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Systemic Aspects of R&D Policy

Subsidies for R&D Collaborations and Their Effects on Private R&D

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Dirk Engel, Michael Rothgang, and Verena Eckl[1]

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Abstract

The paper analyses how context and time dependent factors determine the impulse of R&D subsidies on firm behavior with respect to private R&D expenditures. Based on data from the German R&D survey, we combine propensity-score matching with a difference-in-difference-estimator in order to measure the causal influence of public direct R&D project funding on firm behavior. Our results indicate that (i) repeated participation in R&D projects on average leads to a higher increase in R&D expenditures than one-time funding; (ii) the aggregate effect of R&D funding on R&D expenditures of business firms is somewhat higher for business and business collaboration projects than for science and business collaboration projects; (iii) R&D expenditures of business firms that cooperate with science show a higher share of external R&D spending. Results of one particular cluster programme indicate that at least the short-term development of R&D does not so much depend on which programme direct R&D project funding is applied to.

JEL Classification: C14, C25, H50, O38

Keywords: R&D; public subsidies; collaboration; policy evaluation

November 2015

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1 Introduction

The recent years have witnessed a growing understanding that the effects of innovation policy are dependent on several factors like the context in which policy instruments and programmes are embedded as well as differing patterns of firm behaviour. While other contributions in this volume look at innovation policy from the perspective of policy design (Martin in this volume), regional innovation systems (Brown in this volume), or mission- vs. non-mission-oriented policy approaches (Mazzucato in this volume), our paper focuses on the context-dependency of the use of R&D policy instruments and its systemic effects. While Flanagan and Uyarra (in this volume, see also Flanagan et al. 2011) stress the time- and context-dependency of the use of R&D policy instruments, this contribution looks at different behavioural patterns that can be observed independent of the changing general schemes (mission-oriented or program-dependent) that these instruments are used in.

We analyse the effects of the so-called Direct R&D Project Funding (DPF) scheme, which represents one important strand of instruments that is used by the German Federal Government to promote R&D in private firms. Within direct public funding schemes, public subsidies are offered to all business firms in order to induce additional efforts in R&D. DPFs are used in mission-oriented programmes (especially the programmes of the German Hightech strategy), or focused on target groups (like the Central Innovation Programme for Small and Medium-sized Enterprises - SMEs), and also in Federal programmes that accentuate the role of clusters (like the Leading-Edge Cluster Competition).

The question that arises is how these instruments shape the context of private R&D and influence behaviour with respect to private R&D activities. In our analysis, we look at different factors that determine the context of R&D policies: (i) the role of funding aimed at different forms of R&D cooperations (either between business firms or business firms or business

firms with public research organisations, (ii) the dependence of the policy effect on funding history, and (iii) whether the effect we observed depends on the programme context in which a policy instrument is applied. Systemic patterns become obvious when the use of the instruments influences either the behavioural patterns of the actors involved or the division of functions within the innovation system. Of course, different reactions to R&D funding can be observed for individual firms, depending on the individual situation, such that econometric results are able to identify general trends in a rather diverse field.

The project related R&D expenditures we are focusing on increased continuously since the 1950s to about 5 bn € in 2011 (the total government R&D expenditure was 23,446 Bill. € in 2011).[2] This number can best be compared to the expenditure for basic and applied research (about 55% of total R&D expenditure of business firms of about 51 bn, €, i.e. 28 bn €). Thus, public project expenditure within the DPF scheme relates to about 18% of total firm expenditure for research.

DPFs are quite common in Germany when it comes to promotion of R&D cooperation. Based on the dataset at hand, we estimate, that about 18.2% of all R&D performing business firms in Germany received DPF funding from Federal government for R&D cooperations in 2009, of which about 18.5% cooperate with at least one research institute. SMEs are more likely to attend R&D programmes for collaborative research: 18.9% of all R&D performing SMEs were involved in such programmes, of which about only 10.6% cooperate with at least one research institute. From the perspective of individual firms, DPFs are a significant source of public R&D funding.

The dataset from the R&D survey of the SV Wissenschaftsstatistik which is used in our analysis represents a full survey of the business firms in Germany that perform R&D. Thus, we

[2] Calculation based on BMBF 2014: 498-500.

are able to scrutinize how one important aspect of government R&D policy influences firm R&D behaviour.

The paper is structured as follows: In section 2 an overview of the empirical literature on the effectiveness of R&D programmes is provided. Section 3 discusses the characteristics of our dataset and the methodological approach we use. The results are presented and interpreted in section 4, and section 5 concludes.

2 R&D subsidies and Business Firm R&D Expenditure: Literature Review

The economic effects of R&D subsidies business on firm R&D expenditure have been addressed by many studies. At the same time, R&D subsidies have been widely used in innovation policy within very different contexts and programmes – partly aiming at general promotion of R&D, partly also adapted to more mission-oriented approaches.

Economic studies that apply state-of-the-art methodology mainly focused on effects of that policy instrument on R&D expenditure (Duguet 2004, Czarnitzki and Fier 2002, Wallsten 2000, Czarnitzki and Lopes-Bento 2014). In his pioneer work, David et al. (2000) surveyed empirical studies with respect to the question whether public subsidies crowd out private R&D expenditures. Full crowding out means that total R&D expenditures do not change, and companies reduce private R&D by the amount of public subsidies received. The theoretical background of these papers is derived from a market failure approach: As market incentives lead to a suboptimal level of business firm R&D expenditure, government subsidies induce an increase in private R&D spending in order to internalize the external effects derived from spillovers of R&D.

This paper looks at the effects of R&D expenditure from a systemic viewpoint. We see R&D subsidies as an instrument which could result in quite different effects depending on the con-

text in which they are applied (either with respect to innovation system context, policy mix or time dependent factors like policy missions in which they are analysed, see also the contributions of Brown, Flanagan and Uyarra, and Martin in this volume).

Empirical evidence shows that the impulse that results from public funding is dependent on different structural conditions like subsidy history, subsidy amount, financial constraints, differentiating between total R&D and private R&D, sources of funding (Borrego et al. 2014).

In this paper we focus on how two factors influence the effects of R&D spending on the extent and the composition of R&D with respect to internal and external R&D, namely the role of subsidy history, and the form of collaboration. In addition, we ask whether differences arise from R&D subsidies that are used within a Federal Cluster programme as compared to other programmes. These factors are closely related to the decision mechanisms in R&D departments and to the way how the internal knowledge base is developed by collaborative R&D.

Regarding the role of subsidy history, many studies found a persistence of funding over a long time for a significant share of funded firms (e.g. Borrego et al. 2014 for a summary). In addition, firms with subsidy history have a higher propensity to receive funding than firms without a funding history. Of course, the role of subsidy history for R&D behaviour strongly depends on how internal routines within the individual firms are designed and the way how public funds contribute to the overall R&D budget.

It is uncertain, however, whether repeated funding should lead to an increase or decrease R&D activities of individual firms: The costs of firm specific efforts (e.g. writing proposals, winning partners) to receive additional funding decrease with repeated funding. Partners in collaborative projects profit from the funding experience of firms and thus, previously funded

firms are more likely to acquire adequate partners quickly. The released internal funds can basically be allocated to other activities, e.g. additional R&D activities.

Against these arguments, successful experience might partially increase bandwagon effects. Firms identify R&D subsidies as a continuous financial source and include the subsidies as fixed income for (private) R&D budgets. In this sense, many more R&D projects are offered to the public bodies responsible for R&D programmes and the share of projects which can be potentially funded by internal funds only increases. While the government follows a picking-the-winners strategy (e.g., Borrego et al. 2014), funding bodies prefer those projects which are more likely to be successful. These projects, however, do have a higher chance to be financed by other means. The overall effect might be ambiguous from a theoretical point of view. Aschhoff (2009) finds that frequently funded firms show greater private R&D spending than firms that have been funded for the first time.

The effect of funding instruments on firms' internal and external R&D expenditure is almost neglected by empirical research and is paid only little attention to in recent surveys. Understanding the composition between external and internal R&D and the factors featuring changes in this relationship is rather important for understanding the influence that R&D policy has on the division of labour between business firms and science.[3] While a growing literature indicates that private R&D benefits from knowledge spillovers from universities and other publicly funded research institutes within science and business (S&B) collaborative projects (e.g. Jaffe 1989, David et al. 2000, Adams 2002, Adams et al. 2003, Autant-Bernard 2001, Rosa and Mohnen 2008, Karlsson and Andersson 2009), we still don't know much about the spillover effects of different forms of R&D collaborations on the level of firms. The empirical

[3] Since the relationship between external R&D and innovation output is rather u-shaped (e.g., Grimpe and Kaiser 2010, Berchicci 2013), composition changes are of particular importance. Cassiman and Veugelers (2006) found that firms with internal and external R&D have significant higher sales with new products than firms with particular focus on either internal or external R&D.

study of Czarnitzki et al. (2007) shows that funded firms with collaborations show significant higher R&D expenditures per sales than funded firms without collaborations.

It seems reasonable to assume that the effect of R&D policy instruments differs with the context in which they are used. Programme targets certainly influence the programme related use and design of single policy instruments (Flanagan and Uyarra 2016, Flanagan et al. 2011). At the same time, not much empirical evidence exists on how programme design influences firm behaviour with respect to R&D expenditures.

3 Methodology and data

3.1 Econometric approach

Our objective is to identify the effect of being in a specific group for the group members, for example for firms that received funding. This '**a**verage mean effect of **t**reatment on the **t**reated' (ATT) is assessed by measuring an outcome variable that captures impacts of R&D grants in the treatment performance. Finding a reliable estimate for the counterfactual state, i.e. the outcome if participants had not participated in the program, is the principal task of any evaluation study. We employ the so-called 'hybrid matching' which combines propensity score matching with Mahalanobis distance for major firm characteristics (see e.g. Almus and Czarnitzki 2003 for details) to select suitable control firms. After that we calculate the $ATT\text{-}_{DID}$, evaluating the mean change of the R&D indicator over all treated firms between the year before treatment and k years after becoming a treatment minus the mean change over all matched non-treated firms for the same indicator and the same time period. Compared to a simple comparison of outcomes in the treatment period, the DID estimator has the main advantage that time-invariant effects of selection on unobservable variables (competencies, skills, abilities) are eliminated (see Heckman et al. 1998). While R&D expenditures are di-

rectly linked to output variables, like sales with new products (e.g. Janz et al. 2004), this measure is a suitable variable that has been discussed in many empirical studies to address effects of public subsidies.

3.2 Data, sample construction and variables

We prepare a unique dataset based on three data sources: First of all, we use R&D data collected by the Wissenschaftsstatistik GmbH of Stifterverband (SV Wissenschaftsstatistik).[4] The SV Wissenschaftsstatistik survey of R&D activity in the business enterprise sector is conducted on a two-year-cycle in the form of a questionnaire addressed to all identified R&D-active enterprises in Germany ("full survey"). Since there is no complete register from which this information can be obtained, all enterprises which can be presumed to be active in R&D are contacted. The criteria for the selection are essentially R&D reports in previous years, size of the enterprise, industry sector, and participation in funding programs, patent applications, annual reports or press announcements concerning research results. In this sense, it can be considered to be a full survey of the R&D activities of the business enterprise sector. The reporting unit for enterprises is normally the smallest accounting unit. Enterprise groups, however, are divided up into business units which are classified according to particular economic activities. The data set collected contains information on R&D expenditures (total, internal, external, financing sources), R&D personnel, strategic orientation of R&D activities as well as some basic facts (turnover, employees, industry). We expand the data set by including charac-

[4] The R&D statistics of the SV Wissenschaftsstatistik are part of the official reporting on research, development and innovation of the Federal Government to the EU and the OECD. The underlying definitions of R&D indicators are based on internationally standardized rules that have been set in the "General Guidelines for Surveys on Research and Experimental Development" (Frascati Manual) of the OECD. The micro data set can be used for scientific purposes from the Research data center of the SV Wissenschaftsstatistik.

teristics from Dafne database (Dafne)[5] and from the Federal Government Project Funding Information Database (PROFI).[6]

For the purpose of this study we differentiate between different firm samples.

< **Table 1** about here >

We start with the comparison between firms funded in 2011 and non-funded firms in the same year (sample A). Based on sample B and B1 we ask whether firms with funded business-business collaborations perform better than suitable twins with science-business collaborations. Sample C and C1 highlight the opposite case, funded firms with science-business collaborations compared to suitable twins with business-business collaborations. The samples B and B1 as well as C and C1 differ only with respect to the length over time of funding. Based on sample D we are able to address the effect of repeated funding on R&D expenditures.

In line with related studies (e.g., González and Pazó 2008, Aschhoff 2009, Czarnitzki and Lopes-Bento 2014) we consider major firm characteristics to explain R&D expenditures, namely *(previous) R&D expenditures (log), R&D expenditures related to firm turnover, previous grant receiving (dummy), firm turnover (log), firm age (log), foreign parent company (dummy), legal form (dummy)* to address potential selection effects to become a programme participant or to belong into a specific group of treatment.

3.3 Qualitative Results

In the assessment of the econometric results below, we use qualitative empirical information that was collected in course of the Accompanying Evaluation of the Leading-Edge Cluster

[5] The database is offered by Creditreform, the largest German credit rating agency, and Bureau van Dijk (BvD), a leading company in electronic publishing of business information. Dafne contains current and historical accounting data as well as information to subsidiaries and ownership.
[6] The PROFI database covers the civilian R&D funding of the German Federal Government and contains project related information (amount of funding, name and address of recipients, R&D program, individual versus collaborative projects, and so on).

Competition (Rothgang et al. 2014). We use information from a written survey that asked about differences of DPF projects that were funded in this programme to similar projects funded in other programs. The questionnaire was sent to funding recipients from the first two competition rounds. In addition, we performed expert interviews with firm representatives. While R&D expenditure was one topic scrutinized, we especially addressed the firm context in which the funded projects were performed and the differences towards other programmes. About 30 expert interviews were conducted. These interviews are used here in order to assess the results of the quantitative analysis.

4 Results and discussion

Propensity Score and Balancing of the Samples

Table 2 shows the probit estimation to derive the propensity score for funded and non-funded firms (sample A). The propensity to receive funding is greater for firms with high level of R&D expenditures, previously funded firms and well-prospering firms. Foreign ownership does not matter, although firms that belong to company groups obtain funding to a less extent. Since core R&D activities are concentrated mostly close to headquarters, subsidiaries are less active to acquire external funding.

< **Table 2** about here >

Based on propensity score and Mahalanobis distance matching we match the best suitable non-funded firm to each of the funded firms according to sampling with replacement. For our exemplary constellation, both groups of companies are very similar in terms of key indicators after the matching procedure was applied. The mean values of the variables are very similar for both groups and do not differ significantly from each other (**Table 3**). This result under-

lines the validity of our matching procedure. Despite the high similarity in core variables a good "balancing" for the other variables could be achieved. [7]

< **Table 3** about here >

Effect of R&D Funding

The results for *all funded firms* are depicted in **Table 4**. Funded firms exhibit on average an increase of about 28 per cent in R&D expenditures, whereas matched non-funded firms reduce R&D expenditures significantly. The reduction is driven by a substantial drop in internal R&D expenditures. Against this, funded firms increase internal and external R&D expenditures nearly by the same amount. Funded firms also perform better with respect to related R&D intensity measures, although the difference compared to non-funded firms is only significantly different from zero for external R&D expenditures related to turnover. The level of private R&D spending increases significantly. This finding is in line with many other studies for Germany (e.g. Aschhoff 2009) and suggests the additionality of R&D subsidies.

The findings for the sub-samples of SMEs are similar in a qualitative manner. In fact, the ATT is slightly larger for SMEs compared to larger firms.[8] Among many others, González and Pazó (2008) also found only small differences in the effect of subsidy on R&D expenditures by firm size. We fairly assume that the higher level of underinvestment in R&D by SMEs (e.g., Carpenter and Petersen 2002, Hall 2002, Bond et al. 2005) might matter. Many SMEs are also confronted with no regular R&D budget at all which implies higher costs to prepare R&D projects. In contrast to that, the R&D budget of larger firms is only moderately flexible in the short-term, and thus, probably in many cases the increase in R&D expenditure

[7] In fact, the large number of possible twin firms in the R&D survey of SV Wissenschaftsstatistik is a basic prerequisite to prepare the matching procedure successfully.
[8] The complementary result for the median values supports the main findings. Results are available upon request.

amounted to the sum of the public subsidy.[9] SMEs then are more likely to gain from a subsidy and thus, the leverage effect of public subsidies is larger for SMEs.

< **Table 4** about here >

These results are in line with the results from expert interviews that were conducted with firms that performed funded R&D cooperation projects in one Federal cluster programme, the Leading-Edge Cluster Competition. The interviews showed that R&D managers tended to use the programme participation to extend the R&D budget (in some cases also to address new topics that opened up new promising paths of R&D activity). The private co-funding that is usually demanded as pre-requisite for the R&D subsidies is usually provided by shifting internal sources. These interviews also showed, that some (but not all) SMEs had no possibility to shift internal sources as their R&D activity level did not provide the opportunity. Thus, their leverage effect with respect to R&D activities tended to be higher.

Form of Collaboration and R&D Behaviour

With respect to our first research question, the *role of the form of collaboration*, we test empirically whether the effect of science and business (S&B) collaborative projects on R&D is significantly different from those of business and business (B&B) collaborative R&D projects. The results of the group comparisons between *all* funded firms in B&B and matched firms with S&B collaborative R&D projects[10] are presented in **Table 5**. The B&B group shows a significantly larger increase of about 29 per cent in R&D expenditures compared to 22 per cent increase of the S&B group. We further detect significant changes towards relatively more external R&D for firms with collaborations to science compared to firms with collaborations to other businesses. The results for SMEs point to the same direction in an even

[9] This observation results from the literature on determinants of firm level R&D budgets which show them to be rather persistent and determined by past decisions (see e.g. Brockhoff 1999: 250).
[10] Matched firms are a subset of all firms with the specific characteristics and thus, we must also analyze the opposite case to test the robustness of findings by considering all firms in the group.

stronger manner. The significant higher value for S&B firms in terms of R&D expenditures per employees on the one hand, together with the lower increase of internal R&D on the other hand, indicates that funded B&B collaborative R&D projects outperform S&B collaborations with respect to the number of employees within the firm.[11]

We further test the robustness of results by considering the time span of funding. **Table 6** depicts the findings for at least two years of funding, whereas the time span is not fixed in **Table 5**. Based on a more intense increase in internal R&D expenditures, overall R&D expenditures rise significantly stronger for firms in funded B&B projects than for firms in S&B projects in the mid-term. The composition change towards relatively more external R&D for matched firms with S&B projects is supported again. This finding cannot be confirmed, however, for the sample of SMEs. The change of R&D expenditures does not differ significantly between SMEs with funded R&D collaborations to other businesses compared to SMEs with funded R&D collaborations to science.

The result of composition change is also suggested for the opposite case by looking at *all* firms with funded S&B projects compared to matched firms with funded B&B projects in the short-term (see **Table 7**). The ATTs for the sub-sample of SMEs are just insignificant. The same is true for the samples of large firms and SMEs in the mid-term (**Table 8**)[12]. Therefore, composition change is more likely for larger firms in the short-term.

To sum up, there is some evidence that firms with funded R&D collaborations to science prefer to a larger extent the strategic option of the external R&D procurement than firms with funded collaborations to other businesses. The form of collaboration matters for the composition of R&D expenditures even though the level of private R&D spending does not differ significantly.

[11] The growth rate for firms in B&D projects (15.3%) differs significantly from those for firms in S&B projects (7.9%).
[12] The number of observations is relatively low, however, and therefore, results should be interpreted with caution.

While the interviews with programme participants do not clearly indicate the direct reasons for differences in changing internal vs. external R&D expenditure, they show that firms perform S&B and B&B research cooperations in many cases for different reasons which should also influence their effects on the R&D budget:

- The expert interviews showed, that in a division of labour with firms, public research units often focus their collaborative projects on application oriented basic research which is inspired by applied questions or projects that are precompetitive from the viewpoint of the individual firm. In this manner, firms are able to gain new impulses from collaborative research with research institutes with the aim to enhance their knowledge base from impulses that result from basic research. At the same time, internal R&D is often necessary to make use of externally created knowledge.

- On the contrary, collaboration between business firms is often oriented towards making use of different knowledge bases in the development of new products and production processes. The collaboration is often more oriented towards realizing a common benefit from the project.

From this behavioural perspective, it seems probable that S&B-collaborations lead to an increase both in internal and external R&D expenditure, while B&B collaborations are more associated with a relative increase in internal R&D.

< **Table 5** about here >

< **Table 6** about here >

< **Table 7** about here >

< **Table 8** about here >

Subsidy History and R&D Behaviour

Table 9 sheds light on the role of subsidy history, the second major object of investigation in our study. Frequently funded firms showed a higher increase in R&D indicators than firms funded for the first time regarding total R&D spending, private R&D spending as well as internal R&D expenditures. The pattern confirms findings of Aschhoff (2009). In addition to that, we conclude that repeated funding helps the firms to build up and stabilize their research capabilities. With respect to the discussion in section 2 one may assume that effects on innovation performance might be different. Aschhoff (2009) found no significant differences between firstly funded and frequently funded firms. While her analysis did not address the composition between internal and external R&D, we do not know whether the finding is reasoned by the fact that composition change was observed.

< **Table 9** about here >

Observations from our expert interviews show that there are no simple patterns why firms regularly participate in public programmes while others don't. Many firms that do irregularly participate in public programmes also do not perform own R&D on a regular basis. R&D projects (whether internally or externally financed) in these firms are done on a less regular basis which leads to irregular patterns of R&D expenditure. Projects are done when an opportunity arises and a new project idea comes up. Firms that take part in R&D programmes on a regular basis, on the other hand, seem to have a smoother growth in their R&D expenditure. Our interviews showed that public funding developed into a fixed part of their R&D activities with a close interdependence of externally financed (often more precompetitive) projects and internal projects that are closer to the core R&D tasks on the firm level. This should also lead to a smoother pattern of R&D over time.

Programme Characteristics and R&D Behaviour

While the analysis performed above does not differentiate between the programmes within which the funding scheme is used, another analysis based on the same data set and method compared the effect within one new complex funding programme (the funding instrument Leading-Edge Cluster Competition) with participation in other programmes (Eckl, Engel, Rothgang 2015). Based on these results, first hints can be derived about the effect of the mainly time-invariant funding instrument and about its use in different programme schemes. The aim of the Leading-Edge Cluster Competition is to give an additional impulse by funding projects that are developed under one common cluster strategy by regional firms and research institutes.

The results of the econometric analysis show, that there was no significant difference with respect to the leverage effect on R&D expenditure as compared to firms funded in other programs. The common characteristic is that the involved procedures in application and supervision and the respective requirements from the project executing organisations are rather similar. Thus, from the perspective of the individual firms the projects are regarded as rather similar. This was also confirmed by expert interviews with firms and a written survey conducted in the course of the evaluation of the Leading-Edge Cluster Competition. Firms involved saw not much difference as to whether the projects were funded in one or the other kind of programme and actually most firm representatives stated that their project could be financed in different kinds of programmes with not much practical differences. Differences arose e.g. with respect to contacts with new cooperation partners in programmes that were designed to reach that goal or with respect to programmes that were more or less application oriented. Whether these differences show up in other indicators (or long-term changes in R&D expenditure) has not been scrutinized yet.

5 Conclusions

By looking at the effect of project R&D subsidies on firm behaviour in Germany, our study contributes to the knowledge on the influence of the research system on business sector R&D activities. We combine propensity-score matching with a difference-in-difference-estimator in order to address the effect of R&D subsidies on firm R&D expenditure, the role of funding history as well as the form of funded collaboration on R&D expenditures and its composition.

Our results show that both funding history and form of collaboration influence the effect of R&D subsidies on firm behaviour. Thus, both the long-term development of R&D policy and the R&D program structure are relevant for the outcome:

- Frequently funded firms have shown a larger increase in private R&D spending than firstly funded firms.
- Firms with B&B-collaborations increase their R&D budget by a significantly larger amount which leads to a higher leverage effect (however not automatically a better outcome of R&D).
- Firms with funded R&D collaborations to science increase external R&D procurement by a larger amount than firms with funded collaborations to other businesses even though the level of private R&D spending is unchanged. The results on internal and external R&D expenditures should be regarded in the more general context of firm outsourcing of R&D activities: Firms with funded business-to-business collaborations tend to have a lower composition change towards external R&D than matched firms with science-to-business collaborations. So, from a systemic point of view, funding science-to-business collaborations seems to promote the externalization of R&D tasks. The effect is less pronounced for longer term collaborations, however.

- We find no difference with respect to the effects mentioned for the subsample of SMEs. So, it seems that the system does not exert different effects on SME behaviour compared to large firms although many studies come to the conclusion that SMEs have more problems with R&D funding.

- By comparing the effect of R&D project funding in one programme, the Leading-Edge Cluster Competition, with other programmes, we find no difference in the effect on private R&D expenditure. However, it is of course possible that in line with the targets of the programme either long-term effects on R&D expenditure or effects with respect to other indicators of innovation activities or output can be found.

With respect to the systemic effects of R&D project funding our results also indicate that private R&D spending is not hampered if funding bodies select previously funded firms and that funded collaborations are characterized by heterogeneous actors. The structure of the R&D project landscape (kinds of projects) and the firm landscape (experienced firms that have been funded before vs. firms not receiving R&D project funding in advance) influence the outcome with respect to firm R&D expenditure.

Of course, the relationship between R&D project funding and R&D activities/output is only one aspect of project funding. How the public R&D project funding landscape influences the R&D output should be looked at in future studies.

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Appendix

Table 1: Samples under considerations

sample	Group	2009	2011
A	Treated	Not fixed	Direct project funding (DPF)
A	control	Not fixed	No DPF
B	Treated	Not fixed	Business & Business DPF
B	Control	Not fixed	Science & Business DPF
B1	Treated	Business & Business projects DPF	
B1	Control	Science & Business projects DPF	
C	Treated	Not fixed	Science & Business projects DPF
C	Control	Not fixed	Business & Business projects DPF
C1	Treated	Science & Business projects DPF	
C1	Control	Business & Business projects DPF	
D	Treated	DPF	DPF
D	Control	No DPF	DPF

Table 2: Probit estimations (sample A)

Variables (in 2007)	Coefficient	Robust St.-error
R&D expenditures/turnover	0.005**	0.002
R&D expenditures (ln)	0.165***	0.032
R&D employees (ln)	0.141***	0.023
Turnover (ln)	-0.182*	0.098
Turnover squared (ln)	0.008*	0.005
Growth rate of turnover (2009-2011)	0.312***	0.061
Firm age (ln)	-0.118***	0.031
Part of firm group	-0.347***	0.069
Public company	0.837***	0.270
Non-public limited liability company	0.582**	0.261
Foreign owner	-0.098	0.070
Subsidiaries	0.155**	0.063
Previous funding (Federal, EU)	1.178***	0.053
Constant	-1.464***	0.563
Industry dummies (5)	Considered	
Federals States dummies as well as its aggregates (7)	Considered	
Number of observations	4.038	
LR chi² (27 variables)	958.88***	
Pseudo R²	0.2858	

Sample A: 1: DPF funded firms in 2011, 0: non-funded firms in 2011. * p<0.10, ** p<0.05, *** p<0.01.

Table 3: Balancing test for nearest neighbor matching (sample A)

Variables (in 2007)	funded	Non-funded before Matching	Non-funded after Matching
R&D expenditures/turnover	19.932	6.902***	18.571
R&D expenditures (ln)	6.970	5.925***	6.872
R&D employees (ln)	0.739	0.305***	0.613
Turnover (ln)	9.496	9.696***	9.432
Turnover squared (ln)	95.924	97.708***	94.315
Growth rate of turnover (2009-2011)	0.047	-0.054***	0.042
Firm age (ln)	2.284	2.431	2.265
Part of firm group	0.208	0.261	0.200
Public company	0.146	0.070	0.140
Non-public limited liability company	0.751	0.785***	0.754
Foreign owner	0.193	0.187***	0.188
Subsidiaries	0.416	0.341***	0.407
Previous funding (Federal, EU)	0.818	0.321***	0.813
Propensity score	0.491	0.173***	0.478**

Sample A: DPF Funded firms in 2011 and matched non-funded firms in 2011. Mean values are depicted. Results based on Mahalanobis distance matching (mahal' variables: propensity score, R&D expenditures/turnover, growth rate of turnover and turnover (ln). Mean values for industry dummies and federal state dummies do not differ significantly between both groups and are not depicted in the table. * p<0.10, ** p<0.05, *** p<0.01.

Table 4: Group comparison after matching (sample A, mean values)

Outcome variable	Funded	Non-funded	ATT_{DiD}	t-test	#
All firms (2007-2011)					
Δ R&D-exp./employees	1.633	-3.76	5.393	5.16 ***	990
Δ R&D-exp./turnover	-0.616	-6.739	6.123	7.11 ***	991
Δ internal R&D-exp./turnover	-0.437	-6.236	5.799	7.15 ***	965
Δ external R&D-exp./turnover	-0.164	-0.503	0.339	1.59	965
CGR R&D expenditures	0.281	-1.538	1.819	20.36 ***	990
CGR internal R&D-expend.	0.275	-1.493	1.768	19.92 ***	965
CGR external R&D-expend.	0.236	-0.544	0.779	7.36 ***	966
Ln(private R&D spending)	6.813	5.264	1.548	11.75 ***	987
SME only (2007-2011)					
Δ R&D-exp./employees	0.697	-7.114	7.811	5.88 ***	690
Δ R&D-exp./turnover	-1.267	-8.91	7.643	6.82 ***	691
Δ internal R&D-exp./turnover	-1.007	-7.445	6.438	5.98 ***	668
Δ external R&D-exp./turnover	-0.293	-1.466	1.172	3.60 ***	668
CGR R&D expenditures	0.31[a]	-1.858	2.168	20.34 ***	691
CGR internal R&D-expend.	0.311	-1.789	2.1	19.73 ***	669
CGR external R&D-expend.	0.173	-0.904	1.077	9.28 ***	669
Ln(private R&D spending)	5.812	4.096	1.715	13.83 ***	688

Sample A: DPF Funded firms in 2011 and matched non-funded firms in 2011. Discrete change (Δ) or continuous growth rate (CGR) of mean values. [a] The value 0.31 means an increase of about 31%. ATT_{DiD}: difference between mean values in column 2 and 3. # Number of observations. * p<0.10, ** p<0.05, *** p<0.01.

Table 5: Group comparison after matching (sample B, mean values)

Outcome variable	Funded B&B	Matched Funded S&B	ATT_{DiD}	t-test		#
All firms (2007-2011)						
Δ R&D-exp./employees	1.134	5.778	-4.644	4.12	***	801
Δ R&D-exp./turnover	-0.532	-0.754	0.222	0.32		802
Δ internal R&D-exp./turnover	-0.525	-1.033	0.508	0.80		783
Δ external R&D-exp./turnover	-0.189	0.781	-0.97	4.39	***	782
CGR R&D expenditures	0.289	0.214	0.075	1.77	*	802
CGR internal R&D-expend.	0.289	0.109	0.179	3.46	***	783
CGR external R&D-expend.	0.237	0.72	-0.482	4.37	***	783
Ln(private R&D spending)	6.732	6.644	0.088	0.88		987
SME only (2007-2011)						
Δ R&D-exp./employees	0.645	6.169	-5.523	3.63	***	573
Δ R&D-exp./turnover	-1.073	-1.169	0.096	0.10		574
Δ internal R&D-exp./turnover	-1.002	-1.286	0.285	0.32		556
Δ external R&D-exp./turnover	-0.336	0.559	-0.895	2.96	***	555
CGR R&D expenditures	0.329	0.225	0.104	1.89	*	574
CGR internal R&D-expend.	0.334	0.088	0.245	3.66	***	556
CGR external R&D-expend.	0.187	0.758	-0.571	4.72	***	556
Ln(private R&D spending)	5.841	5.708	0.133	1.48		572

Sample B: DPF Funded firms with business-to-business collaborative projects and matched DPF funded ones with science-to-business collaborative projects in 2011. Discrete change (Δ) or continuous growth rate (CGR) of mean values. ATT_{DiD}: difference between mean values in column 2 and 3. # Number of observations. * p<0.10, ** p<0.05, *** p<0.01.

Table 6: Group comparison after matching (sample B1, mean values)

Outcome variable	Funded B&B	Matched Funded S&B	ATT_{DiD}	t-test		#
All firms (2007-2011)						
Δ R&D-exp./employees	0.177	3.531	-3.354	2.83	***	477
Δ R&D-exp./turnover	-1.544	-1.646	0.102	0.10		477
Δ internal R&D-exp./turnover	-1.418	-0.82	-0.597	0.66		469
Δ external R&D-exp./turnover	-0.479	-0.387	-0.092	0.31		468
CGR R&D expenditures	0.262	0.129	0.133	2.35	**	477
CGR internal R&D-expend.	0.262	0.16	0.102	1.71	*	469
CGR external R&D-expend.	0.175	0.16	0.015	0.12		469
Ln(private R&D spending)	6.893	6.835	0.058	0.47		475
SME only (2007-2011)						
Δ R&D-exp./employees	-0.63	4.008	-4.638	2.88	***	322
Δ R&D-exp./turnover	-2.373	-1.599	-0.774	0.56		322
Δ internal R&D-exp./turnover	-2.204	-0.4	-1.804	1.47		316
Δ external R&D-exp./turnover	-0.696	-0.566	-0.129	0.34		315
CGR R&D expenditures	0.296	0.192	0.104	1.43		322
CGR internal R&D-expend.	0.306	0.253	0.053	0.69		316
CGR external R&D-expend.	0.129	-0.076	0.205	1.34		316
Ln(private R&D spending)	5.944	5.907	0.037	0.33		321

Sample B1 (= subset of sample B): DPF Funded firms with business-to-business collaborative projects in 2009 as well as 2011 and matched DPF funded ones with science-to-business collaborative projects in 2009 as well as 2011. Discrete change (Δ) or continuous growth rate (CGR) of mean values. ATT_{DiD}: difference between mean values in column 2 and 3. # Number of observations. * p<0.10, ** p<0.05, *** p<0.01.

Table 7: Group comparison after matching (sample C, mean values)

Outcome variable	Funded S&B	Matched Funded B&B	ATT_{DiD}	t-test		#
All firms (2007-2011)						
Δ R&D-exp./employees	4.229	-1.27	5.499	1.81	*	178
Δ R&D-exp./turnover	-0.82	0.673	-1.492	0.92		178
Δ internal R&D-exp./turnover	-0.715	1.919	-2.634	1.86	*	172
Δ external R&D-exp./turnover	0.185	-0.705	0.89	1.60		172
CGR R&D expenditures	0.24	0.227	0.013	0.15		177
CGR internal R&D-expend.	0.201	0.285	-0.084	0.78		172
CGR external R&D-expend.	0.289	0.283	0.007	0.03		172
Ln(private R&D spending)	7.544	7.543	0.001	0.00		177
SME only (2007-2011)						
Δ R&D-exp./employees	2.808	-3.19	5.998	1.27		107
Δ R&D-exp./turnover	-2.781	-0.779	-2.002	0.74		107
Δ internal R&D-exp./turnover	-2.504	0.321	-2.825	1.14		102
Δ external R&D-exp./turnover	0.033	-0.836	0.869	1.38		102
CGR R&D expenditures	0.233	0.236	-0.003	0.02		107
CGR internal R&D-expend.	0.192	0.266	-0.074	0.43		103
CGR external R&D-expend.	0.071	0.011	0.06	0.22		103
Ln(private R&D spending)	5.795	5.912	-0.117	0.50		107

Sample C: DPF Funded firms with science-to-business collaborative projects and matched DPF funded ones with business-to-business collaborative projects in 2011. Discrete change (Δ) or continuous growth rate (CGR) of mean values. ATT_{DiD}: difference between mean values in column 2 and 3. # Number of observations. * p<0.10, ** p<0.05, *** p<0.01.

Table 8: Group comparison after matching (sample C1, mean values)

Outcome variable	Funded S&B with subsidy history	Matched Funded B&B with subsidy history	ATT_{DiD}	t-test	#
All firms (2007-2011)					
Δ R&D-exp./employees	3.364	1.957	1.407	0.57	80
Δ R&D-exp./turnover	-3.035	-0.048	-2.987	1.22	80
Δ internal R&D-exp./turnover	-1.681	0.913	-2.594	1.21	79
Δ external R&D-exp./turnover	-0.335	-0.97	0.635	0.79	79
CGR R&D expenditures	0.113	0.348	-0.236	1.61	79
CGR internal R&D-expend.	0.195	0.355	-0.159	0.91	79
CGR external R&D-expend.	0.120	0.163	-0.043	0.10	79
Ln(private R&D spending)	8.037	7.906	0.131	0.30	80
SME only (2007-2011)					
Δ R&D-exp./employees	-0.33	-1.582	1.252	0.39	41
Δ R&D-exp./turnover	-7.646	-1.044	-6.602	1.43	41
Δ internal R&D-exp./turnover	-4.764	-0.43	-4.334	1.03	40
Δ external R&D-exp./turnover	-0.985	-0.614	-0.371	0.37	40
CGR R&D expenditures	0.127	0.198	-0.071	0.44	41
CGR internal R&D-expend.	0.322	0.239	0.083	0.35	41
CGR external R&D-expend.	-0.455	0.22	-0.675	1.33	41
Ln(private R&D spending)	5.839	6.029	-0.191	0.62	41

Sample C1 (= subset of sample C): DPF Funded firms with science-to-business collaborative projects in 2009 as well as 2011 and matched DPF funded ones with business-to-business collaborative projects in 2009 as well as 2011. Discrete change (Δ) or continuous growth rate (CGR) of mean values. ATT_{DiD}: difference between mean values in column 2 and 3. # Number of observations. * p<0.10, ** p<0.05, *** p<0.01.

Table 9: Group comparison after matching (sample D, mean values)

Outcome variable	Funded firms with subsidy history	Matched Funded without subsidy history	ATT_{DiD}	t-test		#
All firms (2007-2011)						
Δ R&D-exp./employees	1.876	1.399	0.477	0.49		413
Δ R&D-exp./turnover	-0.152	-4.183	4.031	5.14	***	413
Δ internal R&D-exp./turnover	-0.155	-4.5	4.345	5.60	***	405
Δ external R&D-exp./turnover	-0.11	0.268	-0.378	2.24	**	405
CGR R&D expenditures	0.294	-0.354	0.648	7.41	***	412
CGR internal R&D-expend.	0.283	-0.372	0.655	7.36	***	404
CGR external R&D-expend.	0.337	0.418	-0.08	0.58		404
Ln(private R&D spending)	6.676	4.924	1.752	10.64	***	411
SME only (2007-2011)						
Δ R&D-exp./employees	2.615	-3.91	6.525	5.49	***	187
Δ R&D-exp./turnover	1.714	-6.311	8.024	6.16	***	187
Δ internal R&D-exp./turnover	1.592	-6.088	7.68	6.14	***	180
Δ external R&D-exp./turnover	-0.032	-0.098	0.066	0.24		180
CGR R&D expenditures	0.399	-0.509	0.907	6.38	***	187
CGR internal R&D-expend.	0.392	-0.553	0.946	6.25	***	180
CGR external R&D-expend.	0.199	0.364	-0.165	0.89		180
Ln(private R&D spending)	5.878	5.525	0.354	2.17	**	180

Sample D: DPF funded firms in 2009 as well as 2011 and matched DPF funded ones in 2011 without funding in 2009. Discrete change (Δ) or continuous growth rate (CGR) of mean values. ATT_{DiD}: difference between mean values in column 2 and 3. # Number of observations. * p<0.10, ** p<0.05, *** p<0.01.