry Val d'Essonne ENS Cachan CentraleSupélec AgroParisTech Institut d'Optique Graduate School
2019	Université Paris Sciences et Lettres	Université Paris Dauphine Mines ParisTech ESPCI Paris ENSCP Observatoire de Paris Ecole Nationale des Chartes EPHE Paris Ecole Normale Supérieure CNSAD
2019	Université de Paris	Université Paris V Paris-Descartes Université Paris VII Paris Diderot

Table A3: French merged entities ranked and their originating institutions.

University name	Country
Graz University of Technology	Austria
Johannes Kepler University Linz	Austria
Katholieke Universiteit Leuven	Belgium
University of Antwerp	Belgium
Université Catholique de Louvain	Belgium
Université Libre de Bruxelles	Belgium
Aarhus University	Denmark
Technical University of Denmark	Denmark
University of Copenhagen	Denmark
University of Helsinki	Finland
Trinity College Dublin, The University of Dublin	Ireland
Brescia University	Italy
Politecnico di Milano	Italy
University of Trieste	Italy
Delft University of Technology	Netherlands
Eindhoven University of Technology	Netherlands
Erasmus University Rotterdam	Netherlands
Leiden University	Netherlands
Radboud University	Netherlands
University of Amsterdam	Netherlands
University of Groningen	Netherlands
University of Twente	Netherlands
Utrecht University	Netherlands
Vrije Universiteit Amsterdam	Netherlands
Universidade Nova de Lisboa	Portugal
Carlos III University of Madrid	Spain
Universitat Jaume I	Spain
University of Almeria	Spain
University of Barcelona	Spain
University of Malaga	Spain
KTH Royal Institute of Technology	Sweden
Karolinska Institutet	Sweden
University of Gothenburg	Sweden
Uppsala University	Sweden
Ecole Polytechnique Fédérale de Lausanne	Switzerland
Eidgenössische Technische Hochschule Zürich	Switzerland
University of Bern	Switzerland
University of Geneva	Switzerland
University of Zurich	Switzerland
Bilkent University	Turkey
Cranfield University	United Kingdom
Heriot-Watt University	United Kingdom
Imperial College London	United Kingdom
King's College London	United Kingdom
Liverpool John Moores University	United Kingdom
Newcastle University	United Kingdom
Swansea University	United Kingdom
The University of Edinburgh	United Kingdom
University of Birmingham	United Kingdom
University of East Anglia	United Kingdom
University of Exeter	United Kingdom
University of Glasgow	United Kingdom
University of Liverpool	United Kingdom
University of Plymouth	United Kingdom
University of Reading	United Kingdom
University of St Andrews	United Kingdom
University of Surrey	United Kingdom
University of Sussex	United Kingdom

Table A4: Non French nor German control European universities.

Strata, Balancing and Placebo tests

	Number	Mean	s.d.	min	max	p50
Number papers	18	2803.44	1567.45	549.00	5581.00	2554.50
Number papers top 1%	18	53.22	34.10	8.00	118.00	41.50
Number papers top 10%	18	413.67	255.04	72.00	866.00	366.50
Number international collab.	18	1525.83	897.12	231.00	3242.00	1449.50
Nombre collab. private sector	18	187.17	100.06	36.00	351.00	172.00
Personnel expenditures (million euro)	18	275.84	127.71	61.16	471.96	276.27
% papers top 1%	18	1.14	0.26	0.60	1.60	1.10
% papers top 10%	18	11.85	1.55	9.20	14.80	11.60
Sh. international collab.	18	53.54	5.40	42.00	63.60	53.30
Sh. private sector	18	6.75	1.23	4.70	9.30	6.70
Observations	18					

Table A5: Descriptive statistics on the treated universities in France and Germany in 2012 (IdEx 1 and Zukunftskonzept 2)

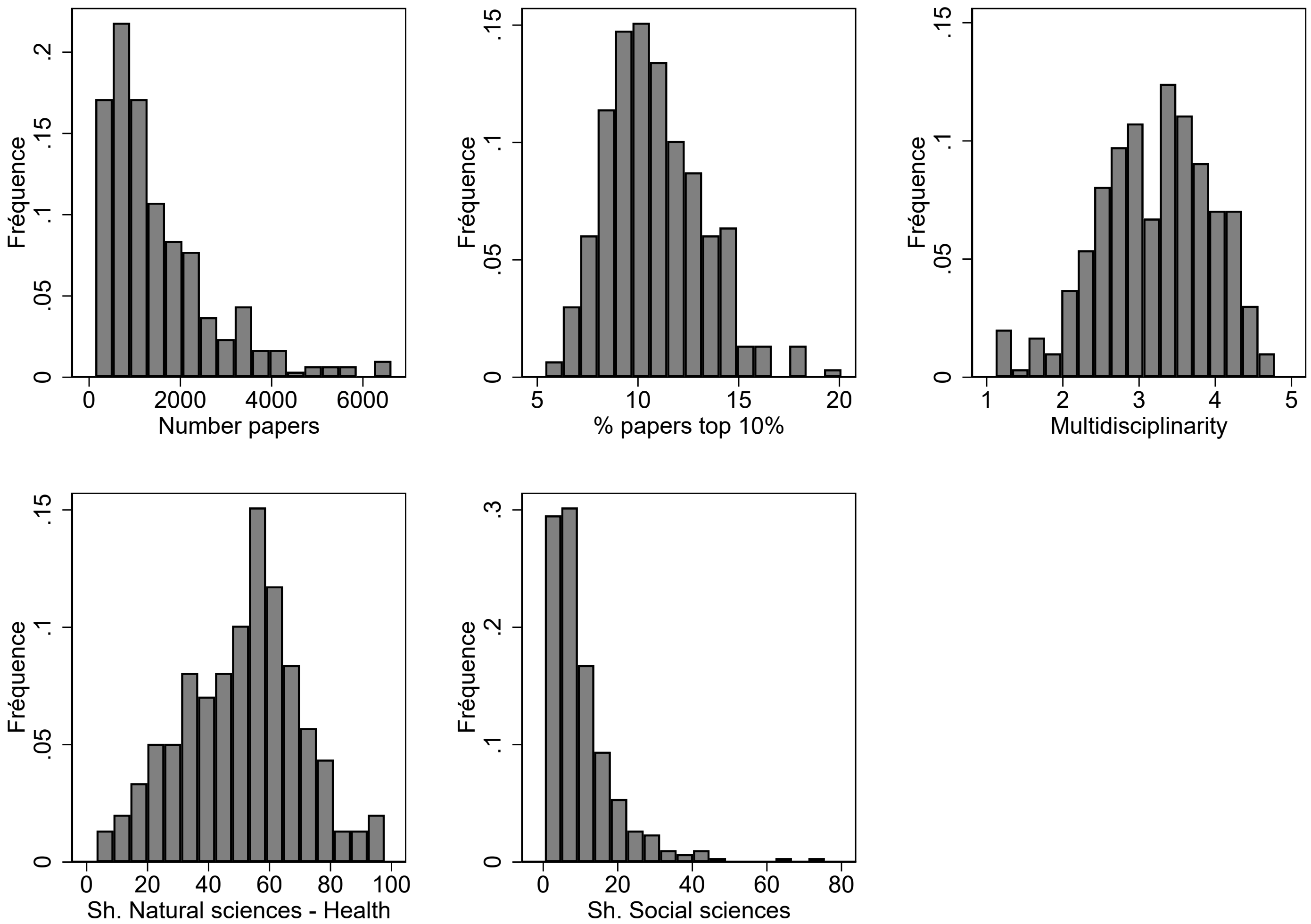

Figure A1: Histogram of the variables used in the CEM

Institution	Country	Status	Stratum
University of Insubria	Italy	Control	1
Åbo Akademi University	Finland	Control	1
Università del Salento	Italy	Control	1
Università Politecnica delle Marche	Italy	Control	1
Paderborn University	Germany	Control	1
University of Angers	France	Control	1
Technische Universität Bergakademie Freiberg	Germany	Control	1
University of Poitiers	France	Control	1
Heriot-Watt University	United Kingdom	Control	1
Chemnitz University of Technology	Germany	Control	1
Carl von Ossietzky University of Oldenburg	Germany	Control	1
University of Potsdam	Germany	Control	1
Graz University of Technology	Austria	Control	1
University of Salerno	Italy	Control	1
Université Sorbonne Paris Nord	France	Treated	1
University of Rouen	France	Control	1
Dublin City University	Ireland	Control	1
Luleå University of Technology	Sweden	Control	1
University of L'Aquila	Italy	Control	1
University of Kassel	Germany	Control	1

Table A6: Treated and Control universities in Stratum 1

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	480.11	145.50	548.50	.	476.51	148.57	-71.99	(.)
% papers top 10%	8.58	1.15	9.90	.	8.52	1.14	-1.38	(.)
Sh. Natural sciences - Health	35.01	16.86	45.67	.	34.45	17.13	-11.23	(.)
Sh. Social sciences	6.37	3.90	4.05	.	6.49	3.97	2.44	(.)
Multidisciplinarity	3.09	0.49	3.28	.	3.08	0.50	-0.20	(.)
Observations	20		1		19		20	

Table A7: Descriptive statistics on Treated and Control universities in Stratum 1 at time of treatment

Institution	Country	Status	Stratum
University of Clermont Auvergne	France	Control	2
University of Jyväskylä	Finland	Control	2
Swansea University	United Kingdom	Control	2
University of Bremen	Germany	Treated	2
University of Surrey	United Kingdom	Control	2
Aalborg University	Denmark	Control	2

Table A8: Treated and Control universities in Stratum 2

	(1)		(2)		(3)		(4)	
	All		Treated		Controls		Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	785.21	70.28	795.00	.	783.25	78.40	-11.75	(.)
% papers top 10%	9.55	0.41	9.20	.	9.62	0.42	0.42	(.)
Sh. Natural sciences - Health	40.74	8.41	47.06	.	39.47	8.75	-7.58	(.)
Sh. Social sciences	13.99	5.35	10.31	.	14.72	5.63	4.42	(.)
Multidisciplinarity	4.26	0.23	4.09	.	4.30	0.24	0.21	(.)
Observations	6		1		5		6	

Table A9: Descriptive statistics on Treated and Control universities in Stratum 2 at time of treatment

Institution	Country	Status	Stratum
Gottfried Wilhelm Leibniz Universität Hannover	Germany	Control	3
Université de Versailles Saint-Quentin-en-Yvelines	France	Treated	3
University of Bath	United Kingdom	Control	3
Université Paris-Est Créteil Val de Marne	France	Control	3
University of Perugia	Italy	Control	3
University of Leicester	United Kingdom	Control	3
Philipps-Universität Marburg	Germany	Control	3
Technische Universität Darmstadt	Germany	Control	3
Vienna University of Technology	Austria	Control	3
Politecnico di Milano	Italy	Control	3
Chalmers University of Technology	Sweden	Control	3
University of Innsbruck	Austria	Control	3
National University of Ireland, Galway	Ireland	Control	3
Saarland University	Germany	Control	3
Vrije Universiteit Brussel	Belgium	Control	3
University of Pavia	Italy	Control	3
University of Bayreuth	Germany	Control	3
Technische Universität Berlin	Germany	Control	3
Institut National Polytechnique de Toulouse	France	Treated	3
Aalto University	Finland	Control	3

Table A10: Treated and Control universities in Stratum 3

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	1050.70	183.21	990.75	2.83	1057.36	192.47	66.61	(0.16)
% papers top 10%	11.05	0.63	11.55	0.35	10.99	0.64	-0.56	(0.21)
Sh. Natural sciences - Health	39.63	19.10	45.05	12.57	39.03	19.87	-6.02	(0.62)
Sh. Social sciences	6.81	4.93	1.31	1.15	7.42	4.81	6.12	(0.00)
Multidisciplinarity	3.00	0.48	3.19	0.61	2.98	0.48	-0.21	(0.71)
Observations	20		2		18		20	

Table A11: Descriptive statistics on Treated and Control universities in Stratum 3 at time of treatment

Institution	Country	Status	Stratum
University of Rennes 1	France	Control	4
Kiel University	Germany	Control	4
Ulm University	Germany	Control	4
Friedrich Schiller University Jena	Germany	Control	4
University of Antwerp	Belgium	Control	4
University of Cologne	Germany	Treated	4
Technische Universität Dresden	Germany	Treated	4
University of Strasbourg	France	Treated	4
University of Lille	France	Control	4
University of Duisburg-Essen	Germany	Control	4
Goethe University Frankfurt	Germany	Control	4
KTH Royal Institute of Technology	Sweden	Control	4
Ruhr-Universität Bochum	Germany	Control	4

Table A12: Treated and Control universities in Stratum 4

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	1778.00	289.47	2079.58	246.20	1687.53	242.57	-392.06	(0.09)
% papers top 10%	11.12	0.59	11.33	0.55	11.05	0.62	-0.28	(0.49)
Sh. Natural sciences - Health	52.75	12.42	54.78	6.23	52.14	13.97	-2.64	(0.65)
Sh. Social sciences	5.85	3.03	5.67	3.07	5.91	3.19	0.23	(0.91)
Multidisciplinarity	3.08	0.42	3.00	0.09	3.11	0.48	0.11	(0.50)
Observations	13		3		10		13	

Table A13: Descriptive statistics on Treated and Control universities in Stratum 4 at time of treatment

Institution	Country	Status	Stratum
Cardiff University	United Kingdom	Control	5
Eindhoven University of Technology	Netherlands	Control	5
Newcastle University	United Kingdom	Control	5
Julius-Maximilians-Universität Würzburg	Germany	Control	5
Johannes Gutenberg University Mainz	Germany	Control	5
University of Liverpool	United Kingdom	Control	5
University of Bordeaux	France	Treated	5
University of Münster	Germany	Control	5
Delft University of Technology	Netherlands	Control	5
University of Montpellier	France	Control	5

Table A14: Treated and Control universities in Stratum 5

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	1986.83	270.41	2208.25	.	1962.22	274.69	-246.03	(.)
% papers top 10%	12.86	0.61	12.20	.	12.93	0.60	0.73	(.)
Sh. Natural sciences - Health	49.40	18.68	49.88	.	49.35	19.81	-0.52	(.)
Sh. Social sciences	7.87	5.48	3.22	.	8.39	5.55	5.17	(.)
Multidisciplinarity	3.09	0.39	3.38	.	3.06	0.41	-0.32	(.)
Observations	10		1		9		10	

Table A15: Descriptive statistics on Treated and Control universities in Stratum 5 at time of treatment

Institution	Country	Status	Stratum
Université Toulouse III - Paul Sabatier	France	Treated	6
Aix-Marseille University	France	Treated	6
Uppsala University	Sweden	Control	6
Claude Bernard Lyon 1 University	France	Control	6
Friedrich-Alexander-Universität Erlangen-Nürnberg	Germany	Control	6

Table A16: Treated and Control universities in Stratum 6

	(1)		(2)		(3)		(4)	
	All		Treated		Controls		Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	2979.10	363.05	3218.50	109.60	2819.50	402.60	-399.00	(0.22)
% papers top 10%	11.20	0.62	10.80	0.71	11.47	0.51	0.67	(0.39)
Sh. Natural sciences - Health	55.90	5.04	56.97	2.57	55.18	6.75	-1.78	(0.71)
Sh. Social sciences	4.10	2.66	3.50	1.93	4.51	3.42	1.01	(0.70)
Multidisciplinarity	3.13	0.33	3.45	0.03	2.91	0.20	-0.54	(0.04)
Observations	5		2		3		5	

Table A17: Descriptive statistics on Treated and Control universities in Stratum 6 at time of treatment

Institution	Country	Status	Stratum
University of Bonn	Germany	Control	7
University of Birmingham	United Kingdom	Control	7
Université Paris Sciences et Lettres	France	Treated	7
Universität Hamburg	Germany	Control	7
Aarhus University	Denmark	Control	7
University of Nottingham	United Kingdom	Control	7
University of Glasgow	United Kingdom	Control	7
Université Grenoble Alpes	France	Control	7

Table A18: Treated and Control universities in Stratum 7

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	2685.84	237.18	2760.25	.	2675.21	254.12	-85.04	(.)
% papers top 10%	12.78	0.37	13.40	.	12.69	0.30	-0.71	(.)
Sh. Natural sciences - Health	50.80	15.32	24.68	.	54.53	12.00	29.85	(.)
Sh. Social sciences	10.15	5.40	5.47	.	10.82	5.46	5.35	(.)
Multidisciplinarity	3.26	0.38	2.73	.	3.34	0.34	0.60	(.)
Observations	8		1		7		8	

Table A19: Descriptive statistics on Treated and Control universities in Stratum 7 at time of treatment

Institution	Country	Status	Stratum
Technical University of Munich	Germany	Treated	8
Ecole Polytechnique Fédérale de Lausanne	Switzerland	Control	8

Table A20: Treated and Control universities in Stratum 8

	(1)		(2)		(3)		(4)	
	All		Treated		Controls		Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	2720.25	500.99	3074.50	.	2366.00	.	-708.50	(.)
% papers top 10%	16.35	2.19	14.80	.	17.90	.	3.10	(.)
Sh. Natural sciences - Health	37.35	20.04	51.52	.	23.17	.	-28.35	(.)
Sh. Social sciences	2.21	0.36	2.46	.	1.95	.	-0.51	(.)
Multidisciplinarity	2.90	0.52	3.27	.	2.53	.	-0.74	(.)
Observations	2		1		1		2	

Table A21: Descriptive statistics on Treated and Control universities in Stratum 8 at time of treatment

Institution	Country	Status	Stratum
University of Groningen	Netherlands	Control	9
Katholieke Universiteit Leuven	Belgium	Control	9
Sorbonne University	France	Treated	9
Université Paris-Saclay	France	Treated	9
The University of Manchester	United Kingdom	Control	9

Table A22: Treated and Control universities in Stratum 9

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	4714.85	936.59	5580.63	0.53	4137.67	710.73	-1442.96	(0.07)
% papers top 10%	13.26	0.62	13.25	0.49	13.27	0.81	0.02	(0.98)
Sh. Natural sciences - Health	51.87	10.94	44.06	12.03	57.07	8.08	13.01	(0.34)
Sh. Social sciences	9.27	7.30	1.51	0.06	14.45	2.46	12.94	(0.01)
Multidisciplinarity	3.23	0.39	3.21	0.35	3.25	0.49	0.04	(0.93)
Observations	5		2		3		5	

Table A23: Descriptive statistics on Treated and Control universities in Stratum 9 at time of treatment

Institution	Country	Status	Stratum
University of Southern Denmark	Denmark	Control	10
Eberhard Karls University of Tübingen	Germany	Treated	10
Medical University of Vienna	Austria	Control	10

Table A24: Treated and Control universities in Stratum 10

	(1)		(2)		(3)		(4)	
	All		Treated		Controls		Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	1836.58	459.22	2349.00	.	1580.38	167.05	-768.63	(.)
% papers top 10%	10.87	0.76	10.00	.	11.30	0.14	1.30	(.)
Sh. Natural sciences - Health	78.77	14.77	74.14	.	81.08	20.11	6.94	(.)
Sh. Social sciences	6.87	5.63	6.66	.	6.97	7.96	0.32	(.)
Multidisciplinarity	1.99	0.72	2.26	.	1.86	0.96	-0.40	(.)
Observations	3		1		2		3	

Table A25: Descriptive statistics on Treated and Control universities in Stratum 10 at time of treatment

Institution	Country	Status	Stratum
University of Oslo	Norway	Control	11
Humboldt-Universität zu Berlin	Germany	Treated	11
University of Helsinki	Finland	Control	11
Lund University	Sweden	Control	11

Table A26: Treated and Control universities in Stratum 11

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	3559.63	192.13	3785.75	.	3484.25	145.88	-301.50	(.)
% papers top 10%	10.88	0.51	11.40	.	10.70	0.46	-0.70	(.)
Sh. Natural sciences - Health	69.75	2.55	67.79	.	70.40	2.68	2.61	(.)
Sh. Social sciences	9.56	1.46	8.22	.	10.00	1.42	1.79	(.)
Multidisciplinarity	2.73	0.23	2.58	.	2.79	0.25	0.21	(.)
Observations	4		1		3		4	

Table A27: Descriptive statistics on Treated and Control universities in Stratum 11 at time of treatment

Institution	Country	Status	Stratum
Université de Paris	France	Treated	12
Ludwig-Maximilians-Universität München	Germany	Treated	12
University of Copenhagen	Denmark	Control	12
Karolinska Institutet	Sweden	Control	12

Table A28: Treated and Control universities in Stratum 12

	(1) All		(2) Treated		(3) Controls		(4) Test Difference	
	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	diff	p
Number papers	4467.81	623.91	4560.63	911.64	4375.00	549.78	-185.63	(0.83)
% papers top 10%	13.28	0.56	13.60	0.71	12.95	0.07	-0.65	(0.42)
Sh. Natural sciences - Health	77.52	11.00	69.42	3.22	85.63	9.47	16.21	(0.22)
Sh. Social sciences	5.54	1.80	5.07	2.54	6.01	1.55	0.94	(0.71)
Multidisciplinarity	2.11	0.60	2.35	0.31	1.86	0.87	-0.49	(0.57)
Observations	4		2		2		4	

Table A29: Descriptive statistics on Treated and Control universities in Stratum 12 at time of treatment

Multivariate L1 distance: .996
Univariate imbalance:

	$\mathcal{L}_1$	mean	min	25%	50%	75%	max
Number Papers	.4571	5168.9	1651	4642	4787	7056	-4178
% papers top 10%	.32208	.78291	3.8	1.4	.7	.4	-5.3
Sh. Natural sciences - Health	.2384	1.4007	20.188	10.842	-2.0608	-2.9952	-23.651
Sh. Social Sciences	.34599	-6.8325	.05159	-2.3583	-5.1961	-7.8367	-65.225
Multidisciplinarity	.21308	-.08091	1.0143	.07929	-.2215	-.2093	-.69337

Table A30: Multivariate and univariate imbalance before Coarsened Exact Matching

Multivariate L1 distance: .926
Univariate imbalance:

	$\mathcal{L}_1$	mean	min	25%	50%	75%	max
Number Papers	.13139	1612.9	1138	1547	-68	1650	3210
% papers top 10%	.21891	-.04311	3.8	0	-.2	.2	-3.1
Sh. Natural sciences - Health	.20586	-1.5659	20.188	2.3225	-4.3651	-3.5266	-21.163
Sh. Social Sciences	.26604	-3.4115	-.5413	-1.3628	-3.8352	-5.1743	-10.313
Multidisciplinarity	.2207	.14821	.95113	.20264	.07776	-.01885	-.56023

Table A31: Multivariate and univariate imbalance after Coarsened Exact Matching

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Private
Treated × Before	3.149	0.085	2.575	2.358	4.060
	(13.406)	(2.554)	(90.653)	(63.523)	(9.910)
Observations	192	192	192	192	192
Adjusted R^2	.97	.94	.98	.97	.97

Table A32: Placebo tests: Regression results of excellence treatment on previous policy period.

*Notes: This table reports the estimated coefficients of the interaction between being selected into the excellence program and the pre-treatment period of Equation 3. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. We limit ourselves to two observation points, in 2009 and 2012 to assess pre-treatment trends, but several tests were conducted over different prior periods. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Private
Treated × Before	0.890	-2.083	59.189	32.863	1.713
	(26.451)	(4.473)	(175.639)	(125.324)	(18.486)
Observations	158	158	158	158	158
Adjusted R^2	.97	.94	.98	.96	.97

Table A33: Placebo tests: Regression results of IdEx treatment on previous policy period.

*Notes: This table reports the estimated coefficients of the interaction between being selected into the excellence program and the pre-treatment period of Equation 3. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. We limit ourselves to two observation points, in 2009 and 2012 to assess pre-treatment trends, but several tests were conducted over different prior periods. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

	(1)	(2)	(3)	(4)	(5)
	Top 10%	Top 1%	Papers	International	Private
Treated × Before	12.095	3.539	-125.075	-58.484	6.807
	(18.414)	(3.860)	(102.919)	(68.396)	(11.738)
Observations	52	52	52	52	52
Adjusted R^2	.98	.94	.98	.96	.98

Table A34: Placebo tests: Regression results of Zukunftskonzept treatment on previous policy period.

*Notes: This table reports the estimated coefficients of the interaction between being selected into the excellence program and the pre-treatment period of Equation 3. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. We limit ourselves to two observation points, in 2009 and 2012 to assess pre-treatment trends, but several tests were conducted over different prior periods. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

Impact by Country

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Private
Treated × Post	16.703	4.743	173.304	148.516	18.265
	(29.369)	(4.244)	(208.078)	(165.115)	(14.914)
Observations	646	646	727	727	727
Adjusted R^2	.97	.96	.98	.98	.97

Table A35: Regression results of IdEx treatment.

*Notes: This table reports the estimated coefficients of the interaction between being selected into the excellence program and the post treatment period of Equation 1. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Our specification retains the idea of a delay in the appearance of effects so that years 2012-2014 are not considered. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Industry
Euros-Treatment_it	4.580*	0.886**	27.847*	24.070**	2.752**
	(2.497)	(0.397)	(14.244)	(11.898)	(1.061)
Observations	646	646	727	727	727
Adjusted R^2	.97	.96	.98	.98	.97

Table A36: Regression results of IdEx treatment, expressed in Million euros.

*Notes: This table reports the estimated coefficients of the annual spendings in excellence funding expressed in Million euros a expressed in Equation 2. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Our specification retains the idea of a delay in the appearance of effects so that years 2012-2014 are not considered. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

	(1)	(2)	(3)	(4)	(5)
	Top 10%	Top 1%	Papers	International	Private
Treated × Post	29.447	4.593	283.793**	217.655***	30.295***
	(23.885)	(4.180)	(107.975)	(75.133)	(9.110)
Observations	208	208	234	234	234
Adjusted R^2	.97	.96	.98	.98	.97

Table A37: Regression results of Zukunftskonzept treatment.

*Notes: This table reports the estimated coefficients of the interaction between being selected into the excellence program and the post treatment period of Equation 1. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Our specification retains the idea of a delay in the appearance of effects so that years 2012-2014 are not considered. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Industry
Euros-Treatment_it	2.695	0.363	23.994***	17.874***	2.250***
	(1.761)	(0.282)	(7.198)	(4.975)	(0.556)
Observations	208	208	234	234	234
Adjusted R^2	.97	.96	.98	.98	.97

Table A38: Regression results of Zukunftskonzept treatment, expressed in Million euros.

*Notes: This table reports the estimated coefficients of the annual spendings in excellence funding expressed in Million euros a expressed in Equation 2. In columns (1) and (2) the dependent variables are the number of top 10% and the number of top 1% most cited papers (in their field). In column (3), the dependent variable is the number of published articles. In column (4), the dependent variable is the number of those papers that are internationally co-authored whereas in column (5) it is the number of those that are co-authored with a company. Each observation corresponds to a university×year. In all regressions, observations are weighted thanks to the first stage Coarsen Exact Matching so that selection effects are removed. All regressions include year, university, and country-year fixed effects and control for human resources spendings (excluding excellence funding) and regional level covariates. Our specification retains the idea of a delay in the appearance of effects so that years 2012-2014 are not considered. Standard errors are clustered at the university level. Significance levels are given by: * p<0.1, ** p<0.05, *** p<0.01.*

Excluding UK universities

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Industry
Treated × Post	28.104	2.763	337.638*	242.558*	19.658
	(23.141)	(3.701)	(171.156)	(124.421)	(14.308)
Observations	588	588	662	662	662
Adjusted R^2	.96	.94	.97	.97	.95

Table A39: Regression results of excellence treatment (excluding UK universities)

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Industry
Treated × Pre-period	4.332	2.931	55.185	86.347	-3.512
	(20.445)	(3.581)	(115.735)	(81.058)	(9.031)
Observations	150	150	150	150	150
Adjusted R^2	.96	.93	.97	.95	.96

Table A40: Placebo tests: Regression results of excellence treatment on previous policy period (excluding UK universities)

	(1) Top 10%	(2) Top 1%	(3) Papers	(4) International	(5) Industry
Euros-Treatment	3.990**	0.529*	30.980***	23.409***	2.354**
	(1.722)	(0.305)	(10.224)	(7.715)	(0.921)
Observations	588	588	662	662	662
Adjusted R^2	.97	.95	.98	.97	.95

Table A41: Regression results of excellence treatment, expressed in Million euros (excluding UK universities)