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Higher education policy: Why hope for quality when rewarding quantity?

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ABSTRACT

This paper analyses the impact of the Excellence Initiative (EI) in Germany, a policy intervention aimed to promote and select outstanding active research universities by competitively allocating additional public funds. Academic debate on efficiency and effectiveness of higher education policy does not addresses issues such as treatment and selection effects, suffers from generalizable measurement problems, and does not take a comparative approach. Our objective is to fill this gap by adopting Italy as a control country. In doing so, this paper examines (1) whether this policy approach is suitable to stimulate the system and the awarded institutions, (2) how the performance impact can be measured and (3) whether the results are driven by country specific effects or are generalizable. To this end, we applied a triple difference-in-differences analysis (DDD) on a dataset of 72 German and 51 Italian state universities during the first round of the EI, from 2004 to 2013. We found that the EI has had a positive effect on research quantity, but a reverse effect on research quality.

1. Introduction

In 1975, Steven Kerr published his famous article 'On the folly of rewarding A while hoping for B'. In 1995, the article was reprinted in the Academy of Management Executive,[1] as 'an academic classic'. As well as presenting several examples of the dysfunctional effects of reward systems, he paid particular attention to these systems in politics and universities. Kerr (1975) placed his original article in the context of the emerging principal-agent literature, suggesting a paradigm shift in economics and management research at the time. He placed doubt not only on the imperfection of the contracts, but on the fact that it is in the nature of "monkeys, rats, or human beings" to seek information concerning what activities are rewarded, "and then to do (or at least pretend to do) those things, often to the virtual exclusion of activities not rewarded" (Kerr, 1995, p. 7). In this article, we borrow his title and concerns about reward systems and apply it to the higher education sector. In particular, we analyse whether public policy approaches in the higher education sector lead to the intended results of the reward system.

In a rational choice context, Italy and Germany are both characterized by a public university system with the public or taxpayer as the principal, and policy makers as agents (Braun and Guston, 2003) that delegate goals to university managers (Rutherford and Meier, 2015). However, compared to the classic employer-employee relationships discussed in the principal-agent literature, the relationship that is present in higher education is further complicated by the advantages of information asymmetry that university presidents have over part-time governing boards and state policymakers (Rutherford and Meier, 2015). In Germany and Italy, university presidents report to the board as political principals representing taxpayers as their most valuable stakeholders.

Public policy in general, and higher education policies in particular, can be divided into three categories. First, there is performance-based funding where public finance is allocated according to defined performance criteria, mostly research activities. The second category is the sprinkler approach that allocates public resources according to size. The third category encompasses policy initiatives to subsidize disadvantaged universities. All of the categories are primarily based on performance rankings, size or even locational (dis-) advantages. The first approach differs from the other two in that competition for funds is explicitly desired, while egalitarianism in the higher education sector favours moral hazard and adverse selection effects at the costs of taxpayers, as well as the outperforming universities.

Neoliberal perspectives throughout the 80s, which were supported by scientists like Milton Friedman (e.g. 2017), sought to make those that benefit from an investment in human capital pay (in this case, the students). As a result, competition for research funding – in other words, "picking the winners" – was evaluated almost entirely on the

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[1] In 2006 the journal title was changed to "Academy of Management Perspectives".

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number of articles published in outstanding scientific journals, as determined by journal rankings (Vogel et al., 2017; Saisana et al., 2011). European universities have become stuck in the middle in regards to research activities, and a paradigm change is needed (Audretsch et al., 2015). As a response, systems that were traditionally competition-oriented, like the Anglo-Saxon countries (Dill and Soo, 2005), as well as continental European countries, like Germany (Auranen and Nieminen, 2010; Menter et al., 2018), Italy (Rebora and Turri, 2013) and Spain (De Filippo et al., 2016), introduced competitive funding mechanisms. As the strongest market economy in the EU, Germany launched the Excellence Initiative (EI) in 2006. This policy intervention aimed to increase the international visibility of German universities and spur high-class research by introducing a competitive environment for additional public funds (Menter et al., 2018). At the time, this was met with scepticism (Kehm, 2013; Morgan, 2016), particularly because it was unclear whether such a policy intervention could lead to adverse effects, whereby costs outweigh benefits (Geuna and Martin, 2003; Teichler, 2008), or increase and perpetuate existing inequality among universities and regions (Cremonini et al., 2014). Jan-Hendrik Olbertz, the former non-affiliated education minister in Saxony-Anhalt, stated: "[…] I'm not sure [if] we are a role model in quality. The answer lies in finding a balance between the aim of quality and the aim of social justice and democratic access to the university" (Morgan, 2016).

The hope of politicians might have been to enlarge the locational advantage of their country through the international reputation that comes from having high quality universities. In response, universities put their effort into improving their rankings, as this is recognized as the primary way to increase a university's international reputation. However, rising in the ranks is not necessarily connected to research quality, and may, instead, point to research quantity (Auranen and Nieminen, 2010; Hicks, 2012). As is known from the principal-agent theory, when the principal (i.e. government) is hoping for 'A' (i.e. increased quality) s/he should not reward the agent (i.e. university) for 'B' (i.e. increased quantity).

As such, the aim of this study is to analyse whether the provision of additional public funds by competitive performance measures leads to the desired increase in research quality. Specifically, we look at this matter by shedding light on the quantitative effects of the EI's intervention on university performance. Our paper is based on existing studies concerning the EI and performance triggers in the higher education system (Bruckmeier et al., 2017; Gawellek and Sunder, 2016; Menter et al., 2018). These studies place their focus exclusively on the German context and compare Excellence with non-Excellence Universities in several dimensions, such as efficiency scores (Gawellek and Sunder, 2016), ranking positions (Menter et al., 2018) or the adverse effects when the label of Excellence is withdrawn (Bruckmeier et al., 2017). The results of these studies are not as clear as expected.

While the comparison within a country might be intuitive, the comparison between countries assumes that Excellence Universities were not picked arbitrarily, and a comparison of Excellence and non-Excellence Universities may be biased based on the existing differences in institutional characteristics that lead to the respective status ascription. In order to isolate the pure policy intervention and connected locational advantage effect, we make use of a control group of comparable Excellence and non-Excellence Universities from Italy. In Italy, the Valutazione Quadriennale della Ricerca (Research Quality Assessment) (VQR) exercises provide an up-to-date assessment of the state of research in various scientific fields for the purpose of promoting research quality improvements in the assessed institutions, and to allocate the performance-based share of the block grant assigned to Italian universities by the national government.

To understand the mode of action of the employed policies, we rely on three levels of analysis: efficiency of a university, research quantity and research quality (Auranen and Nieminen, 2010; Hicks, 2012; Moed, 2008). By comparing 72 German and 51 Italian state universities, we found a positive effect on research quantity in German Excellence Universities, and the entire German system, whereas we found a negative effect for German Excellence Universities both within the country and in the comparison between countries.

Our results are of interest to politicians in the higher education context, university managers and other university stakeholders. The rest of the paper is organized as follows; the second section presents a review of higher education policies in Germany, the third section poses the exploratory framework for the strategy of 'picking the winner' in the university context, the fourth section outlines our research design, the fifth section reports the results of the empirical analysis and the sixth section concludes the paper.

2. The excellence initiative and what we know so far

In the German system, the EI was introduced to encourage institutions to become world-class (Cremonini et al., 2014; Menter et al., 2018). The aim of the EI is to enhance the attractiveness, as well as the international competitiveness of Germany by promoting high-class research and overall quality in German universities (Deutsche Forschungsgemeinschaft (DFG), 2013). To achieve such objectives, the Federal and State Governments provided a total of €1.9 billion to fund the chosen universities until the end of 2012. The initiative, organized by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) and the German Council of Science and Humanities (Wissenschaftsrat), called for three lines of funding: Graduate Schools to promote young scientists and researchers, Clusters of Excellence to promote top-level research and Institutional Strategies to develop project-based, top-level university research. Universities have to be distinguished in all three funding lines to be classified as an 'Excellence university'. The assessment mainly aimed to evaluate performances ex-ante by submitting future strategies. Initially designed as a unique and one-time initiative, the federal and state governments decided to extend it in 2009 for an additional 5-year period (2012-2017), with an added investment of €2.7 billion. On the basis of the administrative agreement reached by the federal and state governments on the 16th of June 2016, the DFG and the German Council of Science and Humanities implemented the 'Excellence Strategy', combining the 'EI' (2005/6-2017) with 'Clusters of Excellence' for project-based funding in internationally competitive fields of research at universities or university consortia.[2]

Existing literature for the EI identified the announcement effect and found that Excellence Universities developed less compared to universities that were not selected after the decision (Menter et al., 2018). A Matthew effect was detected in terms of industrial collaboration and industry funding for Excellence Universities (Lehmann and Stockinger, 2019). Additionally, applying universities lost efficiency compared to non-applying institutions. Unsuccessful applications led to a recuperation, whereas successful ones experienced no positive effect when additional funding was excluded (Gawellek and Sunder, 2016). In the case of Karlsruhe, a university that recently lost its Excellence status, Bruckmeier et al. (2017) provided evidence to the striking citation of Laband (1907) that "[…] the award of a title does not nearly elevate the awardee to the extent that the loss of the title debases him". They showed that the worsening performance was not due to an actual decline in university quality, but to the loss of the Excellence status. Using a bibliometric analysis, Möller et al. (2016) showed that clusters of excellence (another stream of the EI) exclusively supported the "winners" of the competition, while the overall German research system did not experience benefits.

[2] See https://www.dfg.de/en/research_funding/programmes/excellence_strategy/index.html, accessed 12.11.2019.

3. Effects of the 'Picking the winner' approach

Based on the principal agent theory, politicians can be seen as principals that want to achieve the aim of creating and improving locational advantages, but experience information asymmetry. Agents – in this context, universities – tend to follow their aims to increase input (i.e. resources) and improve their reputation. The desired outcome of the EI "international visibility" cannot be perfectly measurable (Cremonini et al., 2014; Hicks, 2012). This study evaluates the positive effects and/or adverse effects of the initiative, particularly those that are ex-ante adverse selections or ex-post moral hazard behaviour. On the one hand, ex-ante refers to the fact that only universities that are big enough and have the resources to prepare three high quality applications (one for each funding stream) can apply for excellence status. On the other hand, ex-post refers to universities shifting their efforts after being designated Excellence Universities, which is a moral hazard as the outcomes are not perfectly measurable by the principal. In this context, incentives have to be chosen carefully to avoid hoping for 'A' when rewarding 'B' (Kerr, 1975).

Our objective implies an evidence-producing, rather than a hypothesis-testing, design. We want to verify whether the desired effect of policy makers, to increase the quality of the entire higher education system, is realized through the EI. Possible outcomes include affecting the winning universities and the system in general. They might be described as "Role Model", "Losing Winners", "Winners Track" and "Dysfunction".

3.1. Role model

Evidence that points to scientific productivity increasing following the introduction of competing funding schemes is widely documented (Auranen and Nieminen, 2010; Moed, 2008; Geuna and Piolatto, 2016). Based on scientists' perception of what generates reputation and is valued as "good work", they shifted their focus from resources and efforts to the things that are valued as being important (Haeussler and Colyvas, 2011), like gaining international visibility. Consequently, both Excellence and non-Excellence Universities will invest in international visibility resulting in a higher education policy role model. The entire system could benefit from focusing on the winners, and thus generate a bandwagon effect (Agrawal et al., 2017; Aksnes and Rip, 2009; Debackere and Rappa, 1994).

3.2. Losing winners

Winning universities get the Excellence University reward and, after the "Probation Period", efforts are reduced due to exhaustion and a feeling of security, as well as the lack of incentives for continuing efforts (Gawellek and Sunder, 2016; Bruckmeier et al., 2017). In contrast to the losing winners, we would expect an "Academic Ratchet" effect in the entire university system (Massy and Zemsky, 1994) as the focus on "good behaviour" is clearly set in the EI to improve research outcomes and international visibility.

3.3. Winners track

The winners in the competition might benefit from their improved reputation and be incentivized to further increase performance and productivity (Autio and Rannikko, 2016; Bolli and Somogyi, 2011). The increased notoriety of scholars from those universities can lead to an increase in publication and citations, generating a so-called 'halo effect' (Amara et al., 2015). There could also be adverse effects on the system, as the differences induced may reduce the losers' drive to compete with superstars (Agrawal et al., 2017; Brown, 2011). Given this context, many critics feared that the few strong universities would break away from the other mediocre ones in the rest of the country (Vogel et al., 2017).

3.4. Dysfunction

While the winners might face the probation period effect (Riphahn and Thalmaie, 2001), 'losers' might be decoupled in terms of their attractiveness, funding and motivation (Brown, 2011; Geuna, 2001). Additionally, sabotage-effects and game strategies, like publication inflation (Geuna and Martin, 2003), may occur; as Jauernig et al. (2016) stated, "Apparently it is naive to assume that the mode of competitiveness and the wish to outperform others is switched off after the blow of the referee's whistle at the end of the game […]." The EI might introduce new barriers by encouraging competition rather than co-operation (Cremonini et al., 2014; Kehm, 2013).

4. Methodology

4.1. Sample and data source

Our sample consisted of 123 state universities, 72 from Germany and 51 from Italy, that were observed in the period between 2004 and 2013. Throughout this period, we were able to study the first two rounds of the EI, which were officially launched in 2005 and 2006 and resulted in 9 universities being classified as 'Excellence Universities'.[3] At the time of writing, a third phase was ongoing (from 2012 to 2017), which allocated another €2.7 billion and led to two universities losing their Excellence status (the University of Goettingen and the Karlsruhe Institute of Technology). Full data on the third round is not yet available.

The EI in Germany was exclusively designed for public universities. This led to the exclusion of private universities, universities of applied sciences or specialized universities. In the case of Italy, we excluded traditional private institutions, distance-learning institutions, public doctoral universities and universities for foreigners, so that institutions would be comparable across both countries (Agasisti and Pohl, 2012). The dataset was based on institutional data, the sources and explanations of which can be found in Table 1.

The comparison between Germany and Italy is not new in higher education literature (see for example Agasisti and Pérez-Esparrells, 2009; Agasisti and Pohl, 2012; Geuna and Nesta, 2006). On the systemic side, both countries have significant similarities: (i) they are supporters of the Bologna reform (starting in 1999, Sursock, 2015); (ii) they have historical roots in academic and cultural exchanges (Harrison and Leitch, 2010); (iii) they changed from a one-cycle to a two-cycle education system, which affected how attractive academia was for young researchers (Froehlich, 2016); (iv) they share the perception that universities combine teaching and research, as well as subject-specific differences (e.g. in Technical Universities) ("*Technische Universität*" and *"Politecnico")*; (v) graduation rates and public expenditure per GDP are consistently below the OECD and EU average (Eurostat, 2012; OECD, 2013a, b); (vi) there are regional gaps (South-North for Italy and East-West for Germany) and they share historical parallels as both countries were late democracies. However, the main difference is that education in Germany is a decentralized organisation (i.e. it is managed by the states), whereas in Italy it is organized centrally by the Italian Ministry for University and Research.

Through the EI, Germany adopted a "picking the winners" approach. The extra funding is concentrated in the hands of a few universities. In contrast, the VQR[4] exercise in Italy allows for the

[3] Namely KIT (Karlsruhe Institute of Technology), LMU (Ludwig-Maximilians-University, Munich) and TUM (Technical University Munich) in 2006, followed by RWTH Aachen (Rhine-Westphalia Technical University Aachen), FU Berlin (Free University, Berlin), Albert-Ludwigs-University (Freiburg), University of Göttingen, University of Constance and the Ruprecht-Karls-University, Heidelberg).

[4] Implemented by the Italian National Agency for the Evaluation of

Table 1
Variables. Every variable is measured by university per year. DEA VRS bootstrapping has been calculated using state funding as input, and graduates, citations and patents as output.

Variables	Description	Sources
Panel A: dependent variables		
DEA VRS bootstrapping	Efficiency bias-corrected score retrieved by Data Envelopment Analysis (DEA)	Own calculation (MaxDEA)
Citations/publication	Citations-recorded by publications listed in Scopus per university per year	SCOPUS
Publications/professor	Number of publications listed in Scopus per professor per university per year	SCOPUS; Destatis; MIUR
High-cited publications (%)	Number of high-cited papers divided by the total number of papers published per university per year. High cited means that they received enough citations to place it in the top 1% of the academic field of Social Sciences between July and August 2019 (this is generally the highly cited threshold for the field and publication year). They were then divided by the total number of papers published per university per year.	Web of Science
X	Latent research quality variable estimated through the Structural Equation Model, by combining the following performance measures: percentage of high cited articles; average citations per year received by each paper published in the given year; Citations per publication ratio; Publications per professor ratio; DEA scores. The normalized values were used in the regression.	SCOPUS Web of Science
Panel B: triple DID variables		
Excellence university	Dummy variable equal to 1 if a university is considered an Excellence university, 0 otherwise.	DFG
Excellence Initiative	Dummy variable, equal to 1 after 2006, 0 otherwise.	DFG
Country	Dummy variable equal to 1 for Germany, 0 for Italy.	
Panel C: control variables at institutional level		
Fees per students (000€)	Fees payed by students for their studies	Destatis; MIUR
Hospital (%)	Dummy variable equal to 1 if a university has an affiliated hospital, 0 otherwise	Destatis; MIUR
Graduates in Human Sciences (%)	Share of graduates in Human Sciences, including Language and Cultural studies, Arts Sciences per university per year.	Destatis; MIUR
Graduates in Sports (%)	Share of graduates in Sports per university per year.	Destatis; MIUR
Graduates in Business and Social Sciences (%)	Share of graduates in business and social sciences, including law and psychology, per university per year.	Destatis; MIUR
Graduates in Medicine (%)	Share of graduates in Human Medicine and Health Sciences, including Veterinary and Pharmacy, per university per year.	Destatis; MIUR
Graduates in agricultural (%)	Share of graduates in Agricultural Studies, including Forrest and Nutrition Sciences, per university per year.	Destatis; MIUR
Graduates in Engineering (%)	Share of graduates in Engineering, including Architecture, per university per year.	Destatis; MIUR
Graduates in Natural Sciences (%)	Share of graduates in Natural Sciences, including Mathematics, Physics, Chemistry and Biology, per university per year.	Destatis; MIUR
Graduates in Other Studies (%)	Share of graduates in other fields of studies per university per year.	Destatis; MIUR
Panel D: control variables at the regional level		
Unemployment rate (%)	Number of unemployed people as a percentage of the labour force per year by NUTS 2 level.	Eurostat
Population density	Absolute number of inhabitants per square meter per year by NUTS 2 level.	Eurostat
Public expenditure on higher education	Public expenditure on higher education as a percentage of total public expenditure per year	Eurostat

The German Excellence Universities were selected through detailed proposals submitted to the DFG, and Italian Excellence Universities were selected though a statistical matching approach. In our analysis, 2006 is considered the year when the Excellence Initiative officially started. Deutsche Forschungsgemeinschaft (DFG) is the German Research Foundation that organized the Excellence Initiative in collaboration with the German Council of Science and Humanities (Wissenschaftsrat, WR). SCOPUS is a database by Elsevier. Destatis is the Federal Statistic Office for Germany, while MIUR is the Italian Ministry for University and Research. Eurostat is the EU statistical office.

identification of universities that are either over-performing or under-performing in terms of research. Accordingly, a greater or lesser amount of the annual basic operational grant for Italian universities is allocated. In fact, in the Italian case, there is no extra funding allocation, but a redistribution of their basic operational grants on a competitive basis according to research output.

Despite these differences, their similar evolution is attested by our data. In fact, the growth in publications per professor, and in citations per publication, do not differ statistically.

4.2. Methodology and main variables

We applied the Coarsened Exact Matching (CEM) method to estimate the causal effects of institutional peculiarities on the probability of being evaluated as an Excellence university. The CEM algorithm consisted of three steps: (1) desired variables of all universities are coarsened temporarily; (2) all universities in the initial cohort are sorted into strata on the basis of their coarsened variables; and (3) only universities with strata containing at least one Italian university and one German Excellence university are kept, while the others are discarded (Iacus et al., 2011, 2012). Universities are matched based on pre-treatment variables (values in 2004 and 2005) to avoid announcement or direct effect biases by the introduced Initiative (Menter et al., 2018). The selected variables for matching are the efficiency scores, the number of publications and the citations-to-publications ratio.

The initial population of universities consisted of 73 German and 60 Italian universities, which was reduced to 72 and 51 after the matching procedure.[5] 6 statistical Italian equivalents were retrieved for the 9 German Excellence universities. The matching covariates of a T test

(*footnote continued*)
Universities and Research Institutes (ANVUR); the first round was in 2004-2010, ex-post rewarding was in 2013 and the redistribution totalled €142 million (Rebora and Turri, 2013).

[5] The universities excluded from the analysis were the Johannes Gutenberg University Mainz in Germany and the University of Bologna, the University of Molise, the University “Magna Grecia” (Catanzaro), the University of Foggia, the University for Foreigners (Perugia), the University "La Sapienza" (Rome), the University of Sassari, the University of Varese and the University of Piemonte Orientale (Vercelli) in Italy.

Table 2
Matching covariates for the sample of 9 German Excellence Universities, and the 6 Italian equivalents for the German Excellence Universities resulting from the matching.

	DE	IT	Difference	P-value
DEA VRS bootstrapping	0.78	0.90	-0.12	0.21
Average publications per year	1961.11	1304.67	656.44	0.65
Citations/publications	22.45	24.47	-2.02	0.24
Observations per year	9	6		

This table reports the descriptive statistics for the matched sample of German Excellence Universities and their Italian equivalents. P values refer to T tests on the equality of the mean, assuming equal variance between the two groups.

(Table 2) show the appropriateness of our matching procedure.

To identify the effect of the initiative, we conducted a triple DDD. This quasi-experimental technique is useful in terms of eliminating selection biases. According to Hillman et al. (2014), the introduction of performance funding can simulate a natural experiment, where the new policy is a plausible source of exogenous variation. We assumed that German Excellence Universities and German non-Excellence Universities performed differently following the implementation of the policy. At the same time, we assumed that the Italian equivalents for German Excellence Universities and German non-Excellence Universities performed differently after the implementation of the policy. Nevertheless, German Excellence Universities could have had a different trend than the Italian equivalents, and the same is true for the German non-Excellence Universities and their respective Italian equivalents. Empirically, this is due to the specification of the model, whereas in real terms this is due to differences in the two systems. We tested for the equivalent trend assumption according to Autor (2003). Fig. 1 represents the trend in citations per publication of the German Excellence Universities and German non-Excellence Universities, as well as the Italian equivalents for both.[6]

Eq. (1) represents the triple DDD.

$$\begin{aligned} Y_{it} = {} & \alpha_1 \text{Excellence Universities}_i + \alpha_2 \text{Excellence Initiative}_t + \alpha_3 \text{Country}_j \\ & + \beta_1 \text{Excellence Universities}_i \times \\ & \text{Excellence Initiative}_t + \beta_2 \text{Excellence Initiative}_t \times \text{Country}_j \\ & + \beta_3^{DDD} \text{Excellence Universities}_i \times \\ & \text{Excellence Intitiative}_t \times \text{Country}_j + \gamma X_{it} + \tau_t + \mu_i + \varepsilon_{it} \end{aligned} \quad (1)$$

Y_{it} represents the dependent variable, which can be described as the efficiency score, the research quantity and the research quality, respectively. Excellence Universities$_i$ × Excellence Intitiative$_t$ × Country$_j$ is the triple interaction term. It compares the effect of the EI on German Excellence Universities and the trend of their Italian equivalents throughout the same period. By implementing a fixed effects model, we captured the net effect of unobserved factors that were relatively stable over time, but might have made our estimates biased if ignored (Hillman et al., 2014)[7].

We based our analysis on three dependent variables: (1) the efficiency score retrieved by the Data Envelopment Analysis (DEA), (2) the publications to professor ratio and (3) the citations to publications ratio.

(1) To define the efficiency of universities we used the nonparametric DEA method (Charnes et al. 1979) in accordance with Banker et al. (1984). We were interested in the effect of policies on the efficient translation of financial measures provided by the state to universities' missions. We calculated output-oriented variable returns to scales as in Banker et al. (1984). Zero values were handled according to Sueyoshi and Goto (2013), and scores were calculated per year and country. By using the bootstrapping approach from (Simar and Wilson, 1998, 2000), we prepared nonparametric scores for a parametrical analysis. As input, we used financial measures provided by the government, which are the main source of income for public universities in both countries (Agasisti and Pohl, 2012; Athanassopoulos and Shale, 1997). As output, we used graduates, citations and patents according to the three missions of a university: teaching, research and contribution to society through innovation (Acs et al., 2002; Agasisti et al., 2012; Etzkowitz and Leydesdorff, 2000).
(2) The quantity of academic research is measured by the publications-to-professor ratio, a number that is directly affected by individual researchers (Menter et al., 2018).
(3) The quality of academic research is proxied by the citations-to-publications ratio, which is mostly unaffected by individual researchers and expresses originality in general, thus reflecting the quality of a single publication. This measure is assumed to be independent from the effects of size (Katerattanakul et al., 2003; Katz, 2000). As for robustness, we measured the quality of research in two different ways: the percentage of high-cited papers and the latent quality. The highly cited papers are those provided by the Web of Science, which received enough citations between July and August 2019 to place them in the top 1%, based on the highly cited threshold for the field and publication year. We employed a structural equation model (SEM) to estimate a latent variable (X) in order to measure research quality (He et al., 2009; Liping et al., 2009). In our case, the latent variable was research quality (X). The measurement model includes the relationship between latent variable X and the observed variables: Highly cited articles; average citations per year; citations per publication; publications per professor; and VRS bootstrapping. The normalized values were used in the regression.

Control variables were in line with previous studies on the performances of higher education systems from a comparative perspective (Agasisti et al., 2012; Agasisti and Pérez-Esparrells, 2009; Agasisti and Pohl, 2012). Controls include institutional (*fees per student, shares of university graduates, hospital dummy*) and environmental variables (*unemployment rate, population density*). Further details are shown in Table 1.

5. Results and robustness check

5.1. Descriptive statistics

Table 3 reports descriptive statistics for the entire sample (i.e. for both Excellence and non-Excellence Universities), as well as for the pre- and post-treatment period. Unsurprisingly, the statistics differed across Italy and Germany. Universities in Germany were less efficient than Italian universities (in line with Lehmann et al., 2018), even though the former improved after the EI and seemed to produce more high quality work. While the growth rate of the citations per publication was higher in Italy (26.8%) than in Germany (19.85%) after the treatment period, the growth rate of publications per professor was the same (29.5%). Comparing Excellence and non-Excellence Universities, the former performed better according to efficiency, quantity and quality in Italy; yet, interestingly, the same was not true for Germany when we considered the number of citations per publication. Indeed, while the treated units (i.e. Excellence Universities) increased their research quality by 6.2%, the non-treated counterpart improved by 22.4% (in line with Stockinger, 2020).

[6] The graphs are qualitative, and measure efficiency scores and publications per professor.
[7] The results from the Hausman test support the fixed-effect model approach. Furthermore, the results from the Breusch-Pagan Lagrange multiplier test support our choice, instead of an OLS model approach.

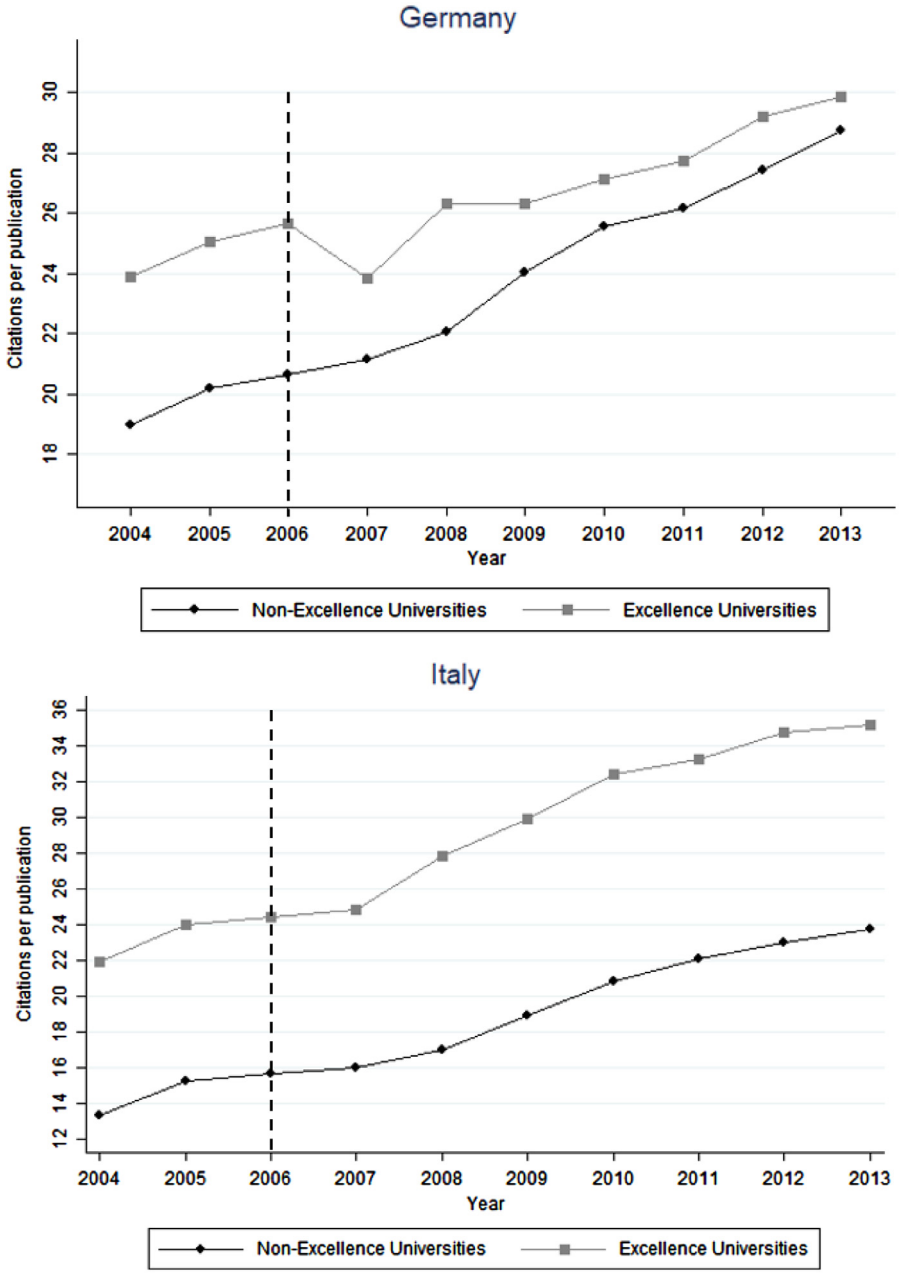

Fig. 1. Graphical representation of the difference-in-differences approach. The figure represents the trend in citations per publication of the German Excellence Universities and German non-Excellence Universities, as well as the Italian equivalents for both the German Excellence and non-Excellence Universities. For citations per publication, we plotted margins resulting from the regression on the interaction between three variables: Country, Excellence Universities and Year.

Moreover, as shown in Table 4, both citations and publications grew, although at a different pace. Specifically, German Excellence Universities grew by 5.7% in terms of publications per professors and 9.6% in terms of citations per publications. German non-Excellence Universities grew by 9.6% in terms of publications per professor and 7.5% in terms of citations per publication. By focusing on Italy, the statistical equivalents of German Excellence Universities grew by 8.1% in terms of publications per professor and 6.1% in terms of citations per publication, whereas the statistical equivalents of German non-Excellence Universities grew by 10.2% in terms of publications per professor and 11.2% in terms of citations per publication. Table 5 depicts the correlation matrix.

5.2. Empirical results and discussion

The findings of the fixed-effects model are presented in Table 6.[8] The reference case according to which all results were interpreted is the average efficiency, the average publications per professor and the average citations per publication of both German and Italian universities before the EI. The only effect of the EI on efficiency was the general increase, by 0.036. Average efficiency scores rose by 5.5%, compared to the average efficiency score of 0.66 in both German and Italian universities before the EI.

The EI has augmented the publications per professor by 0.089,

[8] Multicollinearity tests dismissed the potential for problems, since none of the mean variance inflation factors exceeded 3.27, which is below the cut-off of 10.

Table 3
Descriptive statistics.

	Total		Before Excellence Initiative		After Excellence Initiative		Excellence Universities		Non-Excellence Universities		Before Excellence Initiative Excellence Universities		Non-Excellence Universities		After Excellence Initiative Excellence Universities		Non-Excellence Universities	
	DE	IT	DE	IT	DE	IT	DE	IT	DE	IT	DE	IT	DE	IT	DE	IT	DE	IT
DEA VRS bootstrapping	0.54	0.91	0.51	0.87	0.55	0.92	0.83	0.96	0.50	0.91	0.78	0.90	0.48	0.85	0.84	0.98	0.51	0.92
Publications/ professors	3.04	0.71	2.49	0.58	3.22	0.76	5.36	0.90	2.70	0.69	4.36	0.73	2.24	0.58	5.70	0.95	2.87	0.73
Citations/ publications	22.51	19.03	19.59	15.84	23.48	20.09	25.61	27.16	22.07	17.94	24.47	22.45	19.08	14.26	25.99	28.73	23.13	18.94
High-cited papers (%)	0.32	3.14	0.00	2.94	0.40	3.18	0.64	16.98	0.28	1.59	0.00	16.67	0.00	1.40	0.80	17.06	0.35	1.64
Fees per students (000€)	0.35	1.27	0.00	1.13	0.46	1.32	0.47	1.36	0.33	1.26	0.00	1.31	0.00	1.09	0.63	1.38	0.44	1.31
Hospital (%)	45.83	56.86	45.83	56.86	45.83	56.86	88.89	100.00	39.68	51.11	88.89	100.00	40.63	59.26	88.89	100.00	39.68	51.11
Graduates in Human Sciences (%)	28.00	15.15	27.40	14.94	28.20	15.23	20.43	11.85	29.08	15.59	21.16	11.92	29.12	15.64	21.28	11.94	29.19	15.66
Graduates in Sports (%)	1.64	3.30	1.60	3.07	1.65	3.38	1.65	1.92	1.63	3.49	1.69	2.04	1.62	3.52	1.70	2.06	1.64	3.56
Graduates in Business and Social Sciences (%)	25.06	40.27	25.16	41.01	25.02	40.02	22.49	42.02	25.42	40.04	21.99	40.76	25.4	39.89	22.19	40.78	25.43	39.92
Graduates in Medicine (%)	8.82	8.77	10.31	8.98	8.33	8.71	10.46	11.31	8.59	8.44	9.33	11.29	8.09	8.31	9.43	11.39	8.16	8.35
Graduates in Agricultural Studies (%)	1.74	2.11	1.78	2.27	1.73	2.06	3.24	1.69	1.53	2.17	3.09	1.64	1.51	2.07	3.13	1.69	1.53	2.11
Graduates in Engineering (%)	13.50	20.53	14.35	20.58	13.22	20.51	15.90	15.96	13.15	21.14	15.39	16.28	16.28	21.04	15.44	16.31	12.89	21.07
Graduates in Natural Sciences (%)	21.16	9.73	19.41	9.14	21.75	9.92	25.83	15.17	20.50	9.00	26.79	15.72	15.74	9.18	26.83	15.77	21.09	9.21
Graduates in Other Studies (%)	0.08	0.13	0.00	0.01	0.11	0.18	0.00	0.08	0.09	0.14	0.00	0.03	0.02	0.04	0.00	0.06	0.07	0.12
Unemployment rate (%)	9.01	7.91	11.46	8.27	8.19	7.79	8.09	5.86	9.14	8.19	10.08	5.77	11.60	8.63	7.43	5.89	8.30	8.05
Population density	481.24	237.29	481.94	234.03	481.01	238.38	688.16	187.54	452.14	242.82	687.51	183.75	453.04	239.61	688.38	188.80	451.84	243.89
Public expenditure on higher education	2.35	2.04	2.21	1.95	2.39	2.06	2.42	2.00	2.34	2.04	2.27	1.93	2.20	1.96	2.47	2.03	2.38	2.07
Observations per year	72	51	72	51	72	51	9	6	63	45	9	6	63	45	9	6	63	45
Observations	576	408	144	102	438	360	72	48	504	360	72	48	504	360	72	48	504	360

The descriptive statistics are split into several different groups. First, the total sample of 72 German universities and 51 Italian universities; second, the total sample of universities by country in the pre-treatment period (i.e. before the Excellence Initiative in 2006); third, the total sample of universities by country in the post-treatment period (i.e. after the Excellence Initiative in 2006); fourth, the sample of Excellence Universities including 9 German Excellence Universities and their 6 Italian counterparts; fifth, the sample of non-Excellence Universities including all the universities that were different from the second group, both for Italy and Germany; sixth and seventh, all the universities in the pre-treatment period and in post-treatment period.

Table 4
Matching covariates for the sample of 123 universities resulting from the matching.

	Growth publication per professor	Growth citation per publication	Difference in the mean growth	P-values
German Excellence Universities	0.057	0.096	-0.039	0.623
Italian statistical equivalents of German Excellence Universities	0.081	0.061	0.020	0.346
German non-Excellence Universities	0.096	0.075	0.022	0.306
Italian statistical equivalents of German non-Excellence Universities	0.102	0.112	-0.009	0.755

This table reports the descriptive statistics for the matched sample of German and Italian universities. P values refer to T tests on the equality of the mean, assuming equal variance between the two groups. The differences are calculated between the average growth of publications per professor and citations per publication.

Table 5
Correlation matrix. This table reports the correlation coefficients among the dependent and independent variables employed in the regressions. Significant correlations of less than 5% are in bold.

	1	2	3	4	5	6	7	8	9	10
1. VRS bootstrap	1.000									
2. Publications/professors	-0.027	1.000								
3. Citations/publications	0.071	0.535	1.000							
4. Excellence Universities	0.292	0.206	0.232	1.000						
5. Country	-0.537	0.629	0.239	-0.105	1.000					
6. Excellence initiative	0.065	0.126	0.243	0.000	0.000	1.000				
7. Fees per student	0.392	-0.344	-0.029	0.113	-0.605	0.194	1.000			
8. Hospital	0.356	0.285	0.386	0.274	-0.167	0.000	0.061	1.000		
9. Graduates of Human Sciences (%)	-0.042	-0.031	-0.167	-0.139	0.369	0.011	-0.226	-0.203	1.000	
10. Graduates of Sports (%)	0.103	-0.052	-0.102	-0.049	-0.093	0.012	0.096	-0.078	-0.107	1.000
11. Graduates of Business and Social Sciences (%)	0.136	-0.416	-0.186	-0.055	-0.453	-0.025	0.179	0.080	-0.183	-0.118
12. Graduates of Medicine (%)	0.187	0.253	0.332	0.094	-0.066	-0.040	-0.061	0.639	-0.274	-0.042
13. Graduates of Agricultural and Nutrition (%)	0.027	0.005	0.059	-0.011	-0.080	-0.014	-0.053	0.147	-0.114	-0.033
14. Graduates of Engineering (%)	-0.121	-0.045	-0.074	0.084	-0.101	-0.003	0.189	-0.306	-0.445	-0.121
15. Graduates of Other Sciences (%)	-0.003	-0.047	-0.021	-0.024	-0.031	0.074	0.064	-0.073	-0.061	-0.026
16. Unemployment rate (%)	-0.209	-0.208	-0.232	-0.160	-0.062	-0.176	-0.373	-0.001	-0.068	0.035
17. Population density	-0.022	0.104	0.197	0.019	0.199	0.000	-0.137	0.017	0.021	-0.021
18. Public expenditure on higher education	-0.161	0.240	0.108	-0.062	0.324	0.126	-0.256	-0.045	-0.004	-0.072
	11	12	13	14	15	16	17	18		
11. Graduates of Business and Social Sciences (%)	1.000									
12. Graduates of Medicine (%)	-0.070	1.000								
13. Graduates of Agricultural and Nutrition (%)	0.019	0.009	1.000							
14. Graduates of Engineering (%)	-0.430	-0.274	-0.078	1.000						
15. Graduates of Other Sciences (%)	-0.037	-0.058	0.003	0.122	1.000					
16. Unemployment rate (%)	0.054	-0.043	0.120	0.032	-0.042	1.000				
17. Population density	-0.092	-0.094	0.000	0.021	0.169	0.173	1.000			
18. Public expenditure on higher education	-0.101	0.021	-0.010	0.012	0.036	0.102	0.163	1.000		

which represents a 5.2% increase on average. When considering the difference within countries, the effect of the policy intervention grew to 0.408 (i.e. 0.089 + 0.319) in Germany, where both Excellence and non-Excellence Universities increased by nearly 24%. By taking a step forward, the effect of the EI on the German Excellence Universities was 0.955 (the sum of the above-mentioned effects and the coefficient of the triple interaction 0.547). After 2006, German Excellence universities improved their publications per professor by more than 56%. By considering the average value of publications per professor after the EI, the performance of both German Excellence Universities and German non–Excellence Universities got even better. Indeed, after the EI, the former increased the average productivity per professor by 28.6%, and the latter by more than 83%.

Similarly, the EI augmented the citations per publication by 3.322, which represents an 18.4% increase on average (citations per publication for both German and Italian universities were 21.07). By analysing the effect of the EI on German Excellence Universities and their Italian equivalents, the effect of the policy intervention grew to 5.585 (i.e. 3.322 + 2.253). This corresponds to an increase of nearly 31%. Considering the differences within countries, the effect of the policy intervention in Germany was equal to 2.255 (i.e.3.322-1.067), which corresponds to a 12.5% increase in citations per publication. Taking a step forward, the effect of the EI on the German Excellence Universities was -1.007 (calculated as 3.322 + 2.253-1.067-5.515). After 2006, German Excellence Universities received fewer citations per publication, falling by almost 5.6%. When considering the average value of citations per publication after the EI, the performance of both German Excellence Universities and German non–Excellence Universities got even worse. After the EI, the former decreased their citations per publication by 30% (coefficient is 6.582), while the latter decreased by 6%.

The results related to controls are in line with previous literature (Agasisti and Pohl, 2012; Kempkes and Pohl, 2010; Shin, 2010).

Due to the positive impact of the EI on the research quantity of both German Excellence and non-Excellence Universities, the policy intervention may lead to a situation described in the theoretical section as a *Role model*. According to Cremonini et al. (2014), the generated additionality is expected to originate from reputational benefits. The EI was intended to stimulate collaboration and strategic partnerships between universities, research programs and private R&D. Although not the key argument for initiating the program, such developments were also justified in terms of their gains for system efficiency.

When considering the research quality dimension, we observed a reverse situation for both German Excellence and non-Excellence Universities, as described in our *Dysfunctional model*. There are two interpretations of this finding. First, that Excellence Universities exhausted all the resources available in the system, leaving the rest of the system with not enough resources to perform well. Second, our results can be interpreted in light of the bandwagon phenomenon, as both the Excellence and non-Excellence Universities improved their performance

Table 6
The effect of the Excellence Initiative on university performance.

	(1) VRS bootstrapping	(2) Publications/ professors	(3) Citations/ publications
Excellence initiative	0.034***	0.078**	2.926***
	(0.012)	(0.032)	(0.356)
Excellence Universities * Excellence Initiative	0.043	0.078	1.887*
	(0.034)	(0.094)	(1.045)
Country * Excellence initiative	-0.018	0.326***	-1.106**
	(0.016)	(0.045)	(0.498)
Excellence Universities * Excellence Initiative * Country	-0.009	0.546***	-5.323***
	(0.045)	(0.123)	(1.362)
Fees per student	0.020**	0.020	0.413
	(0.010)	(0.026)	(0.292)
Graduates of Human Sciences (%)	0.530***	-0.219	-4.409
	(0.145)	(0.399)	(4.431)
Graduates of Sports (%)	1.171***	-1.161	4.092
	(0.368)	(1.012)	(11.23)
Graduates of Business and Social Sciences (%)	0.446***	-1.172***	-12.92***
	(0.128)	(0.351)	(3.896)
Graduates of Medicine (%)	0.992***	-1.533***	-18.11***
	(0.142)	(0.390)	(4.331)
Graduates of Agricultural Sciences (%)	-0.429	-5.172***	1.240
	(0.395)	(1.086)	(12.05)
Graduates of Engineering (%)	0.158	-0.788	-6.034
	(0.175)	(0.481)	(5.336)
Graduates of Other Sciences (%)	-0.007	-2.150	-24.99
	(0.573)	(1.573)	(17.45)
Unemployment rate	-0.003	-0.029***	-0.038
	(0.002)	(0.007)	(0.073)
Population density	-0.003	-0.004***	-0.005
	(0.004)	(0.001)	(0.012)
Public expenditure on higher education	0.106***	0.596***	9.699***
	(0.035)	(0.097)	(1.071)
Constant	0.061	2.923***	7.366
	(0.197)	(0.540)	(5.995)
Observations	1230	1230	1230
R-squared	0.127	0.554	0.378
Number of universities	123	123	123

This table reports the results of the fixed effects panel model. The sample consists of 72 German universities and 51 Italian universities observed between 2004 and 2013. The dependent variables are the efficiency (non-biased scores retrieved by a DEA analysis); the publications-to-professor ratio; and the citations-to-publication ratio. Natural Sciences is the reference case for the field of study. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at levels less than 1%, 5%, and 10%, respectively.

after 2006, as observed in both the descriptive statistics and the main analysis. In line with Cremonini et al. (2014), performance-based research funding might lead to side effects without necessarily improving the quality, and decreasing returns in the long run (Geuna and Martin, 2003) generating the "salami-slicing" phenomenon (Liefner, 2003). The loss of research quality as a consequence of being considered an Excellence University might be explained by the classical Principal-Agent interaction: politicians want to increase international visibility and – based on information asymmetry – believe this is primarily achieved by an increase in research quality. In fact, as they cannot measure research quality directly, they hope for locational advantages through new research innovations and a connected international reputation. To signal their effort, universities increase research productivity and potentially encourage the salami-slicing strategy (or something similar) (Liefner, 2003) through which at least some results get published earlier and can be counted as achievements of the program. Nonetheless, despite politicians increasing international visibility using research quality, the international visibility arose from agents' efforts toward research quantity, through which they "got a bang for their buck" (Morgan, 2016).

Table 7
Structural equation modelling results.

Path	Coef.	Std. Err	Chi2	P value
High cited articles (%) → X	4.50	0.96	4.64	***
Average citations per year → X	4.41	10.94	50.06	***
Citations per publication → X	57.45	142.28	56.15	***
Publications per professor → X	6.39	15.86	25.92	***
VRS bootstrapping → X	0.34	0.85	42.03	***

This table reports the significance of the t-test results in each path, with parameters in the SEM process. Paths represent the relation between observable measures of performance, namely percentage of high-cited articles; average citations per year received by each paper published in the given year; Citations per publication ratio; Publications per professor ratio; DEA scores. ***, **, and * indicate significance at levels the less than 1%, 5%, and 10%, respectively.

5.3. Robustness checks

Table 7 shows details of the structural equation model (i.e. the paths), the coefficients, the standard errors, the chi squared and the p values of the measurement model. The relationships are positive and statistically significant. They are tested according to the significance of the t-test result in each path, with parameter estimates ($p < 1.0$) being made in the SEM process (see for example Li et al., 2013).

Table 8 shows the results of the reliability analysis that was conducted to evaluate the stability and consistency of the measured items in the latent construct, *research quality*. The criteria used to include an item is a corrected item-to-total correlation above 0.30 (Nunnally and Bernstein, 1978). Cronbach Alpha coefficients exhibit values greater than 0.60, attesting to the satisfactory reliability of the test.

Table 9 reports further checks on the fit of the model with commonly accepted measures (Kenny, 2015). All tests supported our choice of model.[9]

Simultaneously, X was used as a dependent variable in the regression analysis and the independent and control variables were used for the main analysis. In Table 10, model 2 exhibits the results of the structural model. Table 10 exhibits the estimations on alternative measures of quality, citing both the percentage of highly cited publications and the latent quality variable X. The percentage of highly cited publications increased by 14.4% after the EI. By analysing the effect of the EI on German Excellence Universities and their Italian equivalents, the effect of the policy intervention led to a growth of 20%. By considering the difference within countries, the effect of policy intervention in Germany was equal to 0.12, which corresponds to an increase in citations per publication of just below 10%. In terms of taking a step forward, the effect of the EI on the German Excellence Universities was modest, at around 5%. By interpreting the change in the latent quality variable in terms of standard deviation changes, it grew by 0.30 after the EI, except for German Excellence Universities, which augmented by less than 0.1.

To deal with concerns on the statistical matching procedure in the robustness section, we included theoretical, rather than the already

[9] Namely, the saturated model, test of close fit (Root Mean Square Error of Approximation, RMSEA < 0.05), Comparative fit index (CFI) and the Tucker–Lewis index (TLI). Standardized root mean squared residual (SRMR) and the coefficient of determination (CD)

Table 8
Tests for internal reliability of the structural equation modelling results.

Items	Observations	Sign	Mean	Item-total correlation	Alpha coefficients
High cited articles	1230	+	0.0450	0.4692	0.822
Average citations per year	1230	+	2.8897	0.6696	0.7895
Citations per publication	1230	+	21.8674	0.9098	0.6103
Publications per professor	1230	+	2.1201	0.9093	0.6101
VRS bootstrapping	1230	+	0.7150	0.6776	0.8315

Table 9
Tests for model fit of the structural equation modelling results.

Chi-Square	88.386
Pr > Chi-Square	0.000
RMSEA estimation	0.054
Pclose	0.366
Bentler's Comparative fit:	
Comparative fit index (CFI)	0.931
Tucker-Lewis index (TLI)	0.942
Size of residuals:	
Standardized root mean squared residual (SRMR)	0.036
Coefficient of determination (CD)	0.983

Table 10
The effect of the Excellence Initiative on university quality (alternative measures).

VARIABLES	(1) High cited articles	(2) X
Excellence initiative	3.764	0.044***
	(6.744)	(0.005)
Excellence Universities * Excellence Initiative	155.3***	0.028*
	(19.78)	(0.015)
Country * Excellence initiative	-3.795	-0.014*
	(9.520)	(0.007)
Excellence Universities * Excellence Initiative * Country	-149.8***	-0.074***
	(25.79)	(0.020)
Fees per student	-1.371	0.006
	(5.566)	(0.004)
Graduates of Human Sciences (%)	-9.266	-0.057
	(86.77)	(0.065)
Graduates of Sports (%)	-44.46	0.065
	(227.7)	(0.166)
Graduates of Business and Social Sciences (%)	-6.481	-0.192***
	(75.60)	(0.058)
Graduates of Medicine (%)	-284.9***	-0.264***
	(82.93)	(0.064)
Graduates of Agricultural Sciences (%)	-68.84	-0.035
	(238.9)	(0.178)
Graduates of Engineering (%)	-23.27	-0.089
	(103.1)	(0.079)
Graduates of Other Sciences (%)	25.67	-0.385
	(330.9)	(0.258)
Unemployment rate	-0.018	-0.007
	(1.394)	(0.001)
Population density	0.073	-0.001
	(0.218)	(0.002)
Public expenditure on higher education	-7.600	0.152***
	(20.47)	(0.016)
Constant	39.70	-0.233***
	(115.8)	(0.089)
Observations	1230	1230
Number of universities	123	123
R-squared	0.093	0.404

This table reports the results of the fixed effects panel model. The sample consists of 72 German universities observed between 2004 and 2013. The dependent variables are the percentage of high-cited papers and the latent quality variable X, respectively. Natural Sciences is the reference case for the field of study. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at levels less than 1%, 5%, and 10%, respectively.

Table 11
Robustness check.

	(1) VRS bootstrapping	(2) Publications/ professors	(3) Citations/ publications
Excellence initiative	0.040***	0.066**	3.242***
	(0.012)	(0.033)	(0.367)
Excellence Universities * Excellence Initiative	-0.010	0.128	-0.816
	(0.029)	(0.080)	(0.887)
Country * Excellence initiative	-0.023	0.338***	-1.390***
	(0.017)	(0.046)	(0.506)
Excellence Universities * Excellence Initiative * Country	0.043	0.499***	-2.641**
	(0.040)	(0.111)	(1.230)
Fees per student	0.019**	0.019	0.399
	(0.010)	(0.026)	(0.293)
Graduates of Human Sciences (%)	0.524***	-0.251	-4.626
	(0.145)	(0.399)	(4.434)
Graduates of Sports (%)	1.162***	-1.157	3.612
	(0.369)	(1.011)	(11.24)
Graduates of Business and Social Sciences (%)	0.433***	-1.178***	-13.54***
	(0.128)	(0.350)	(3.892)
Graduates of Medicine (%)	0.981***	-1.473***	-18.83***
	(0.143)	(0.392)	(4.362)
Graduates of Agricultural Sciences (%)	-0.425	-5.161***	1.404
	(0.396)	(1.084)	(12.06)
Graduates of Engineering (%)	0.158	-0.776	-6.033
	(0.175)	(0.480)	(5.344)
Graduates of Other Sciences (%)	-0.011	-2.126	-25.25
	(0.573)	(1.571)	(17.47)
Unemployment rate	-0.002	-0.030***	-0.029
	(0.002)	(0.007)	(0.074)
Population density	-0.001	-0.004***	-0.005
	(0.004)	(0.001)	(0.012)
Public expenditure on higher education	0.106***	0.601***	9.673***
	(0.035)	(0.096)	(1.073)
Constant	0.066	2.927***	7.566
	(0.197)	(0.540)	(6.002)
Observations	1064	1064	1064
R-squared	0.119	0.532	0.342
Number of universities	133	133	133

Italian Excellence Universities (based on ANVUR) as a control group. This table reports the results of the fixed effects panel model. The sample consists of 72 German universities and 51 Italian universities observed between 2004 and 2011. The dependent variables are the efficiency non-biased scores retrieved by a DEA analysis; the publications-to-professor ratio and the citations-to-publication ratio, respectively. Natural Sciences is the reference case for the field of study. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at levels less than 1%, 5%, and 10%, respectively.

Table 12
Alternative DEA analysis.

	(1)	(2)	(3)
Excellence initiative	0.024***	0.052***	0.063***
	(0.009)	(0.009)	(0.009)
Excellence Universities * Excellence Initiative	-0.033	-0.031	-0.054**
	(0.026)	(0.027)	(0.026)
Country * Excellence initiative	0.002	-0.009	-0.034***
	(0.012)	(0.013)	(0.012)
Excellence Universities * Excellence Initiative * Country	-0.019	0.035	0.012
	(0.034)	(0.035)	(0.034)
Fees per student	0.022***	0.014*	0.012*
	(0.007)	(0.007)	(0.007)
Graduates of Human Sciences (%)	0.160	0.543***	0.292***
	(0.110)	(0.113)	(0.109)
Graduates of Sports (%)	0.432	1.141***	0.776***
	(0.279)	(0.287)	(0.276)
Graduates of Business and Social Sciences (%)	0.174*	0.412***	0.298***
	(0.0967)	(0.099)	(0.096)
Graduates of Medicine (%)	0.149	0.497***	0.645***
	(0.107)	(0.111)	(0.107)
Graduates of Agricultural Sciences (%)	-0.792***	-0.039	-0.617**
	(0.299)	(0.307)	(0.296)
Graduates of Engineering (%)	-0.171	0.267*	0.0831
	(0.132)	(0.136)	(0.131)
Graduates of Other Sciences (%)	-0.683	0.168	0.179
	(0.433)	(0.445)	(0.429)
Unemployment rate	-0.005***	0.001	-0.001
	(0.002)	(0.002)	(0.002)
Population density	-0.001***	-0.005	-0.001
	(0.003)	(0.003)	(0.003)
Public expenditure on higher education	0.047*	0.0669**	0.136***
	(0.027)	(0.027)	(0.026)
Constant	0.977***	0.338**	0.088
	(0.149)	(0.153)	(0.147)
Observations	984	984	984
R-squared	0.141	0.144	0.208
Number of universities	123	123	123

This table reports the results of the fixed effects panel model, where the DEA efficiency scores are the dependent variable. Model 1 includes the DEA efficiency scores calculated with professors, funding, students as inputs, and graduates, and publications as outputs. Model 2 includes the DEA efficiency scores calculated with the input/output specification adopted in the main analysis, but with data pooled per country. Model 3 includes the same DEA efficiency scores as Model 2, but with data pooled per Excellence/Non-Excellence Universities. Robust standard errors are reported in parentheses. ***, **, and * indicate significance at levels less than 1%, 5%, and 10%, respectively.

used statistical equivalents, for the German Excellence Universities. For the research quality evaluation, and the respectively picked universities as theoretical equivalents, we relied on the report by the Italian National Agency for the Evaluation of Universities and Research Institutes (ANVUR). Results, which were found to be robust, are reported in Table 11.

Finally, we conducted some robustness checks for the DEA analysis in Table 12. Specifically, we ran DEA models with differing inputs and outputs (Model 1), as well as pooled data (Model 2, 3). The tendencies and main analysis remained robust.

6. Conclusions

The aim of this study is to show the effects of the 'picking the winner' policy initiative in Germany. We found that the initiative not only stimulated the higher education system as such, but also the winners. However, the evaluation of the outcome is dependent on how it is measured. Compared to Italy, Germany had lower performance in terms of efficiency; however, it is above Italian performance in terms of research output and research impact. Furthermore, the entire German university system increased their research quantity compared to the Italian university system. In contrast, instead of finding a general positive trend for research quality in Excellence Universities, we found a negative one. The effects were even stronger– both positive and negative – for the chosen German universities compared to their Italian counterparts.

We traced this reverse effect of research quantity and quality not to an increase in publications, but rather to a considerably slower increase in citations; this reflected the actual impact, rather than a simple increase in quantity.

Our results show that researchers are considering output maximization instead of impact maximization. The question of who should actually get the rewards of such a competition – the one that "sells the most" or the one that "sells the most valuable" – should be questioned and consequently answered (Kerr, 1975). To invert such a trend, one has to consider possible policy rationales: If the target of policies is to increase ranking visibility, one should continue to incentivize the maximization of output, as this is a pervasive way to increase ranking visibility (Vogel et al., 2017). If the target is to increase research impact, one should not incentivize "salami-publishing" (Geuna and Martin, 2003; Martin, 2012), but rather publishing in journals with high impact factors. This takes time and is not reflected in the EI in two ways; first, the time dimension of the funding is too small to experience a sustainable quality improvement and, second, the graduate schools ("*Graduiertenkolleg*") funded by the Initiative for fast track (mostly cumulative) promotions are considered to incentivise the exact opposite (i.e. as many publications and as quickly as possible) (Cremonini et al., 2014).

Two steps could be considered in the future: (1) The winners of the initiative could be tracked and the consecutive pay-outs based on milestone strategies to monitor the progress of the submitted drafts over a longer period of time, and (2) transparency is needed to incentivize more than purely financial measures, the utilization of which remains unclear after allocation.

This study has some limitations in that citations are not an immediate measure and, since Scopus and Web of Science are databases constantly being updated, there are several lag effects (see also reliance and different results from Morgan, 2016). However, this problem could only be solved using a bigger timeframe that consequently includes the third round of the EI. For this purpose, comprehensive and balanced data is not yet accessible, and the effect of the first initiative might be blurred. The choice of Italian Excellence Universities is a matter of discussion, yet we used a quantitative (CEM) and qualitative (ANVUR ranking) approach.

CRediT authorship contribution statement

Alice Civera: Funding acquisition, Methodology, Writing - original draft, Writing - review & editing. **Erik E. Lehmann:** Conceptualization, Supervision, Writing - review & editing. **Stefano Paleari:** Supervision, Writing - review & editing. **Sarah A.E. Stockinger:** Formal analysis, Methodology, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Corrigendum

Corrigendum to "Higher Education Policy: Why hope for Quality when rewarding Quantity?" [Research Policy Volume 49, Issue 8(2020) / 104083]

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The authors regret to have reported in the *Section 5.2 Empirical results and discussion*, comments that are incorrect because the calculations were inaccurate due to information updates. The significance of the results is not undermined yet, we explained the coefficients of a wrong table. Therefore, we kindly ask for a corrigendum of our article by substituting the paragraphs at page 8 with the following ones: "which represents a 5% increase on average. When considering the difference within countries, the effect of the policy intervention grew to 0.404 (i.e. 0.078+0.326) in Germany, where both Excellence and non-Excellence Universities increased by nearly 24%. By taking a step for-ward, the effect of the EI on the German Excellence Universities was 0.950 (the sum of the above-mentioned effects and the coefficient of the triple interaction 0.546). After 2006, German Excellence universities improved their publications per professor by more than 54% compared to the publications per professors in Germany and Italy before 2006). Similarly, the EI augmented the citations per publication by 2.926, which represents an 14% increase on average (citations per publication for both German and Italian universities were 21.07). By analysing the effect of the EI on German Excellence Universities and their Italian equivalents, the effect of the policy intervention grew to 4.813 (i.e. 2.926+1.887). This corresponds to an increase of nearly 23%. Considering the differences within countries, the effect of the policy intervention in Germany was equal to 1.82 (i.e 2.926 -1.106), which corresponds to a 8% increase in citations per publication. Taking a step forward, the effect of the EI on the German Excellence Universities was -1.616 (calculated as 2.926+1.887-1.106-5.323). After 2006, German Excellence Universities received fewer citations per publication, falling by almost 7%. However, these results do not confirm a failure of the Excellence-Initiative in general and on the long run. The results just show that citations of the treated universities are declining comparing their expected incline before the treatment period, reflecting their effort in winning the contest. The short run effect also reflects adjustments after the treatment like hiring new scientists with lower experience and skills in academic writing, and also time-consuming effects like administrational efforts and reporting".

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