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DISCUSSION PAPER

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Heterogeneous Regional University Funding and Firm Innovation: An Empirical Analysis of the German Excellence Initiative

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Heterogeneous regional university funding and firm innovation
An empirical analysis of the German Excellence Initiative

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Abstract

This paper estimates the effect of heterogeneous university funding stemming from the German Excellence Initiative on a regional firm's probability to innovate by using a multi-valued two-way fixed effects difference-in-differences model. The estimations show that funding an additional Excellence Cluster focused on internationally competitive research within a labor market region increases a regional firm's probability to innovate between 0.3 and 0.9 percentage points. This effect is driven by firms within labor market regions receiving a high number of Excellence Clusters. There is no statistically significant effect for receiving a low number of Excellence Clusters. Moreover, we find no consistent statistically significant effect of funding Graduate Schools concentrating on training scientists nor of funding University Strategies promoting the overall long-term plan of a university.

Keywords University funding – Firm innovation – Knowledge transfer

JEL Code O32 – O33 – O38

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1. Introduction

The scientific knowledge of universities is an important driver of the innovativeness of regional firms (Cowan and Zinovyeva, 2013; Bellucci and Pennacchio, 2016; Helmers and Rogers, 2015). Aiming to strengthen their universities in the international competition, industrial countries implemented competitive large-scale university funding programs during the last decades. The programs targeted fostering the scientific excellence of universities. Knowledge transfer to the private sector was not their primary objective (e.g., Koenig et al., 2017). Research on the effects of recent competitive large-scale university funding programs, therefore, focused on their impact on the scientific performance and teaching of universities and not knowledge transfer.

The German Excellence Initiative was implemented in 2006 and acted as a role model for funding programs in various countries, such as France, Japan, Malaysia, and Spain. It added 4.6 billion EUR to the university system of Germany and consisted of three different funding lines: i) Excellence Clusters, ii) Graduate Schools, and iii) University Strategies. Excellence Clusters focused on funding internationally competitive research in future-oriented topics. Graduate Schools aimed at training young researchers by supporting the implementation of graduate schools in Germany. University Strategies supported all measures allowing universities to establish themselves as an international top university in the long term. (DFG, 2015)

This paper estimates the effect of heterogeneous regional Excellence Initiative funding on a firm's probability of innovating. It modifies the multi-valued two-way fixed effects difference-in-differences model described by Callaway et al. (2021) and utilizes information from the Mannheim Innovation Panel and the GEPRIS database. As a result, it adds to two streams of research: i) the stream about the heterogeneous effects of universities on regional innovativeness, and ii) the stream about the effects of the German Excellence Initiative.

The literature about the heterogeneous effects of universities on regional innovativeness increasingly exploits variation in the number of universities within a region as an identification strategy (e.g., Lehnert et al., 2020; Pfister et al. 2021; Schlegel et al., 2022a/b).[1] Thus, the identification strategy relies on variation from the foundations and closures of universities but ignores variation related to established universities. However, in particular, in developed countries, the foundation and closure of universities becomes rare, whereas established universities continuously contribute to regional innovativeness. As a result, our analysis contributes by i) utilizing variation in funding for graduate schools, research clusters, and university strategies of established universities triggered by the German Excellence Initiative, ii) by investigating the separate effect of each funding line, and iii) by investigating the importance of different funding doses.

[1] Examples are Andrews (forthcoming), Cowan and Zinovyeva (2013), Kamhöfer et al. (2019), Kyui (2016), Toivan and and Väänänen (2016), and Valero and Van Reenen (2016).

The literature about the effects of the German Excellence Initiative concentrated on universities, researchers, and students.[2] Research about its effect on the private sector corresponds to the work of Cunningham and Menter (2021) and Lehmann and Stockinger (2018). Cunningham and Menter (2021) show a positive effect of each funding line on regional high-tech entrepreneurship, and Lehmann and Stockinger (2018) find an increase in universities' private sector funding after receiving University Strategy funding. However, Cunningham and Menter (2021) analyze each funding line within separate regressions, and Lehmann and Stockinger (2018) exclusively consider University Strategy funding, even though most universities receive funding from more than one funding line. Thus, both studies have a risk of omitted variable bias. Therefore, our study extends their analysis by i) using the innovativeness of regional firms as an alternative outcome, and ii) taking omitted variable bias due to the presence of multiple funding lines into account.[3]

The results are heterogeneous. Funding an additional Excellence Cluster within a labor market region increases a regional firm's probability to innovate between 0.3 and 0.9 percentage points. This effect stays robust to a multitude of robustness tests. In particular, there is no evidence of a violation of the common trend assumptions established by Callaway et al. (2021). The positive effect is driven by labor market regions receiving funding for more than three Excellence Clusters. Receiving funding for fewer Clusters does not have a statistically significant effect on the innovativeness of firms. There is no consistent statistically significant effect of funding Graduate Schools or University Strategies.

These results show a positive effect of established universities on regional innovativeness. Moreover, they demonstrate the heterogeneous effects of funding programs on firm innovations. The positive effects related to Excellence Cluster funding are "good news" for governments promoting the implementation of similar funding programs and aiming at strengthening regional private sector innovation, at least as a side product. However, they also demonstrate the necessity of a significant dose of funding to trigger regional firm innovations.

2. The German Excellence Initiative

2.1. Excellence Initiative background

The Excellence Initiative marked a change in the funding system of German universities. It aimed to break with the prevailing egalitarian funding system and selectively develop internationally leading universities (Menter et al., 2018). Therefore, it competitively awarded

[2] Examples are studies on research productivity, scientific publications, funding, patents, ratings, research visibility, and its impact on students' university choices (Bornmann, 2016; Bruckmeier et al., 2017; Fischer and Kampkötter, 2017; Fritsch et al., 2017; Gawallek and Sunder, 2016; Koenig et al., 2017; Menter et al., 2018; Möller et al., 2016; Wollersheim et al., 2018).

[3] In addition, both studies do not consider the dose of funding. Thus, our investigation of funding doses also adds to this literature stream.

4.6 billion EUR to German universities from 2006 to 2017, making up four percent of Germany's university research spending (IEKE, 2016).[4]

The Excellence Initiative consisted of three funding lines: i) Excellence Clusters, ii) Graduate Schools, and iii) University Strategies. Excellence Clusters financed university scientists and their research by offering additional yearly funding for personnel, materials, or investments between three million and eight million EUR per year. It was the largest funding line and constituted 57.8 percent of the Excellence Initiative's total funding. Graduate Schools focused on the promotion of young researchers and their training. Their funding ranged from one million to 2.5 million EUR per year. The funding could be used for the recruitment of graduate students, as well as for personnel, materials, and investments. Graduate Schools were the smallest funding line, with 13.2 percent of the initiative's funding. Whereas Excellence Cluster and Graduate School funding was bound to specific schools or research topics within universities, University Strategy funding focused on entire universities. University Strategy funding covered between 9.6 million and 13.4 million EUR per year and was moderately attached to specific usages. It covered all measures allowing universities to develop their long-term strategies and to establish themselves as internationally leading institutions. Moreover, universities acquiring University Strategy funding were awarded the prestigious title of "Excellence University." University Strategy funding accounted for 29.0 percent of Excellence Initiative funding. (DFG, 2015)

Full universities in Germany were eligible to receive Excellence Initiative funding. They could apply to receive funding for several Excellence Clusters or Graduate Schools and one University Strategy. Collaborations with other universities, research institutes, and firms within Excellence Cluster applications were endorsed to enhance scientific networking. Moreover, only universities receiving funding for at least one Excellence Cluster and Graduate School were eligible to receive University Strategy funding. The awardee selection process focused on scientific excellence and comprised two steps. First, universities were able to submit draft proposals. Second, universities with the most qualitative proposals were invited to submit extensive funding applications. The invitations for extensive applications are publicly available.

The Excellence Initiative covered three funding rounds. The first took place in 2006, the second in 2007. Both rounds covered funding periods up to 2014.[5] They jointly funded 39 Graduate Schools, 37 Excellence Clusters, and 9 University Strategies. The third round was in 2012 and

[4] Even though the 4.6 billion EUR from the Excellence Initiative formed four percent of German university research spending and significantly improved the financing situation of individual universities, the amount is relatively small compared to the revenues of, for instance, MIT of 1.9 billion USD in 2021 (MIT, 2022), or Harvard University of 5.2 billion USD (Harvard University, 2022). Thus, the external validity of our analysis rather relates to university systems similar to the one in Germany.

[5] However, the funding was prolonged for a duration of around two years if a cluster or school did not acquire Excellence Initiative funding in the third round. The prolongation aimed at securing their adequate closure or transition to other funding sources.

covered a funding period from 2012 to 2017.[6] This time, 45 Graduate Schools, 43 Excellence Clusters, and 11 University Strategies were financed (DFG, 2013). After the third funding round, the Excellence Strategy, a similar program with an increased emphasis on Excellence Clusters superseded the Excellence Initiative.

Receiving funding from the initiative had the potential to significantly improve the financing situation of individual universities. In 2003, the year before the announcement of the Excellence Initiative (Kehm and Pasternack, 2008), Universities receiving funding within one of the three rounds had on average 64 million EUR of earnings, whereas the German Science Foundation contributed on average 16 million EUR, and the German Federal State on average ten million EUR.[7] Therefore, winning an individual Excellence Cluster of eight million EUR equaled 45 percent of the funding by the German Science Foundation and 80 percent of the funding by the German Federal State. Accordingly, winning an individual Graduate School of 2.5 million EUR equaled 16 and 25 percent, and an Excellence Strategy of 13.4 million EUR equaled 84 and 134 percent. Moreover, breaking down the financing by the German Science Foundation into science fields and comparing it to the funding amounts of Graduate Schools and Excellence Clusters demonstrates the importance of Excellence Initiative funding for the individual departments within a university. Universities winning within one of the funding rounds of the Excellence Initiative received on average 3.3 million EUR by the German Science Foundation related to social sciences, 8.8 million EUR related to life sciences, 5.5 million EUR related to natural sciences, and 4.8 million EUR related to engineering sciences in 2003.[8] Thus, an individual Excellence Cluster could add between 37.5 and 242 percent and an individual Graduate School between 11.4 and 75.8 percent to the total yearly funding of a science field by the German Science Foundation.

2.2. Excellence Initiative effects on academia

The literature about the effects of the German Excellence Initiative on academia focused on teaching, research, and funding, whereas a limited amount of studies partly entailed analyses of its effects on universities' patenting activities.[9]

University Strategy funding – Research on the effects of University Strategy funding forms the largest part of the German Excellence Initiative literature. First, regarding teaching, Bruckmeier et al. (2017) find universities receiving University Strategy funding and the concomitant title of Excellence University to increase their number of first-year students. Moreover, Fischer and Kampkötter (2017) find that students with higher GPAs selected into universities winning a University Strategy due to a short-term increase in their perception of

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[6] The same prolongations, as mentioned in Footnote 5 for the first and second funding round of the Excellence Initiative, were available for clusters and graduate schools from the third round.

[7] Data stems from the „Hochschulfinanzstatistik" of the German Statistical Office.

[8] Data stems from Table A-8 of the Funding Ranking of the German Science Foundation in 2006 (DFG, 2006).

[9] In the following, we focus on studies trying to establish causal effect estimates. Therefore, we only cover a few selected descriptive studies. All other studies on the German Excellence Initiative, descriptive or too unrelated to our research topic, are covered in Footnote 2.

the university's teaching quality and their future job market opportunities. Second, considering research, Menter et al. (2018) identify University Strategy funding to decrease the publications per researcher of a university after receiving the funding. However, they find weak evidence for a positive anticipation effect of University Strategy funding, increasing the publications per research prior to its award date. In contrast, Frietsch et al. (2017) find a positive effect on the number of publications by a university, and statistically insignificant results for the publications per employee, the number of citations, and the share of highly-cited publications. Third, with respect to funding, Buenstorf and Koenig (2020) demonstrate that winning University Strategy funding increases universities' funding from the German Science Foundation and decreases funding from the Federal State of Germany. Furthermore, they find no statistically significant impact on funding from the private sector. In contrast, Lehmann and Stockinger (2018) find a positive effect on the amount of private funding per professor. Finally, Mergele and Winkelmayer (2021) show descriptively that University Strategy funding raises the total third-party funding of winning universities. However, this surge corresponds to a one-off level shift and not a dynamic process resulting in the increasing divergence concerning third-party funding of winning and not-winning universities. Fourth, in addition to results on research, teaching, and funding, Fritsch et al. (2017) find a negative effect of strategy funding on the number of patents, and Lehmann and Stockinger (2018) find no statistically effect on patenting activities.

Excellence Cluster funding – Research on Excellence Cluster funding is the second largest literature stream on the German Excellence Initiative. Due to the focus of the Excellence Cluster line on basic research funding, the literature on its effects concentrates on different measures of research performance as outcome variables. First, Moeller et al. (2016) descriptively demonstrate that Excellence Clusters cover a relatively high share of the highly cited publications of the German science system and increasingly collaborate with extramural research institutions. Second, Frietsch et al. (2017) show a positive effect of Excellence Cluster funding on universities' number of publications and publications per employee. However, they do not find an effect on universities' citations, the share of highly-cited publications, or patents per employee. Finally, rather in contrast to Frietsch et al. (2017), Menter et al. (2018) find a negative effect of winning an Excellence Cluster and/or Graduate School funding on a university's publications per researcher.

Graduate School funding – There is no research investigating Graduate School funding as the primary research object. Moreover, the only study separately analyzing its effects is Frietsch et al. (2017). They find no statistically significant effects of Graduate School funding on any research performance measure. However, they see that receiving graduate school funding increases universities' concentration on specific science fields with regard to their student and publication population. Lastly, as mentioned before, Menter et al. (2018) show a negative impact of Excellence Cluster and/or Graduate School funding on the number of publications per researcher.

In sum, the effects of the three different funding lines on academia are heterogeneous. University Strategy funding seems to have attracted more and better students. However, it appears to have had no clear effect on the research performance of universities at this point. The results on receiving additional funding are not precise either and vary concerning funding type and measurement method. An interesting additional findings is its potentially harmful effect on university patenting. The effects of Excellence Cluster funding on research performance are ambiguous too. Finally, there is little evidence on the effects of Graduate Schools. However, they seem to increase a university's student and publication concentration in specific science fields and to be rather neglectable for outcomes related to research performance.

2.3. Excellence Initiative effects on private sector

The analyses by Cunningham and Menter (2020) and Lehmann and Stockinger (2018) are the two studies on the German Excellence Initiative concentrating on its private sector effects. As described in Subsection 2.2., the work of Lehmann and Stockinger (2018) investigates the effects of University Strategy funding on universities' patenting performance and universities' funding by industry, thereby interpreting the former as entrepreneurial and the latter as collaboration activities. Cunningham and Menter (2020) focus their work on the effects of all three lines of Excellence Initiative funding on regional high-tech firm foundations. They find all three funding lines to have positive effects, whereas the effect of University Strategy funding is the highest, the effect of Excellence Cluster funding is the second highest, and the effect of Graduate School funding the lowest.

The effect of the Excellence Initiative and its three individual funding lines on further regional private sector outcomes is hard to predict and presents an empirical exercise. First, recent literature on the effects of universities on regional innovativeness (e.g., Andrews, forthcoming; Pfister et al., 2021), competitiveness (e.g., Garcia-Alvarez-Coque et al., 2021; Mas-Verdu et al., 2020), and economic growth (e.g., Agasisti et al., 2019; Chu et al., 2022; Schubert and Kroll, 2014) yielded diverse results depending on their investigated type of universities, effect channels, regions, and methodological approaches.[10] For instance, Andrews (forthcoming) finds a positive effect of college foundations in the US. However, he demonstrates the effect not being driven by former graduates. In contrast, the literature focused on the instruction of Universities of Applied Sciences in Switzerland, particularly Lehnert et al. (2020), demonstrates positive effects of graduates entering a region's labor market. Similarly, Atta-Owusu et al. (2021) find that regional universities' research intensity and quality are negatively associated with Norwegian firms' university-industry collaboration. However, Bellucci and Pennacchio (2016) find a positive relationship between universities' research quality and university-industry knowledge transfer for a large pool of European countries. Finally, most studies find positive effects of universities on regional private sector outcomes (e.g., Cowan,

[10] Schlegel et al. (2022b) provide an overview of the recent literature on higher education institutions and their effect channels on private sector outcomes.

2013; Leten et al., 2014), whereas Chu et al. (2022) demonstrates in the case of research universities in China that positive effects are not a prerequisite, but are potentially even negative. Second, the literature on the effects of the German Excellence Initiative on academia is ambiguous. Thus, besides graduates, research, and university types having heterogeneous effects in the general literature, there is no clear evidence of the initiative's effect on knowledge transfer channels at the university, university department, or researcher level.

3. Data

3.1. Databases

The Mannheim Innovation Panel builds the core of our analysis. It is augmented with information on the Excellence Initiative from the GEPRIS database and the German Science Foundation's press releases, as well as with information on further university characteristics stemming from the German Federal Statistical Office and the Funding Ranking of the German Science Foundation. The databases are linked at the level of the labor market region.

The Mannheim Innovation Panel is an annual survey constructed as a representative sample of firms with five or more employees in the German manufacturing and service industries. It is the German part of the European Community Innovation Survey and covers various information on firms' introduction of new or significantly improved products and processes. In addition, the Mannheim Innovation Panel contains various information on firm structure, such as size, age, or internal R&D activities.

The GEPRIS database is the funding database of the German Science Foundation and covers information about all funded Excellence Clusters, Graduate Schools, and Universities Strategies. We extract i) the funding period of each Excellence Cluster, Graduate School, and University Strategy, and ii) the main applicant of each Excellence Cluster, Graduate School, and University Strategy.

The press releases of the German Science Foundation covered the lists of universities invited to submit extensive funding applications for Graduate Schools, Excellence Clusters, and University Strategies. The lists were published under the title "Results of the Meeting of the Joint Commission.[11] They included a list of all main applicants invited to submit an extensive application and the names of the planned Excellence Clusters and Graduate Schools.

Information on further university characteristics refer to their value in 2003. Our data from the Federal Statistical Office stems from the German Higher Education Statistics. We gather the number of students finishing their PhD, the attachment of a clinic to a university, and if the university is a Technical University or not. Our data from the Funding Ranking covers the

[11] To be exact: i) „Ergebnis der Sitzung der Gemeinsamen Kommission am 20. Januar 2006," „Ergebnis der Sitzung der Gemeinsamen Kommission am 12. Januar 2007," and „Ergebnis der Sitzung der Gemeinsamen Kommission am 2. März 2011."

separate numbers of scientific employees in social sciences, life sciences, natural sciences, and engineering sciences.[12]

3.2. Variable construction

Firm innovation – Firm innovation is identified by two yearly yes-no questions from the Mannheim Innovation Panel asking for the introduction of new or significantly improved i) products or services, and ii) internal processes within the last three years. We create a dichotomous variable equal to one if a firm answered yes for at least one of the two questions and zero otherwise.

Excellence Initiative funding – Regional university funding through the three different funding lines of the Excellence Initiative is constructed using the regional match of the Mannheim Innovation Panel and the GEPRIS databases. We generate three count variables corresponding to the number of funded Excellence Clusters, Graduate Schools, and Universities Strategies within a firm's labor market region.

Excellence Initiative invitations – To consider firms from preferably comparable regions within our empirical analysis, we construct dichotomous variables indication if a labor market region's universities were invited to submit extensive funding applications for i) Excellence Clusters, ii) Graduate Schools, or iii) University Strategies within at least one of the three funding rounds of the Excellence Initiative. Therefore, by focusing on subsample regressions based on these variables, we control for i) differences in regional university quality and ii) the anticipations/preparations by regional universities resulting from being invited to submit an extensive application.

Controls – We consider a variety of controls to avoid omitted variable bias within our difference-in-differences estimations. Moreover, to avoid bad controls, we concentrate on regional university characteristics before the introduction of the Excellence Initiative and rarely changing firm characteristics.[13]

Labor market characteristics – Based on the Federal Statistical Office data, we consider the structure of regional universities by counting the number of Technical Universities and universities affiliated with a clinic within a labor market region. Moreover, we take the number of awarded doctoral degrees by a region's universities into account to cover their overall size. Furthermore, based on the funding ranking, we extract the number of regional university scientists in i) social sciences, ii) life sciences, iii) natural sciences, and iv) engineering sciences to control for differences in the scientific specialization of universities. All created labor market controls refer to the year 2003.

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[12] The numbers of scientific employees in each science field are based on information from the Federal Statistical Office and estimations of the German Science Foundation. They are available for all universities receiving more than 0.5 million EUR of funding from the German Science Foundation from the period 2002 to 2004. They are available in Table A-5 of the Funding Ranking in 2006 (DFG, 2006). Mergele and Winkelmayer (2021) provide a detailed description of the Funding Ranking.

[13] A recent discussion on bad controls is provided, for example, by Cinelli et al. (2022).

Firm characteristics – To take firm characteristics into account, we exploit the information available from the Mannheim Innovation Panel on firm size, age, industry, and internal R&D. Firm size is measured by three dichotomous variables indication i) if a firm has less than 50 employees, ii) if a firm has between 50 and less than 250 employees, and iii) if a firm has more than 250 employees. Firm age is measured by differentiating between firms i) being younger than seven years, ii) being between seven and less than 21 years, and iii) being older than 21 years. Industries correspond to the industry classification frequently used for the empirical analysis of the Community Innovation Survey covering 21 industries that are based on an aggregation of the Nace Rev. 2 classification. Finally, we consider firms' internal R&D activities by generating dichotomous variables for their i) occasional and ii) continuous engagement in internal R&D. All generated firm controls are time constant and correspond to the value answered by a firm most frequently during the period 2000 to 2016.

3.3. Descriptive statistics

The created unbalanced panel covers 26,897 firms from the years 2000 to 2016. The overall number of firm-year observations is equal to 155,119. All firms are distributed across 258 labor market regions, whereas 69 regions cover at least one of 76 selected full universities.[14] Descriptive statistics for our regression sample are shown at the firm-year level in Table 1.

[14] We do not, for instance, consider full policy or military universities. Moreover, we remove highly specialized universities to increase the comparability of regions considered a „region with universities" in our subsample regressions. The number of regions with selected universities corresponds to the same number as in Koenig et al. (2017).

Table 1 Descriptive regression sample statistics

Variables	Mean	Sdt. dev.	Min.	Max.
Innovation outcome				
Firm innovated within the last three years (0/1)	0.53	-	-	-
Excellence Initiative				
EC in region (0/1)	0.25	-	-	-
# of EC in region	0.65	1.41	0	6
GS in region (0/1)	0.23	-	-	-
# of GS in region	0.72	2.06	0	10
US in region (0/1)	0.11	-	-	-
# of US in region	0.17	0.51	0	2
Region controls				
Scientists in social sciences in region	388.79	581.21	0	2218
Scientists in life sciences in region	769.72	1279.32	0	4616
Scientists in natural sciences in region	261.34	386.11	0	1360
Scientists in engineering sciences in region	306.12	502.90	0	1728
# of awarded doctoral degrees in region	343.63	550.15	0	1982
# of technical universities in region	0.18	0.38	0	1
# of university clinics in region	0.46	0.68	0	2
Firm controls				
Sized less than 50 employees (0/1)	0.58	-	-	-
Sized between 50 and less than 250 employees (0/1)	0.25	-	-	-
Sized more than 250 employees (0/1)	0.17	-	-	-
Aged less than 7 years (0/1)	0.09	-	-	-
Aged between 7 and less than 21 years (0/1)	0.47	-	-	-
Aged more than 21 years (0/1)	0.44	-	-	-
Occasional internal R&D activities (0/1)	0.10	-	-	-
Continuous internal R&D activities (0/1)	0.31	-	-	-

Number of observations for each variable equals 155,119.

Table 2 compares the innovativeness of firms located in labor market regions with and without different combinations of Excellence Initiative funding. In particular, it demonstrates the importance of Excellence Cluster funding. Firms located in regions with only Excellence Cluster funding are six percentage points more likely to introduce innovation within the last three years than firms located in a region without funding. Firms located in regions with only Graduate School funding have a smaller difference of two percentage points. Moreover, firms located in regions receiving only Graduate School and Excellence Cluster funding are not more likely to innovate than firms in regions receiving only Excellence Cluster funding. Also, they are six percentage points more likely to innovate than firms in non-funded regions, thus, the same amount as firms receiving only Excellence Cluster funding. Finally, firms in regions receiving funding for Excellence Clusters, Graduate Schools, and University Strategies are two percentage points less likely to innovate than firms in regions receiving only Excellence Cluster and Graduate School funding; therefore, hinting at a potentially negative effect of strategy funding.

Table 2 Firm innovativeness in regions with and without Excellence Initiative funding

Comparison Groups		Firm innovated within the last three years (0/1)		
Group I	Group II	Group I	Group II	Group I - II
EC only (13,104)	no EI (91,827)	0.57	0.51	0.06***
GS only (7,732)	no EI (91,827)	0.53	0.51	0.02***
EC & GS only (13,813)	no EI (91,827)	0.57	0.51	0.06***
EC & GS only (13,813)	EC only (13,104)	0.57	0.57	-0.00
EC & GS only (13,813)	GS only (7,732)	0.57	0.53	0.03***
EC & GS & US (28,643)	EC & GS only (13,813)	0.55	0.57	-0.02***

Differences are estimated by employing t-tests on the equality of means assuming unequal variances of the unpaired data. Number of observations in parentheses. P-values correspond to * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 demonstrates the distribution of Excellence Cluster, Graduate School, and Excellence Strategy funding across labor market regions i) with and without universities, ii) with universities, iii) across regions with different invitations to submit extensive funding applications, as well as iv) across universities. Thus, it informs about the extensive-margin variation of Excellence Initiative funding used in our empirical strategy. In particular, Table 3 shows that the extensive margin variation for the three different Excellence Initiative funding lines decreases with an increasing consideration of universities and invitations for funding applications. In particular, there is little variation left within the subsample of regions invited to submit extensive applications for Excellence Clusters and Graduate Schools, as well as for the subsample of regions invited to submit extensive applications for all three funding lines.

Table 3 Distribution of Excellence Initiative funding across regions and universities

	EC (0/1)	GS (0/1)	US (0/1)	no EI (0/1)	# of obs.
Regions with and without universities	0.11	0.12	0.05	0.88	258
Regions with universities	0.41	0.46	0.17	0.46	69
Region with uni. invited to EC	0.74	0.74	0.32	0.13	38
Region with uni. invited to GS	0.68	0.84	0.32	0.08	38
Region with uni. invited to EC & GS	0.84	0.90	0.39	0.00	31
Region with uni. invited to EC, GS & US	0.93	1.00	0.80	0.00	15
Universities	0.43	0.46	0.19	0.46	76

Figures 1 to 3 show the geographical distribution of labor market regions in Germany. Each figure highlights labor market regions without any universities in light grey. Moreover, each figure focuses on demonstrating the geographical distribution of one of the Excellence Initiative's funding lines in 2006, 2007, and 2012. Figure 1 covers Excellence Clusters, Figure 2 Graduate Schools, and Figure 3 University Strategies. Medium-light grey labor market regions are regions with universities but without funding from the considered line. Medium-dark grey labor market regions correspond to regions with a low dose of funding from the considered line, whereas dark-grey labor market regions are regions with a high dose of funding. First, the figures demonstrate the funding consistency between years. After rounds one and two of the Excellence Initiative were established, there were only a few changes between the funding statuses of labor market regions. Second, the figures exhibit the high success of Berlin and Munich universities in all three funding rounds. Both regions are the only regions receiving a high dose of funding within the three lines.[15]

[15] Figures A-1 and A-2 in the Appendix illustrate the geographical distribution of our sample firms and their average innovativeness across labor market regions.

Figure 1 Geographical distribution Excellence Cluster funding across regions

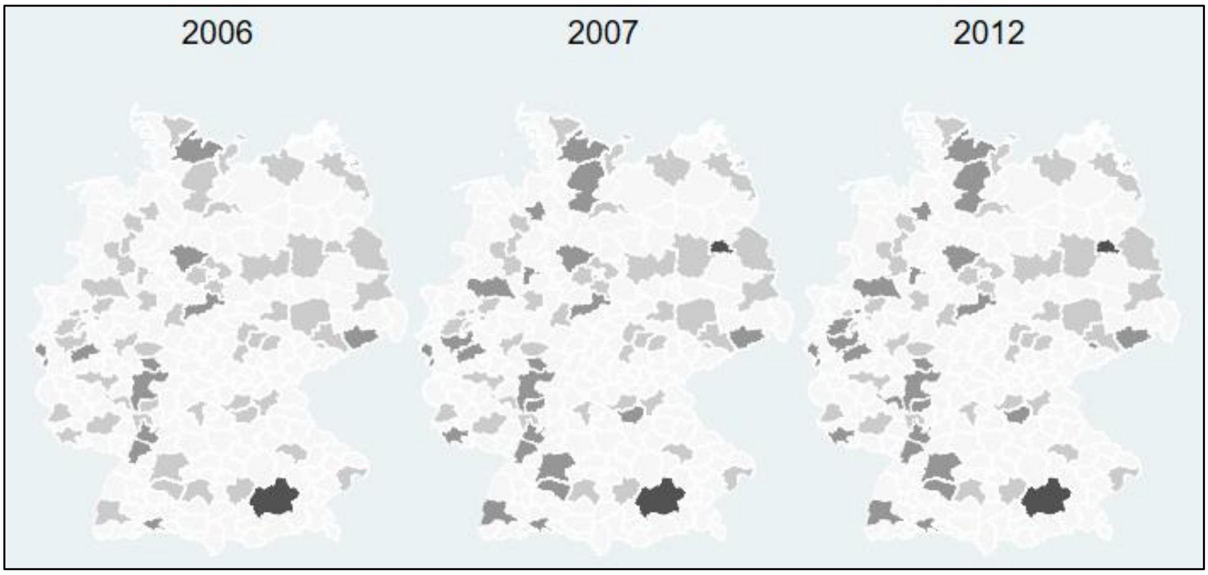


Figure 1 shows the population of labor market regions within Germany. Light-grey represents regions without universities or Excellence Cluster funding, medium-light grey regions with universities and without Excellence Cluster funding, medium-dark grey regions with universities and between one and three funded Excellence Clusters, and dark grey regions with universities and more than three funded Excellence Clusters.

Figure 2 Geographical distribution of Graduate School funding across regions

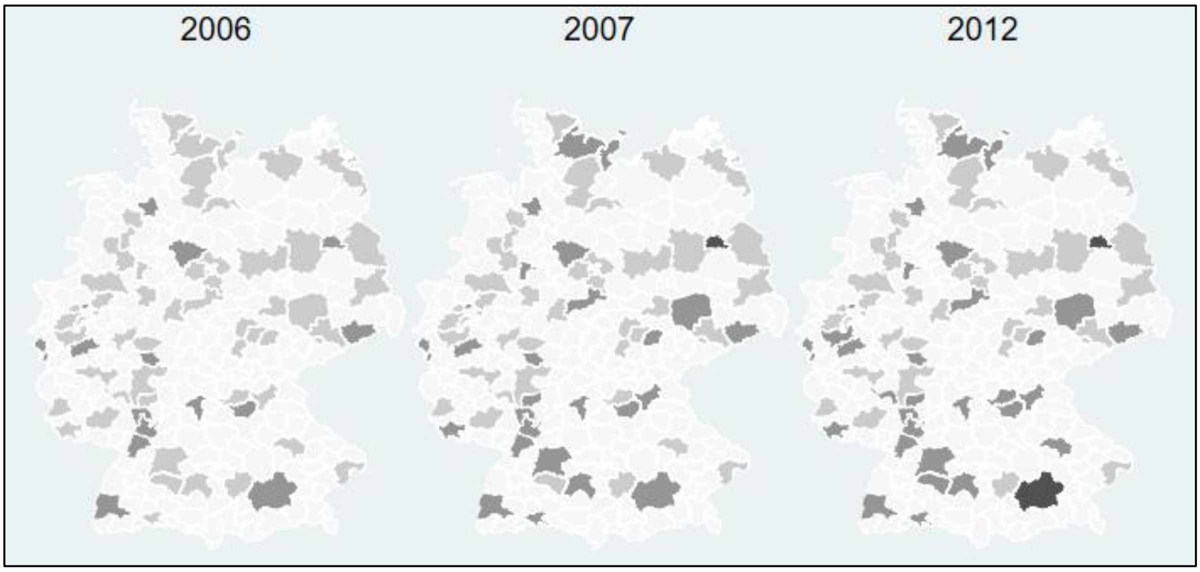


Figure 2 shows the population of labor market regions within Germany. Light-grey represents regions without universities or Graduate School funding, medium-light grey regions with universities and without Graduate School funding, medium-dark grey regions with universities and between one and three funded Graduate Schools, and dark grey regions with universities and more than three funded Graduate Schools.

Figure 3 Geographical distribution of University Strategy funding across regions

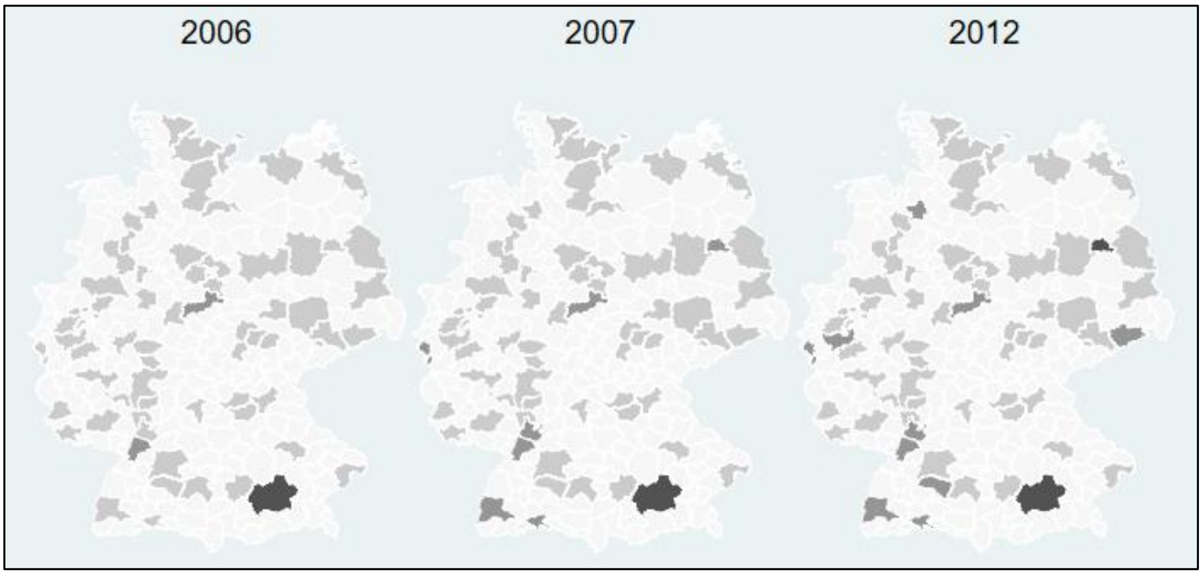


Figure 2-3 shows the population of labor market regions within Germany. Light-grey represents regions without universities or University Strategy funding, medium-light grey regions with universities and without University Strategy funding, medium-dark grey regions with universities and one funded University Strategy, and dark grey regions with universities and two funded University Strategies.

4. Empirical strategy

We modify the multi-valued two-way fixed effects difference-in-differences model described by Callaway et al. (2021) to our setting and introduce each Excellence Initiative funding line as an independent multi-valued treatment:

$$I_{it} = \beta_0 + \beta_1 EC_{it} + \beta_2 GS_{it} + \beta_3 US_{it} + \theta_i + \tau_t + \varepsilon_{it}. \quad (1)$$

I_{it} is defined as the innovation output of firm i at time t. EC_{it} is defined as the number of funded Excellence Clusters within the region of firm i at time t and β_1 corresponds to the difference-in-differences estimate of regional Excellence Cluster funding. The coefficient β_1 therefore measures the average effect of the treatment on the treatment group. The variables for funding Graduate Schools, GS_{it}, and funding University Strategies, US_{it}, are defined in the same manner and the coefficients β_2 and β_3 correspond to their difference-in-differences estimates. θ_i indicates firm-level fixed effects and controls for unobserved time-constant firm-specific effects. τ_t represents industry-year fixed effects and controls for aggregate year-effects, which are the same across firms in the same industry. ε_{it} is the idiosyncratic error term and β_0 is the constant term.

Callaway et al. (2021) show that multi-valued two-way fixed effects difference-in-differences models extend the dichotomous view of the standard common trend assumption and assume the same development of non-treated units and treated units independently of their treatment dose. In addition, they demonstrate the models' sensitivity with regard to (i) heterogeneous treatment effects across treatment doses, (ii) heterogeneous effects across different treatment timings, and (iii) dynamics of the treatment effect. We implement a variety of robustness tests evaluating the reasonability of these assumptions in our setting.

Our estimations of Equation (1) use a linear probability model. Lechner (2010) shows that nonlinear models, such as probit and logit, using the standard difference-in-differences specification require the absence of group-specific effects for a consistent estimation of the difference-in-differences estimate. Standard errors are heteroscedasticity-robust and clustered at the labor market region-level to avoid Moulton bias.[16]

5. Results

Table 4 presents the results of our difference-in-differences estimations. Each column represents a subsample of labor market regions, as stated at the bottom of the table. The results demonstrate a statistically significant effect of regional Excellence Cluster funding. Funding an additional Excellence Cluster within a labor market region increases a firm's probability to innovate by around 0.4 to 0.5 percentage points. Moreover, the significance level of the difference-in-differences estimate mostly decreases by each column: (1) 0.034, (2) 0.045, (3) 0.054, (4) 0.053, (5) 0.061, and (6) 0.098. We cannot find an effect of funding Graduate Schools or University Strategies.[17]

Table 4 Baseline difference-in-differences

	Firm innovated within last the three years (0/1)					
	(1)	(2)	(3)	(4)	(5)	(6)
# of EC in region	0.004**	0.005**	0.004*	0.005*	0.004*	0.005*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
# of GS in region	0.003	0.003	0.003	0.003	0.003	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
# of US in region	-0.008	-0.008	-0.007	-0.007	-0.007	-0.006
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.009)
Regions with	or without university	university	uni. invited to EC	uni. invited to GS	uni. invited to EC, GS	uni. inv. to EC, GS, US
R-squared	0.548	0.562	0.566	0.568	0.569	0.569
Observations	155,119	84,276	64,170	60,127	55,463	29,958

Estimates are based on a LPM. Standard errors are in parentheses and clustered at the labor market region. Firm FE, year-industry FE, and constant are included. P-values correspond to * p < 0.1, ** p < 0.05, *** p < 0.01.

Table 5 takes heterogeneous treatment doses into account. Otherwise, it mirrors Table 4. We define labor market regions with a high dose of Excellence Clusters or Graduate Schools funding as regions with more than three funded clusters or schools. Regions with a high dose of University Strategy funding receive funding for more than one strategy. Investigating the high and low doses of the different Excellence Initiative variables reveals that the Excellence

[16] Moulton bias refers to seriously downward biased standard errors resulting from correlated disturbances within firms. For more information, see Moulton (1990) and Bertrand et al. (2009).

[17] Table A-1 demonstrates the robustness of our results in using different combinations of control variables and fixed effects. Moreover, it shows that using firm fixed effects combined with industry-year fixed effects is the most restrictive specification. To control for the time constant differences between the treatment and control groups, we include the maximum number of funded Excellence Clusters, Graduate Schools, and University Strategies within our regressions without labor market region or firm fixed effects. Our estimations are robust to using the average number of funded Excellence Clusters, Graduate Schools, and University Strategies as alternative specification.

Cluster effect is driven by regions receiving funding for more than three Excellence Clusters. There is no statistically significant effect for having a low number of excellence clusters within a labor market region, whereas having a large number of excellence clusters in a region increases the probability of introducing an innovation between four and five percentage points. These results are robust to all subsamples, besides the most restrictive one limited to regions with universities invited to submit applications for Excellence Clusters, Graduate Schools, and University Strategies. Moreover, there is a sporadic negative effect of University Strategy funding on firm innovativeness.

Table 5 Difference-in-differences with heterogeneous treatment doses

	Firm innovated within the last three years (0/1)					
	(1)	(2)	(3)	(4)	(5)	(6)
Low # of EC	0.003	0.002	0.001	-0.001	-0.004	-0.030
in region (0/1)	(0.007)	(0.008)	(0.010)	(0.009)	(0.010)	(0.019)
High # of EC	0.046***	0.052***	0.050***	0.044***	0.045***	0.034
in region (0/1)	(0.010)	(0.011)	(0.012)	(0.012)	(0.013)	(0.021)
Low # of GS	0.005	0.005	0.003	0.005	0.001	-0.008
in region (0/1)	(0.007)	(0.007)	(0.008)	(0.008)	(0.009)	(0.019)
High # of GS	0.003	-0.001	-0.004	0.001	-0.006	-0.021
in region (0/1)	(0.008)	(0.009)	(0.010)	(0.010)	(0.011)	(0.023)
Low # of US	-0.016	-0.017*	-0.017*	-0.016	-0.016*	-0.013
in region (0/1)	(0.009)	(0.009)	(0.010)	(0.010)	(0.010)	(0.013)
High # of US	-0.020*	-0.023**	-0.021*	-0.018	-0.020	-0.021
in region (0/1)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)	(0.018)
Regions with	or without university	university	uni. invited to EC	uni. invited to GS	uni. invited to EC, GS	uni. inv. to EC, GS US
R-squared	0.548	0.562	0.566	0.568	0.569	0.569
Observations	155,119	84,276	64,170	60,127	55,463	29,958

Estimates are based on a linear probability model. A high dose of EC or GS in a region corresponds to more than EC or GS. A high dose of US corresponds to more than 1 US. Standard errors are in parentheses and clustered at th labor market region. Firm FE, year-industry FE, and constant are included. P-values correspond to * p < 0.1, ** p 0.05, *** p < 0.01.

Table 6 repeats our baseline estimations but includes lags and leads of our independent treatment variables. Significant lead variables indicate a violation of the common trend assumption. However, all lead variables are statistically insignificant and lower in magnitude than the significant lag variables. The results demonstrate that funding an additional Excellence Cluster within a labor market region increases a firm's probability of innovating during the next year by around 0.7 to 0.9 percentage points. Again, we find no effect for Graduate Schools or University strategies.[18]

[18] Table B-2 in Appendix B further investigates the selection of different lags for our treatment variables. More precisely, it demonstrates the results of re-estimating the specifications from Table 2-4 when using the first, second, third, or fourth lag of our treatment variables. In sum, the positive and statistically significant effect of Excellence

Table 6 Dynamic difference-in-differences with multi-valued treatment

	Firm innovated within the last three years (0/1)					
	(1)	(2)	(3)	(4)	(5)	(6)
t+2 - # of EC	-0.004	-0.004	-0.004	-0.004	-0.006	-0.004
in region	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
t+1 - # of EC	0.002	0.002	0.002	0.003	0.003	0.006
in region	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
t - # of EC	-0.002	-0.002	-0.003	-0.004	-0.003	-0.002
in region	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
t-1 - # of EC	0.008***	0.009***	0.009***	0.009***	0.009***	0.007
in region	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)
t+2 - # of GS	0.002	0.002	0.003	0.003	0.003	0.002
in region	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
t+1 - # of GS	-0.004	-0.005	-0.006	-0.006	-0.005	-0.007
in region	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.008)
t - # of GS	0.007	0.008	0.008	0.009	0.010	0.011
in region	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)	(0.010)
t-1 - # of GS	-0.005	-0.005	-0.005	-0.006	-0.007	-0.005
in region	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.006)
t+2 - # of US	0.007	0.008	0.009	0.010	0.011	0.010
in region	(0.011)	(0.012)	(0.011)	(0.011)	(0.011)	(0.015)
t+1 - # of US	0.013	0.010	0.010	0.009	0.008	0.008
in region	(0.010)	(0.011)	(0.010)	(0.011)	(0.010)	(0.011)
t - # of US	-0.019*	-0.016	-0.017	-0.015	-0.016	-0.020
in region	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)	(0.015)
t-1 - # of US	0.005	0.003	0.004	0.003	0.004	0.015
in region	(0.012)	(0.012)	(0.012)	(0.011)	(0.012)	(0.013)
Regions with	or without university	university	uni. invited to EC	uni. invited to GS	uni. invited to EC, GS	uni. inv. to EC, GS, US
R-squared	0.559	0.575	0.58	0.581	0.582	0.584
Observations	131,083	71,019	53,636	50,092	46,108	24,378

Estimates are based on a linear probability model. Standard errors are in parentheses and clustered at the labor market region. Firm FE, year-industry FE, and constant are included. P-values correspond to * p < 0.1, ** p < 0.05, *** p < 0.01.

Repeating the analysis from Table 6 but lagging the indicators for receiving low and high doses of funding results in completely statistically insignificant results. We expect this specification to be too demanding with regard to the statistical power of our estimations, as it includes 24 variables related to the amount of Excellence Initiative funding in its regressions. Therefore, we focus the regressions in Table 7 on our two indicators for receiving low or high doses of Excellence Cluster funding and their lags and leads. There is no statistically significant effect for any lag or lead of receiving a low dose of Excellence Cluster funding. However, the lag of receiving a high dose of Excellence Cluster funding is mostly statistically significant across our subsample regressions: (1) 0.093, (2) 0.051, (3) 0.046, (4) 0.117, (5) 0.186, and (6) 0.690. There is

Clusters stays largely robust across specifications. We find an inconsistent statistically significant negative effect for the fourth lag of University Strategy funding.

one weakly statistically significant effect of the first lead of receiving a high dose of excellence clusters in Column (6). However, in sum, we interpret these results as no indication of a violation of our common trend assumption.

Table 7 Dynamic difference-in-differences with heterogeneous treatment doses

	Firm innovated within the last three years (0/1)					
	(1)	(2)	(3)	(4)	(5)	(6)
t+2 - High # of EC	-0.004	-0.006	-0.007	-0.004	-0.013	-0.023
in region (0/1)	(0.020)	(0.021)	(0.024)	(0.022)	(0.024)	(0.022)
t+1 - High # of EC	0.019	0.017	0.019	0.023	0.022	0.031*
in region (0/1)	(0.018)	(0.017)	(0.016)	(0.016)	(0.013)	(0.015)
t - High # of EC	0.005	0.005	0.005	0.002	0.005	-0.004
in region (0/1)	(0.030)	(0.028)	(0.026)	(0.022)	(0.022)	(0.016)
t-1 - High # of EC	0.022*	0.025*	0.026**	0.019	0.017	0.008
in region (0/1)	(0.013)	(0.013)	(0.013)	(0.012)	(0.013)	(0.020)
t+2 - Low # of EC	-0.000	-0.003	-0.002	-0.003	-0.009	-0.023
in region (0/1)	(0.009)	(0.009)	(0.010)	(0.012)	(0.011)	(0.018)
t+1 - Low # of EC	0.003	0.003	0.005	0.005	0.003	0.011
in region (0/1)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.016)
t - Low # of EC	-0.000	0.000	-0.001	-0.001	-0.000	-0.006
in region (0/1)	(0.011)	(0.012)	(0.013)	(0.013)	(0.014)	(0.023)
t-1 - Low # of EC	0.001	0.003	0.005	-0.000	-0.001	-0.024
in region (0/1)	(0.012)	(0.013)	(0.013)	(0.015)	(0.015)	(0.019)
Regions with	or without university	university	uni. invited to EC	uni. invited to GS	uni. invited to EC, GS	uni. inv. to EC, GS, US
R-squared	0.559	0.575	0.580	0.581	0.582	0.584
Observations	131,083	71,019	53,636	50,092	46,108	24,378

Estimates are based on a linear probability model. A high dose of EC in a region corresponds to more than 3 EC or GS. Standard errors are in parentheses and clustered at the labor market region. Firm FE, year-industry FE, and constant are included. P-values correspond to * p < 0.1, ** p < 0.05, *** p < 0.01.

Table A-2 in the Appendix shows that our results are driven by variation in the number of excellence clusters between 2000 and 2011. For this, we estimate our baseline specification from Table 4 for the following two subsamples: i) the years 2000 to 2011, covering the first two rounds of the Excellence Initiative in 2006 and 2007, and ii) the years 2008 to 2016,covering the third round of the Excellence Initiative. The results in Table A-2 show estimates for excellence cluster funding similar to our baseline estimation for the first subsample. There is no statistically significant effect for excellence cluster funding for the second subsample.[19] However, these results are not surprising as labor market regions successful within the first two rounds of the Excellence Initiative were mostly similarly successful within the third round. Thus, the variation of our treatment variables over time is significantly smaller when focusing on the period 2008 to 2016.

[19] We find a sporadic, statistically weakly significant negative effect of University Strategy funding for the second subsample.

Finally, we use firms' logged innovation expenditure as an alternative, timelier dependent variable. Table 8 presents the results. They mirror our results from the dose analysis shown in Table 5. There is a positive and statistically significant effect of receiving a high dose of Excellence Cluster funding within a labor market region on firms' innovation expenditures. Again, there is no statistically significant effect of Graduate School funding, whereas there is a statistically significant negative effect of receiving a high dose of University Strategy funding.[20]

Table 8 Heterogeneous treatment doses and innovation expenditures

	ln(innovation expenditures + 1)					
	(1)	(2)	(3)	(4)	(5)	(6)
Low # of EC	0.366***	0.362**	0.113	0.100	-0.041	-0.345
in region (0/1)	(0.134)	(0.145)	(0.147)	(0.145)	(0.146)	(0.267)
High # of EC	0.829***	0.929***	0.759***	0.659**	0.628**	0.419
in region (0/1)	(0.214)	(0.245)	(0.237)	(0.255)	(0.249)	(0.485)
Low # of GS	-0.062	-0.059	-0.112	-0.121	-0.106	-0.222
in region (0/1)	(0.143)	(0.147)	(0.157)	(0.155)	(0.167)	(0.264)
High # of GS	-0.105	-0.190	-0.344*	-0.291	-0.345	-0.465
in region (0/1)	(0.181)	(0.194)	(0.203)	(0.203)	(0.210)	(0.322)
Low # of US	-0.163	-0.176	-0.190	-0.131	-0.176	-0.112
in region (0/1)	(0.142)	(0.142)	(0.150)	(0.153)	(0.157)	(0.242)
High # of US	-0.387**	-0.460**	-0.529**	-0.389*	-0.489**	-0.357
in region (0/1)	(0.182)	(0.198)	(0.212)	(0.228)	(0.236)	(0.418)
Regions with	or without university	university	uni. invited to EC	uni. invited to GS	uni. invited to EC, GS	uni. inv. to EC, GS, US
R-squared	0.757	0.775	0.785	0.784	0.788	0.788
Observations	92,571	50,216	37,991	35,617	32,674	17,712

Estimates are based on a linear probability model. A high dose of EC or GS in a region corresponds to more than 3 EC or GS. A high dose of US corresponds to more than 1 US. Standard errors are in parentheses and clustered at the labor market region. Firm FE, year-industry FE, and constant are included. P-values correspond to * p < 0.1, ** p < 0.05, *** p < 0.01.

6. Conclusion

The German Excellence Initiative acted as a role model for funding programs in various countries, such as France, Japan, Malaysia, and Spain. It added 4.6 billion EUR to the university system of Germany and consisted of three different funding lines: i) Excellence Clusters, ii) Graduate Schools, and iii) University Strategies. We use the variation in regional public university funding introduced by the initiative to estimate the effect of heterogeneous types of public university funding on the innovativeness of regional firms. Thus, we add to the literature on the effects of universities on regional innovativeness by investigating changes in the funding structure of established universities instead of focusing on the foundation or

[20] The number of observations differs from our main analysis because innovation expenditures are not part of the additional non-response telephone survey of the Mannheim Innovation Panel. Using the same specification as for our main regressions in Table 4 yields similar results for the effects of winning an additional Excellence Cluster.

closure of universities (e.g., Andrews, 2019; Lehnert et al., 2020). More precisely, we i) utilize variation in funding for graduate schools, research clusters, and university strategies of established universities, ii) investigate the separate effect of each funding line, and iii) investigate the importance of different funding doses.

The results are heterogeneous. Funding an additional Excellence Cluster within a labor market region increases a regional firm's probability to innovate between 0.3 and 0.9 percentage points. However, the positive effect is driven by labor market regions receiving funding for more than three Excellence Clusters. Receiving funding for fewer Clusters does not have a statistically significant effect on the innovativeness of firms. There is no coherent statistically significant effect of funding Graduate Schools or University Strategies. These findings stay robust to a multitude of robustness tests. Most importantly, there is no evidence of a violation of the common trend assumptions.

Our results demonstrate a positive effect of funding established universities on regional innovativeness. Moreover, they demonstrate the heterogeneous effects of funding programs on firm innovations. The positive effects related to Excellence Cluster funding are "good news" for governments promoting the implementation of similar funding programs and aiming at strengthening regional private sector innovation, at least as a side product. However, they also demonstrate the necessity of a significant dose of funding to trigger regional firm innovations. The insignificant results for the number of funded graduate schools and university strategies indicate a larger relevance of Excellence Cluster funding focused on research for regional firm innovativeness than the funding of graduate schools, and long-term strategies, at least in the medium-term.[21]

There are several limitations to our analysis. First, we do not investigate the interaction of the three different funding lines due to our limited statistical power. Therefore, our estimations might miss existing complementary relationships between the three funding lines. Second, by using the labor market region for linking the Mannheim Innovation Panel and the GEPRIS database, we focus on the relevance of regional university spillovers. As a result, our estimations do not cover any effect of the Excellence Initiative beyond the joint labor market region of universities and firms. Third, even though the Excellence Initiative acted as a role model for similar funding programs, the former egalitarian university funding system is significantly different from more competition-oriented university systems, such as in the US or UK. Therefore, it is necessary to evaluate our results' external validity based on countries' prevailing university systems. Fourth, the labor market regions of Berlin and Munich are the only regions receiving a high dose of Excellence Cluster funding. Moreover, both regions are known for their flourishing innovation systems. Thus, there is a remaining risk of our results

[21] We restrain from interpreting the zero effects of Graduate School funding and the sporadic negative effects of University Strategy funding as conclusive for deriving our policy implications. First, regression analysis is focused on reducing the risks of false positive results and not of false negative results. Thus, it is difficult to verify zero effects. Moreover, our paper has several limitations; for instance, there might be positive long-term or supra-regional effects of Graduate Schools or University Strategies. Both of them are not considered within our analysis.

being driven by Berlin- and Munich- specific effects. However, taking i) our tests for a potential violation of the common trend assumption into account, and ii) our high number of increasingly restrictive subsample regressions, we consider the risk as neglectable.

Several starting points for future research emerge from our analysis. With regard to the scope of the Excellence Cluster effect, it seems promising to identify links between funded universities and firms beyond a joint region, such as joint patents or publications. Moreover, investigating the different impact channels of the Excellence Initiative offers possibilities for further research, in particular, its influence on firms' or universities' probability to collaborate in R&D. Considering our non-significant findings on Graduate School funding and University Strategy funding, further verification is desirable, in particular an evaluation of their long-term effects.

Appendix

A.1 Tables

Table A-1 Difference-in-differences with different combinations of controls*

	Firm innovated within the last three years (0/1)				
	(1)	(2)	(3)	(4)	(5)
Excellence Initiative variables					
# of EC in region	0.010***	0.008***	0.004**	0.005***	0.004**
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Maximum # of EC in region	0.014***	-0.012*	-0.002		
	(0.005)	(0.007)	(0.004)		
# of GS in region	-0.003*	-0.002	0.003	0.001	0.003
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Maximum # of GS in region	-0.010**	-0.006	-0.007		
	(0.004)	(0.008)	(0.005)		
# of US in region	-0.012*	-0.007	-0.004	0.002	-0.008
	(0.006)	(0.006)	(0.006)	(0.005)	(0.007)
Maximum # of US in region	0.021	0.000	0.001		
	(0.018)	(0.013)	(0.010)		
Region control variables					
Scientists in social sciences		0.000	0.000		
		(0.000)	(0.000)		
Scientists in life sciences		-0.000	0.000		
		(0.000)	(0.000)		
Scientists in natural sciences		0.000**	0.000		
		(0.000)	(0.000)		
Scientists in engineering sciences		0.000	-0.000		
		(0.000)	(0.000)		
# of awarded doctoral degrees		-0.000	-0.000		
		(0.000)	(0.000)		
# of technical universities		0.038**	-0.005		
		(0.016)	(0.009)		
# of university clinics		0.037**	-0.001		
		(0.016)	(0.010)		

Continuation on next page

Table A-1 – Continuation

Firm control variables					
Sized between 50 and			0.079***	0.080***	
less than 250 employees (0/1)			(0.004)	(0.004)	
Sized more than			0.162***	0.162***	
250 employees (0/1)			(0.006)	(0.006)	
Aged between 7 and			-0.006	-0.005	
less than 21 years (0/1)			(0.006)	(0.006)	
Aged 21 years			-0.024***	-0.023***	
and older (0/1)			(0.006)	(0.006)	
Occasional internal			0.351***	0.350***	
R&D activities (0/1)			(0.006)	(0.006)	
Continuous internal			0.466***	0.466***	
R&D activities (0/1)			(0.006)	(0.006)	
Year FE	✓	✓	-	-	-
State FE	-	✓	✓	-	-
Year-industry FE	-	-	✓	✓	✓
Labor market region FE	-	-	-	✓	-
Firm FE	-	-	-	-	✓
R-squared	0.010	0.019	0.295	0.297	0.548
Observations	155,119	155,119	155,119	155,119	155,119

Estimates are based on a linear probability model. The sample corresponds to all firms from the Mannheim Innovation Panel during our observation period. Standard errors are in parentheses and clustered at the labor market region. Constant is included. P-values correspond to * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A-2 Differences in the selected lag of treatment variables

	Firm innovated within the last three years (0/1)					
	(1)	(2)	(3)	(4)	(5)	(6)
t - # of EC	0.004**	0.005**	0.004*	0.005*	0.004*	0.005*
in region	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
t-1 - # of EC	0.008***	0.009***	0.009***	0.010***	0.010***	0.009**
in region	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)
t-2 - # of EC	0.005**	0.005*	0.006**	0.006***	0.006***	0.006*
in region	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
t-3 - # of EC	0.005**	0.004	0.005*	0.006**	0.006**	0.008**
in region	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
t-4 - # of EC	0.005**	0.004	0.005*	0.007**	0.006**	0.007
in region	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.005)
t - # of GS	0.003	0.003	0.003	0.003	0.003	0.002
in region	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
t-1 - # of GS	0.000	0.000	0.000	0.000	-0.000	-0.000
in region	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
t-2 - # of GS	0.002	0.002	0.002	0.002	0.001	0.001
in region	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
t-3 - # of GS	0.002	0.002	0.002	0.002	0.001	-0.000
in region	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
t-4 - # of GS	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002
in region	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
t - # of US	-0.008	-0.008	-0.007	-0.007	-0.007	-0.006
in region	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.009)
t-1 - # of US	-0.007	-0.009	-0.008	-0.009	-0.009	-0.004
in region	(0.007)	(0.007)	(0.007)	(0.006)	(0.007)	(0.008)
t-2 - # of US	-0.009	-0.009	-0.010	-0.010*	-0.011*	-0.008
in region	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
t-3 - # of US	-0.015**	-0.015*	-0.015*	-0.017**	-0.016**	-0.023***
in region	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
t-4 - # of US	-0.005	-0.005	-0.005	-0.009	-0.006	-0.007
in region	(0.008)	(0.010)	(0.009)	(0.010)	(0.009)	(0.010)
Regions with	or without university	university	uni. invited to EC	uni. invited to GS	uni. invited to EC, GS	uni. inv. to EC, GS, US
Observations	155,119	84,276	64,170	60,127	55,463	29,958

Estimates are based on a linear probability model. The coefficients for each lag-level are estimated in separate regress-ions due to the high multicollinearity between lags. Standard errors are in parentheses and clustered at the labor market region. Firm FE, year-industry FE, and constant are included. P-values correspond to * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

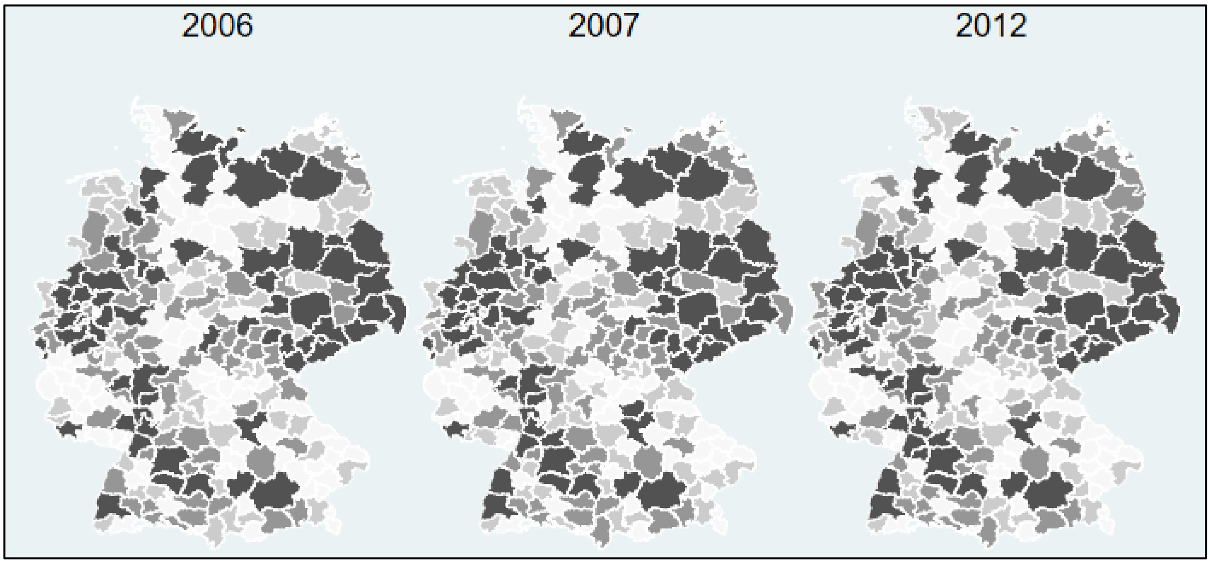
Table A-3 Difference-in-differences for first two funding rounds

	Firm innovated within the last three years (0/1)					
	(1)	(2)	(3)	(4)	(5)	(6)
# of EC in region	0.009**	0.010***	0.011***	0.011***	0.011***	0.010
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.007)
# of GS in region	-0.002	-0.002	-0.002	-0.003	-0.003	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)
# of US in region	-0.007	-0.009	-0.009	-0.010	-0.009	-0.008
	(0.010)	(0.011)	(0.010)	(0.011)	(0.010)	(0.018)
Regions with	or without university	university	uni. invited to EC	uni. invited to GS	uni. invited to EC, GS	uni. inv. to EC, GS, US
R-squared	0.581	0.596	0.6	0.602	0.604	0.602
Observations	95,240	50,814	37,840	35,218	32,264	16,026

Estimates are based on a linear probability model. All samples are limited to the years 2000 to 2011. Standard errors are in parentheses and clustered at the labor market region. Firm FE, year-industry FE, and constant are included. P-values correspond to * $p < 0.1$,** $p < 0.05$, *** $p < 0.01$.

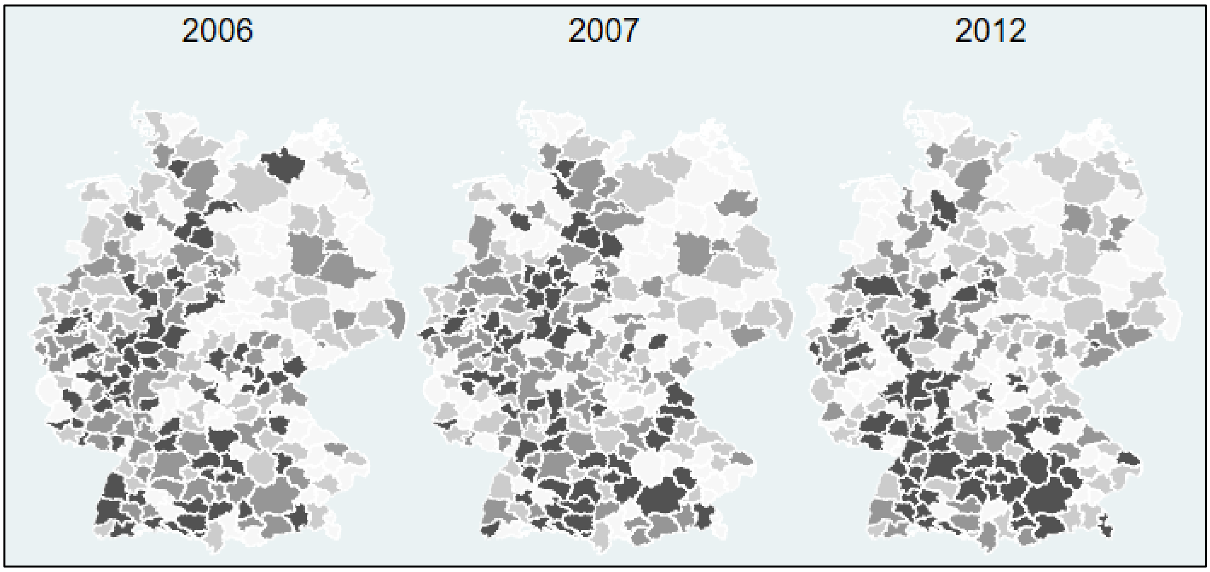
A.2 Figures

Figure A–1 Geographical distribution of sample firms



Note: Figure B-1 shows the distribution of the number of our sample firms across labor market regions within Germany. Light-grey represents regions within the first quartile of the number of firms within a labor market region, medium-light grey, the second quartile, medium-dark grey the third quartile, and dark grey the fourth quartile. Therefore, a darker color represents a higher number of sample firms within a labor market region.

Figure A–2 Geographical distribution of average innovativeness



Note: Figure B-2 shows the distribution of the share of innovating firms across labor market regions within Germany. Light-grey represents regions within the first quartile of the share of innovators within a labor market region, medium-light grey, the second quartile, medium-dark grey the third quartile, and dark grey the fourth quartile. Therefore, a darker color represents a higher share of innovators within a labor market region.

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