

The Effect of R&D Project Subsidies on R&D Investments Revisited – The Role of Firm’s Subsidy History and Subsidy Size

–
Birgit Aschhoff¹

This version: March 2009

– WORK IN PROGRESS –
PLEASE DO NOT QUOTE.

Abstract

This study provides a more detailed insight into the effects of public R&D subsidies on private R&D expenditures in Germany. Previous research has shown that the allocation of R&D project grants is rather stable in Germany regarding the pool of recipients. This is also frequently stated as a drawback of the grant scheme. The question to answer is whether the rather high level of continuity can be justified by its realized effects. In addition, the role of the size of the subsidy is investigated. In doing so, I allow to a certain extent for heterogeneous treatment effects in these dimensions. Most existing studies focus on the average effect of the subsidies for the firms. But a few studies suggest that the effects might vary considerably between firms. Using a sample of about 4,000 German firms a non-parametric matching approach is applied to estimate the effects of public R&D subsidies on firm’s R&D input. Preliminary results show that the stable pattern does not lead to a lower effectiveness of the instrument. In contrast, the impact is dependent on grant size. Small and medium-sized grants have an additionality effect on firm’s privately financed R&D expenditures. In contrast, large grants crowd out private R&D spending. Policy recommendations for more effective design of the policy instrument are derived.

Keywords: R&D, Public Subsidies, Innovative Performance, Germany

JEL Classification: C20, H32, O38

Address: Centre for European Economic Research (ZEW)
Department of Industrial Economics and International Management
P.O.Box 10 34 43, 68304 Mannheim, Germany
Phone: +49/621/1235-182, E-Mail: aschhoff@zew.de

¹ I am grateful to the Federal Ministry of Education and Research for providing the data. Financial support from the Anglo-German Foundation is gratefully acknowledged.

1 Introduction

Direct R&D project funding (DPF) is the most important tool used by the German government to fund R&D in private businesses. The objective of the scheme is to increase firm's R&D activities. The funding is granted on a cost sharing basis. Up to 50 percent of the R&D project costs are covered by the government. Thus, the funding directly reduces firms' R&D costs. The funding directly reduces firms' R&D costs.

Since private firms follow a profit-maximizing strategy applying for a grant is attractive for firms in most cases. On the one hand, the grant turns an unprofitable project in a profitable one or the money closes the funding gap for the project so that additional R&D activities are undertaken by the firm. On the other hand, the grant is seen as cheap money and taken to finance a project which would have been conducted also in the absence of public support due to its expected positive private returns and would have been financed by own financial means. In this case, the grant substitutes private with public expenditures.

The challenge for the government is to select those projects with (high) social returns which the firms would not have conducted in the absence of the grant. Based on the two market failure arguments justifying the subsidies this means more precisely, the government needs to choose projects for which the private returns are too low and/or for which the financing cannot be realized otherwise. Since private returns as well as firm's financing opportunities for a project – and thus the conduct of the project of the project in the absence of the grant – are difficult to assess for the government, the risk of allocation failure exists. But if the agency is able to identify these projects, a stimulation effect is likely.² Whether private R&D investments are indeed substitutes by the grants or whether the aim of stimulating the R&D activities is achieved is investigated here, allowing for heterogeneous effects in certain dimensions. Understanding the effects and effectiveness of the policy instrument could help the government for future designs of it.

Prior analysis reveals that the subsidization of firms via this instrument shows a high continuity. The stable pattern within the support scheme can be due to different reasons, like learning effects of prior participants, preference on the government side to pick the same firms due to its specific characteristics, or the best projects are submitted by the same firms. I cannot identify the specific reasons why the support scheme is rather stable in Germany in terms of its recipients. However, the aim of the paper is to investigate whether this high level of continuity can be justified by its realized effects. It is also conceivable that a long experience with public funding might lead to a different behavior of the firm with respect to public R&D subsidies. This paper provides insights into the impact of R&D grants on R&D inputs, namely private R&D expenditures, distinguishing between groups of firms with different subsidy experience. In addition, the role of the grant size on the effects is investigated.

² In a perfect information situation the government would support the firms only with the minimal subsidy amount which would be necessary that the project would be undertaken. But this is also no incentives for firms to apply only for a smaller amount than necessary and possible.

There are several studies which analyze the effects of public financial support on firms' R&D input and output. Results are somewhat mixed but most studies find a positive average effect like this is the case for most studies for Germany and specifically for the DPF scheme. However, some of the studies also show that the effect have a large variance between firms. There is no study which links the effects to firm's subsidy history by distinguishing between different types of firms in terms of their subsidy experience, i.e. firms which receive an R&D grant for the first time or rather regularly. And except for the study of Görg and Strobl (2007) there is no study which differentiates the effects for different grant sizes. Empirical evidence for the relative grant size, i.e. grant compared to size of overall R&D activities, is not yet presented.

In this study, I analyze empirically the effects of public R&D subsidies on private R&D expenditures in Germany. Thereby I focus on the role which firm's subsidy history and grant size play on the effects. In doing so, I allow for a certain extent heterogeneous treatment effects for these dimensions. The empirical analysis is based on an annual innovation survey, the German part of the Community Innovation Survey (CIS). This is merged with the DPF database in order to identify a firm's subsidy status in each year. The sample consists of over 4,000 different firms covering the manufacturing and knowledge-intensive service sectors over the time period from 1994 to 2005. In order to answer the question a non-parametric matching approach is employed and the effects of public R&D subsidies in terms of firm's innovation input are compared between frequent subsidy recipients and first-time. The analysis is also repeated for subsamples of treated firms, separated on basis of the grant size.

The contribution of this study to the literature lies primarily on the allowance for heterogeneous effects of the subsidies. More precisely, I investigate the effects conditional on firm's subsidy history which has not been done so far. Another distinctive feature is that I condition the effects on the grant size – which only has been conducted for Ireland – and extend the literature by examining the effects conditional on grant size relatively to the scope of firm's R&D activities. In the analysis I distinguish between total & private R&D expenditures for Germany so that it is possible to distinguish between additionality and partial crowding out. Studies for Germany which focus on the average effects of the DPF scheme covers the subsidies until 2000. In this study the dataset is extended to more recent data by including data until 2005.

The paper is organized as follows. In the next section the relevant literature is reviewed. Section 3 sketches the analyzed public funding scheme and derives the hypotheses. Subsequently, the data set as well as the econometric approach underlying the empirical analysis are explained. The estimation results are presented in section 5, before drawing conclusions in the last section.

2 Literature Review

A large number of studies have been conducted over the last decades which try to answer the question whether public R&D subsidies and company-financed R&D are substitutes or complements. Klette et al. (2000) and David et al. (2000) both criticize in their surveys the

underlying assumption of random allocation of subsidies to firms in most analyses. This is a challenging assumption in this context since, e.g., on the application side not all eligible firms are aware of and acquainted with public support programs and therefore apply for subsidies (self-selection). And on the other hand, government authorities which decide on the applications may follow a picking-the-winner strategy in order to increase the probability of success and thus favors more capable or R&D-experienced firms. This leads to a selection bias which needs to be taken into account in order to analyze the question appropriately. Since then a lot of studies have emerged which correct for the potential bias within the analysis of the effects of public R&D subsidies on firms' R&D input.

With regard to studies for other countries or regions the results are somewhat ambiguous but tend to reject the full crowding-out hypothesis on average for R&D inputs.³ Concerning empirical analyses for Germany all studies agree on the rejection of the full crowding-out hypotheses. These include the analysis on all German firms by Czarnitzki et al. (2007) and Aerts and Schmidt (2008) which are part of country comparisons with Finland and Flanders, respectively, as well as studies on subsets of firms like studies by Almus and Czarnitzki (2003), Czarnitzki (2001), Czarnitzki and Hussinger (2004), Fier (2002) and Hussinger (2008) for the manufacturing sector, Czarnitzki and Fier (2002) for the service sector, Czarnitzki (2001), Almus and Czarnitzki (2003) and Czarnitzki and Licht (2006) for Eastern Germany.

The majority of the studies look at the overall receipt of a subsidy, independent of whether it is from the regional, federal and EU government and ignoring the size of the subsidy. Fier (2002), Czarnitzki and Hussinger (2004) and Hussinger (2008) are the only studies which focus on the DPF scheme and the latter two take the amount of the grant into account in order to be able to distinguish between full and partial crowding-out effects. Fier (2002) rejected full crowding-out for firms' total R&D intensities operating in the manufacturing sector with means of the matching approach. Czarnitzki and Hussinger (2004) apply the same approach to investigate the effects of DPF grants for firms in the manufacturing sector, using a sample of pooled cross-sections covering the period 1992-2000. Hussinger (2008) uses a similar dataset and employs parametric and semi-parametric selection models to answer the question. In the two studies both effects – full and partial crowding-out effects – are rejected. All existing studies which focus on the German DPF scheme are based on the same dataset, covering the period 1992 to 2000.

Most existing studies focus on the average effect of the subsidies for the firms. But some studies suggest that the effects might vary considerably. Busom (2000) points out in her study the variation of the found effects – for the majority of the participants public funding induces private efforts, but for 30% of them full crowding-out effects cannot be ruled out–, but do not provide suggestions for the source of heterogeneity. A few analyses have taken a more

³ **Full crowding-out** effects are rejected in studies by Aerts and Czarnitzki (2004, 2006), Aerts and Schmidt (2008) for Flanders, Duguet (2004) for France, González et al. (2005), González and Pazó (2008), Herrera and Heijs (2007) for Spain, Görg and Strobl (2007) for Ireland, Hyttinen and Toivanen (2005) for Finland, Lööf and Heshmati (2007) for Sweden, Streicher et al. (2005) for Austria. **Partial crowding-out** effects cannot not be rejected by Busom (2000, for 30% of firms even full crowding-out effects are not ruled out), Heijs and Herrera (2004) for Spain, Kaiser (2004) for Denmark, Lach (2002) for Israel, Suetens (2002) for Flanders, Wallsten (2000) for USA while it is rejected by Aerts and Czarnitzki (2006) for Flanders and González and Pazó (2008) for Spain. For a review of recent studies see also Aerts et al. (2007).

detailed look at the effects and find heterogeneous effects depending on the type of recipient and subsidy characteristics.

González et al. (2005), González and Pazó (2008) and Lach (2002) find evidence that the effect varies with firm size. For Israeli manufacturing firms Lach (2000) finds positive treatment effects on company financed R&D expenditure for small firms (up to 100 employees), but no significant effect for large firms. For Spanish manufacturing firms González and Pazó (2008) examine (by means of the matching approach) the effect of R&D subsidies on subsidized firms depending on firms' size and technological level of the sectors in which the firms operate. Their results suggest the absence of both complete and partial crowding-out effects between public and private R&D spending for any subsample of firms. But also no stimulation effect is found if the control group consists of R&D performing firms. Allowing all firms as potential control firms, they find a significantly positive effect on private R&D efforts which can be attributed to the group of small firms (up to 200 employees) and firms operating in low technology sector. They explain this with the effect of subsidies on the induction to perform R&D activities for these firms. Both studies agree on that in particular small firms tend to be stimulated by grants

Empirical results which hint on variation of effects by the subsidy size are found by González et al. (2005) and Görg and Strobl (2007). Using the same set of R&D performing firms as used by González and Pazó (2008) but applying a semistructural econometric model González et al. (2005) find overall a positive but only slight effect on privately-financed R&D efforts. The effect is found to increase with the relative size of the subsidy (ratio of total public subsidies to total R&D expenditures). Görg and Strobl (2007) differentiated the effects on Irish manufacturing firms by the (absolute) size of the subsidy. For this purpose they divide the firms into tertiles depending on the absolute volume of subsidies they receive. Estimating the effects of the subsidies for each group separately they show that small grants have an additionality effect for domestic firms whereas large grants crowd out firms' own R&D expenditures. For foreign firms neither additionality nor crowding out effects are revealed for any subgroup.

The differentiation of effects which has been done for Germany so far is concerning firms' location and grant size. Czarnitzki and Licht (2006) find stimulating effects of public R&D subsidies on R&D and innovation expenditures for firms located in Eastern and Western Germany. However, the degree of additionality is larger for firms in the Eastern part. Fier (2002) differentiates the effects of DPF grants on firms' total R&D expenditure – including the volume of the DPF grant – between four classes of grant size and finds larger effects for larger grants. But this could also be solely due to the grant size. (No further elaboration has been conducted on this issue.)

The contribution of this paper is to shed more light on the difference of the effects. In doing so, I examine the role of firms' subsidy history for the relationship between public and private R&D expenditures, an aspect which have not yet been explored. Secondly, I elaborate further on the link between grant size and effect.

3 Contextual Framework

The Direct Project Funding (DPF) Scheme

The focus is set on a specific public support scheme, the German Federal Government's non-defense *Direct R&D Project Funding* (DPF). This is the most important tool used by the German government to fund R&D in private businesses.⁴ In 2005, firms received a total of 745 million Euros under this scheme (BMBF, 2006a)⁵. Since then the importance of this funding scheme has been increased in Germany and will increase further since it is the main distribution channel for the new High-Tech strategy launched by the Federal Government (BMBF, 2006b).

The DPF scheme offers grant aid funding for R&D projects in predefined fields of technology, for example, biotechnology, sustainable development, information technology, and materials research. The fields of technology are selected by the government and the financial support is thematically restrictive to these technologies. Within the technology fields several programs are defined which include funding objectives and rules. These programs run for several years, are made public in calls and applications have to be made within defined dates. Both companies and research institutions - or both together in a joint project – submit project-based applications for funding. Program agencies authorized by the government and responsible for specific thematic areas decide on the application. The funding is granted on a cost sharing basis. Up to 50 percent of the R&D project costs are covered by the government. On average a project lasts for three years and the grants are paid in pre-defined yearly installments.

Firm's subsidy history

Prior analysis of the DPF scheme reveals that the subsidization of firms via this instrument shows a certain extent of continuity (Aschhoff, 2008). This can be due to different reasons. On the application side, firms which participate continuously in the scheme might have information advantages and know the support opportunities better than non-participating firms and apply more often. These firms might also realize learning effects by using their experience for submitting another successful application. Thus, costs for application are less for these firms so that they apply more often and applications of them are better since they know which the best suited projects are and how to set a successful application up. Therefore, on the approval side, their proposals might be selected more often. Furthermore, the regular receipt of DPF grants might also change the behavior of the firms. Firms which have received DPF grants since a longer period experienced the benefits and might view DPF grants as a source of cheap money. Due to their experience with the grants they are acquainted with the inherent procedure and know what it is expected from them. These reasons can lead to a rather stable pattern of supported firms within the DPF scheme and suggest in addition that not necessarily the best projects are supported in order to achieve a stimulation effect. They

⁴ Tax-based R&D incentives are not available in Germany.

⁵ 448.5 million Euros were given by the Federal Ministry of Education and Research, 296.1 million Euros by the Federal Ministry of Economics and Technology.

might already reckon on getting the money again and include it in their R&D planning. These firms may more likely to take advantage of the support and substitute private R&D investments. Therefore the risk of a crowding-out effect, i.e. firms substitute (partially) public for private R&D spending, might be in particular pronounced in these firms.

But the relatively continuous participation of the same firms can also be the result of the selection of the most promising projects or firms. Either projects with the highest quality are submitted by the same firms and accordingly selected by the project agency. Or the government authority “wants to maximize the expected rate of return of their public money” and follows a picking-the-winner strategy, i.e. projects of firms which show high R&D capabilities are selected.⁶ This would mean that the most promising projects are selected and it is more probable – in particular in case of the former reason – that a stimulating effect of the grants is achieved. Thus, the stable pattern is nevertheless conforming to the overall goal of the scheme.

I cannot directly identify the predominant reasons why the support scheme is rather stable in Germany in terms of its recipients. However, the aim of the paper is to evaluate whether the continuous support of (some) firms can be justified by the realized effects. In order to investigate this issue I distinguish between firms with different subsidy histories in the analysis of the effects. I examine the effects of DPF grants on R&D inputs for regular supported firms, i.e. whether DPF grants have a stimulating or crowding-out effect on these firms. In addition, I compare the effects with those of first-time participants, as a benchmark case. First-time applicants cannot reckon on the approval of the application and thus, with the DPF grant. They are not as familiar with the procedure and DPF system. So that if there is a change of behavior due to continuous support, the effects should be different for these two groups of firms

Grant size

In particular for large projects the conducting firms might not be able or willing to bear the risk alone and to finance the project only with own financial means – even in the presence of a positive net present value – and cannot get the project externally financed by another private agent (GIB, 2004: 11). Thus, the conduct of the project might be dependent on the provision of public money. Based on these arguments a stimulation effect is more likely for large projects than for small projects. Vice versa, small projects have a higher tendency to lead to a crowding-out effect than larger projects.

Another situation in which crowding-out effects can take place is when firm’s R&D capacity cannot be extended at will in the short-run, even if the firm gets public support for a project, i.e. R&D activities are inelastic to a certain degree. For instance, R&D capabilities of a firm might be restricted in terms of R&D personal. A firm might not find enough adequate R&D personal necessary for a large project or it hesitates to increase extensively the overall R&D personal – and to stick to them in the long-term. This constraint might specifically apply for

⁶ The criteria for approving a project do not differ between firms that have already participated in the DPF scheme and firms which want to participate for the first time. In contrast, e.g., within the SBIR program additional criteria apply for the evaluation of SBIR applications of firms which had received awards in the past.

relatively large projects, i.e. if the funded project accounts for a large share of firm's R&D activities. A large project might not be conducted completely additional, rather R&D expenditures are reallocated from another project towards the subsidized project so that another project might not be undertaken. Thus, the probability of crowding-out effects increases with grant size. This reasoning contradicts the former derived relation between grant size and effects.

Thus, the grant size might be another characteristic which have an impact on the effect of the public support. Thereby, a priori the direction of the impact is not clear. Results by Görg and Strobl (2007) suggest that the effectiveness differentiated the effect by the size grant. They found for domestic firms the stimulating effect turns negative for large grants. With regard to foreign-owned companies, the effect does not vary by grant size. On an aggregate level it has been shown both theoretically (David and Hall, 2000) and empirically on the country-level (Guellec and von Pottelsberghe de la Potterie, 1999) that high rates of public funding have a negative effect on private-financed R&D.

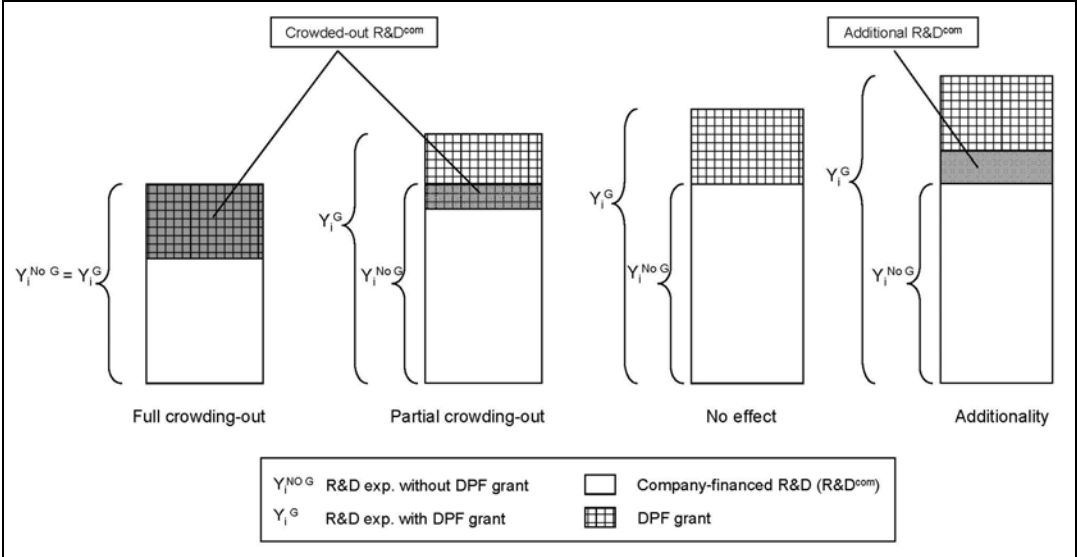
If and which role the size of DPF grants plays, is investigated in this study. In doing so, I look at the absolute size of the DPF grant, i.e. the amount of the subsidy, but also at the relative size of the grant for the specific firm, i.e. the amount of the subsidy in relation to the overall R&D expenditures of the firm in order to relate the grant to firm's overall R&D activities.

Taxonomy of possible effects

Whether private R&D investments are indeed substituted by DPF grants or whether the aim of stimulating the R&D activities is achieved is investigated here, allowing for heterogeneous effects in two dimensions, namely firm's DPF grant history and size. As explained different effects of grants on firm's R&D expenditure are possible, to the extent to which grant and company-financed R&D are substitutes or complements. The taxonomy of possible effects of subsidies on firms' R&D expenditures is as follows. Beginning with the most negative effect, it is possible that the firm substitutes completely company-financed R&D by the subsidies, i.e. the subsidy crowds out privately financed R&D Euro by Euro. In case of full crowding-out firm's total R&D expenditures are the same in case with and without subsidies. Firm's privately-financed R&D is lowered by the amount of the subsidy. In order to test the full crowding-out hypotheses knowing firm's total R&D expenditures is enough. Information on the volume of the subsidy is not necessary. If information on the amount of the subsidy is available more detailed statements can be derived. Partial crowding-out is found if privately-financed (total) R&D is lower (higher) in the situation of public funding than in the situation without funding. However, the decrease is smaller than the amount of the grant. A share of the privately-financed R&D is substituted by the subsidy. No effect of subsidies on firm's R&D efforts arises if firm's privately financed R&D expenditure is the same in the presence and absence of subsidies. Public subsidies and privately-financed R&D behave like complements. The firm does not spend less on R&D. Firm's total R&D expenditures increases by the amount of the subsidy compared to the scenario in which the firm does not receive a subsidy. An additional effect of the subsidy is achieved if the firm increases privately-financed R&D spending due to the receipt of the subsidy, i.e. company-financed R&D is higher if the firm receives a subsidy than if the firm does not receive a subsidy.

Firm's total R&D expenditures can be decomposed into three parts: (i) private expenditures which would have been spent in any case, (ii) additional R&D spending induced by the subsidy and (iii) amount of the subsidy. The four possible types of effects are depicted in Figure 1.

Figure 1: Concept of possible effects of a DPF grant on firm's R&D expenditure



Source: Own illustration.

4 Empirical Specification

The methodological approach chosen to examine the change in firm's R&D arising from DPF grants is outlined in the next subsection. In the subsequent subsections I describe the data set and variables used for the analysis.

Methodological approach/Estimation strategy

In the empirical analysis it needs to be taken into account that the receipt of a subsidy does not happen by chance, but rather is subject to different selection processes, both on firm's and government's side. Several econometric methods have been developed in order to get reliable results even in the presence of selection bias. Such econometric techniques include instrumental variable (IV) regression, difference-in-difference analysis and matching methods.⁷ The latter approach were established and first used in the evaluation of labor market economics (see e.g. Angrist 1998, Heckman et al. 1997, 1998a, 1998b, Lechner 1999, 2000) and has been transferred later to the evaluation of public R&D funding in the field of industrial economics. The matching methodology has been widely used in recent

⁷ For an overview and discussion of the econometric approaches see Heckman et al. (1999), Blundell and Costa Dias (2000) or Aerts et al. (2007). The latter survey concentrates on the evaluation of public R&D subsidies.

years as estimation technique⁸ and is also applied in this study. This has the advantage that results from other studies are more comparable.

My interest lies on effect of DPF grants on firm's R&D activities. In the terminology of evaluation econometrics the receipt of a DPF grant is called 'treatment'; R&D measures are the 'outcome variables'. More precisely I want to measure the difference between the outcome of subsidized firms and the outcome of these firms in the absence of subsidies, the so-called average treatment effect on the treated α_{TT} . This effect can be expressed as

$$\alpha_{TT} = E(Y^T | I = 1) - E(Y^C | I = 1), \quad (0.1)$$

where $I = 1$ indicates the treatment group, Y^T denotes the value of the outcome variable in the treated situation and Y^C in the counterfactual situation. Thus, the effect measures Y^T and Y^C cannot be simultaneously observed for the same individual firm since a firm cannot be a recipient and a non-recipient of DPF at the same time. Since Y^T is observed, $E(Y^T | I = 1)$ can directly be measured by the sample mean of the outcome for the group of DPF recipients. The situation $E(Y^C | I = 1)$ is called the counterfactual situation since it is not observable by design and has to be estimated. In the presence of a selection bias an estimation of the counterfactual outcome via the sample mean of the outcome for the group of non-recipients lead to biased results.

The basic idea of matching is to balance the sample of subsidy recipients and comparable non-recipients by selecting the best twin from the control group for each subsidized firm. Then, the means of the outcome are comparable between the two groups. The advantage of the matching method is – since it is a non-parametric method – that a functional form for the outcome equation is not necessary. The disadvantages are the need of strong assumptions. In order to identify the average treatment effect three assumptions have to hold: the conditional independence assumption (CIA), the stable unit treatment value assumption (SUTVA) and common support. The conditional independence assumption (CIA) was introduced by Rubin (1977) and states that firms with the same set of exogenous characteristics $X = x$, the treatment and outcome variables are independent:

$$Y^T, Y^C \perp I | X = x. \quad (0.2)$$

The CIA implies that all the characteristics which influence both treatment and potential outcome have to be observed. It cannot be tested whether the CIA is fulfilled or not. Given the broad range of variables in our dataset, it is reasonable that I have enough information on the firms to sufficiently approximate the treatment and the outcome so that the CIA holds. This is supported by the fact that comparable data sets have been used in the past for several matching studies (see footnote 8). If the CIA holds, the outcome of the treated group in the counterfactual situation can be approximated by the outcome of a control group of non-treated firms which strongly resembles (i.e. match) the treatment group:

⁸ Aerts and Czarnitzki (2004), Almus and Czarnitzki (2003), Czarnitzki (2001), Czarnitzki et al. (2007), Czarnitzki and Fier (2002), Czarnitzki and Hussinger (2004), Czarnitzki and Licht (2006), Fier (2002), Gonz ales and Paz o (2008), Heijs and Herrera (2007), L o f and Heshmati (2007) apply nearest neighbor matching; Duguet (2004) kernel matching; Aerts and Schmidt (2008), G org and Strobl (2007) a combination of matching and difference-in-difference.

$$E(Y^C | I = 1, X = x) = E(Y^C | I = 0, X = x). \quad (0.3)$$

In addition, the SUTVA demands that the treatment of a particular firm must not influence the outcome of other firms (Rubin, 1990). The validity of SUTVA cannot be tested empirically either. A further requirement is the common support which requires that firms with the same characteristics have a positive probability of being both treated and not treated. This condition assures that for each treated observation a similar control can be found.

If all assumptions hold, the average effect of participating in the DPF schemes (the treatment effect) can be estimated as

$$\alpha_{TT} = E(Y^T | I = 1, X = x) - E(Y^C | I = 0, X = x). \quad (0.4)$$

Differences in the means of the outcome variable between the treated and the selected control groups are then attributed to the treatment, i.e. to the DPF grant (Heckman et al. 1997).

In the ideal case, the best twin for a subsidized firm is the firm which is identical in all relevant characteristics. But if the number of matching criteria is large, it would hardly be possible to find any such observation. Therefore, Rosenbaum and Rubin (1983) developed propensity score matching. The idea is to estimate the propensity score which is the probability of receiving R&D subsidies for the whole sample and find pairs of recipients and non-recipients that have the same probability value of participation. Usually, one does not perform an exact matching but the popular ‘nearest neighbor’ matching, i.e. one selects the control observation with the estimated probability value closest to the participant. Using this propensity score, one reduces the multidimensional problem of several matching criteria to one single measure of distance. Lechner (1998) introduced a modification of the propensity score matching, as one often wants to insert additional variables, e.g. firm size, directly into the matching function. In this case, instead of a single X (propensity score), other important characteristics of the firms may also be employed in X .

In this study, a nearest-neighbor matching based on the Mahalanobis metric is used to select a control. In order to identify the non-participant j which is the closest neighbor to participant i , the distance to minimize is

$$MD_{ij} = (x_i - x_j)' \Omega^{-1} (x_i - x_j) \quad (0.5)$$

with Ω^{-1} being the sample covariance matrix of the comparison group.

In this study, I specify a probit model in order to estimate a propensity score using several firm characteristics to explain the funding. The dependent variable is the receipt of DPF grants. Additionally, we include firm size (no. of employees in logarithm), receipt of other subsidies (from EU, from regional government) and the knowledge within the firm (patent stock) in the calculation of the Mahalanobis distance. The matching protocol is depicted in Table 4 in the appendix.

Data Set

The empirical analysis on potential additionality effects is based on the Mannheim Innovation Panel (MIP), an annual innovation survey conducted by the Centre for European Economic

Research (ZEW) on behalf of the BMBF since 1993.⁹ The MIP is the German part of the European-wide harmonized Community Innovation Survey (CIS). The data contains among other things information on firm's R&D and innovation activities and a wide range of firm characteristics like number of employees, sales, and industry. I use the surveys conducted between 1995 and 2006 covering the time period 1994 to 2005. Since the answering of the questionnaire is not mandatory half of the firms are only observed once. Thus, the different cross sections are pooled for the empirical part. The survey data is supplemented with information on the DPF grants which is extracted from the R&D project database of the German federal government. The project-level data on the grants is aggregated to the firm-level and is used to identify the years in which a firm receive a grant within the DPF scheme. In addition, patent application data from the European Patent Office is merged.

Since the DPF scheme does not aim at motivating firms to start R&D activities – this has been also shown empirically (cf. Aschhoff, 2008) – the sample of firms is limited to R&D-performing firms, i.e. firms with positive R&D expenditures. This restriction ensures that the potential control group – firms without DPF grants – is more similar to firms with DPF grants and that the effect is not overestimated/avoids an overestimation of the effect. The final dataset contains 9,743 firm-year observations from 3,911 different firms from manufacturing and knowledge intensive service sectors.

Variables

Endogenous variables

In this study, I analyze empirically the effects of public R&D subsidies on private R&D expenditures in Germany. We have two endogenous variables: the DPF receipt (treatment) and firm's R&D expenditure (outcome).

Since it is assumed that the DPF grants are not allocated randomly we treat the receipt of a DPF grant as endogenous. Almost 14% of the firms receive DPF grants amounting to 176,000 Euro on average.¹⁰ I want to allow to a certain extent heterogeneous treatment effects for firm's DPF history and DPF size. Therefore I split the sample of DPF recipients into several subsamples. In terms of firm's DPF history I discriminate between two clear-cut subgroups. First, I consider only firms which receive DPF grants for the first time in the current or preceding year within the last 5 year period. Thus, these firms get new grants and they do not have (recent) experience with the scheme. Second, I build a subgroup of firms which received continuously DPF grants for 5 years.¹¹

In order to distinguish between the effects in terms of the size of the DPF grant, I divide the group of treated firms into subgroups. I generate three groups depending on the amount of the DPF grant a firm receive (absolute DPF size): firms with a small, medium and large amount. The separation is based on the tertiles of the size variable (≤ 33.3 , > 33.3 & ≤ 66.6 , > 66.6

⁹ For a detailed description of this database see Rammer et al. (2005).

¹⁰ In the years 2000 and from 2002 on, firms with DPF grants are overrepresented in the sample. Without these additional firms the share of firms receiving DPF is 10%. Results do not change qualitatively with dropping these firms.

¹¹ The grant is not necessarily newly awarded. It can also belong to an ongoing subsidized project.

percentile). Small grants are below 38,270 Euro, large ones larger than 101,480 Eur. In addition, three subgroups are built depending on the relative DPF size, i.e. the amount of the DPF grant in relation to firm's overall R&D expenditures. For firms with a relative small DPF grant the grant accounts for less than 2.6 percent of firm's R&D expenditures, for firms with a large grant, it is more than 22.9 percent.

The interest lies on the effects of the subsidies on firms' R&D expenditure. In order to test the full and partial crowding-out hypotheses I use the following outcome variables: (i) *R&D expenditure*¹² (in million Euro) equals the overall R&D expenditures of the firm, ignoring whether it is financed by subsidies, and (ii) *private R&D expenditure* includes only privately financed R&D expenditures, i.e. R&D minus the amount of DPF grants. Since the dataset includes observations from a 12-year-period, both monetary variables have been deflated (EconStats, 2009). As a robustness check the corresponding intensities defined as R&D variable divided by sales (multiplied by 100) are also considered. Due to the skewed distribution, the variables are also taken as logarithms. In Table 1 R&D efforts for the different groups are presented.

Table 1: Mean values of R&D efforts with and without DPF grant, for different categories

	total R&D [°]	private R&D [°]	total R&D/sales ⁺	private R&D/sales ⁺	no. of obs.
whole sample	1.354	1.337	6.078	5.688	9,701
no DPF	1.056	1.056	5.218	5.218	8,396
with DPF	3.277	3.147	11.607	8.709	1,305
with DPF					
<i>DPF history</i>					
first	2.418	2.337	11.634	8.481	386
frequent	4.954	4.745	12.147	9.560	422
<i>absolute DPF size</i>					
small	2.368	2.249	8.273	6.959	434
medium	2.991	2.926	12.284	9.215	435
large	4.567	4.261	14.250	9.947	436
<i>relative DPF size</i>					
low	7.680	7.610	7.682	7.558	434
middle	1.804	1.632	12.417	10.863	435
high	0.364	0.215	14.706	7.707	436

Note: ° in million Euro, deflated. + in percent.

Looking at firms R&D expenditures, firms which receive DPF grants show higher R&D efforts than not funded firms, both in terms in absolute values and in intensities. Also, subtracting the volume of the grant from the overall R&D expenditures, the picture stays the same. Firms receiving DPF grants spend on average three times more for R&D. Related to their sales the difference is not as large but still significant (8.7% for firms with DPF grants, 5.2% for firms without DPF). Distinguishing by firm's DPF history, it becomes apparent that frequent DPF recipients have larger DPF grants and higher private R&D spending than first-time recipients. However, the R&D intensities is not significantly different. The higher absolute values of the frequent recipients are just due to the fact that this group consists out of larger firms in terms of their sales. Thus, the descriptive comparison gives no indication that

¹² Defined in accordance with the Frascati Manual (OECD, 1993)

the effect on R&D depends on DPF history, once it is controlled for firm's size. Both types show higher R&D efforts than non-participants.

Firm's private R&D spending increases with the amount of the R&D grant. Firms receiving a large amount of DPF – the average amount is about 300,000 Euro – spend significantly more on R&D with own financial means than firms which receive smaller amounts. In terms of R&D intensities firms with middle- and large-sized amounts have a higher intensity than small grant recipients. This indicates that might increase with grant size.¹³ Differences between privately financed R&D expenditures are in particular pronounced between groups of firms based on relative DPF size. Firms, for which the grant accounts only for small share of R&D expenditures, have very high expenditures.¹⁴ Firms, for which the grant accounts for a relatively high share, spend extremely few on R&D, only a quarter of non-recipients. But they do not have many other projects, per definition. With regard to the R&D intensities, the difference is not as large. The group of firms for which the grant is middle-sized has indeed the significantly largest R&D intensity. The descriptive statistics point out differences of R&D efforts between firms according to DPF grant size. In order to have the greatest stimulation effect, the descriptive results suggest that the grant needs to exceed a certain amount and it need to account for a certain share of R&D activities but the share should not be too high at the same time, i.e. the firm needs to undertake other R&D as well. The relevance will be verified in the econometric model which accounts for the inherent selection bias.

Explanatory variables

The selection of explanatory variables is based primarily on the results of previous empirical studies and are the following: Receipt of subsidies from European schemes within the last three years (Sub_EU), receipt of subsidies from the regional level within the last three years (Sub_regional), amount of subsidies provided from the federal government (Sub_supply), firm size (number of employees in logarithms), firm's age (in years and logarithms), whether a firm conducts R&D on a continuous basis (R&D_con), qualification of the employees (share of employees with a university degree), R&D knowledge within the firm (lagged patent stock divided by the industry mean on the three-digit-level), whether the firm belongs to a national or foreign group, location of the firm in Eastern Germany, sector and year dummy variables. Summary statistics of all explanatory variables are provided in Table 5 in the appendix. [...]

5 Results

The results of the probit model give evidence for the presence of a selection into the DPF scheme. The estimation results on the probability of receiving a grant are presented in Table 6 in the appendix. The results of the matching for the whole sample and conditional on firm's

¹³ Although frequent recipients are on average larger and get larger grants than the other recipients, only half of this group receive a large size in absolute terms.

¹⁴ This must not be necessarily the case since the amount of the grant is not a fixed value. It could also had been due to a small amount of the R&D.

subsidy history are shown in Table 2, results for subsamples depending on the size of the DPF grant in Table 3.

Table 2: Comparison of R&D efforts after the matching for the whole sample and subsamples depending on firm's DPF history

Treatment group	DPF		First DPF		Frequent DPF	
	DPF firms	Control firms	DPF firms	Control firms	DPF firms	Control firms
total R&D	3.2774	2.8565	2.4181	2.4470	4.9538	3.6779*
ln(total R&D)	-0.2533	-0.7400***	-0.5867	-0.9563**	0.2591	-0.2209***
ln(total R&Dint)	1.5897	1.0795***	1.4846	1.1079***	1.7731	1.3110***
private R&D	3.1471	2.8565	2.3374	2.4470	4.7453	3.6779
ln(private R&D)	-0.6066	-0.7400	-0.9396	-0.9563	-0.0604	-0.2209
ln(privateR&Dint)	1.2364	1.0795**	1.1317	1.1079	1.4536	1.3110
no. ob obs.	1,304	1,304	386	386	422	422

Note: Mean values are shown. Blue numbers indicate that the mean value of DPF firms is smaller than the mean value of control firms. *** (**, *) indicate significance level of 1% (5%, 10%) of the two-sided t-tests on mean equality between the firms with DPF and the selected control group. The standard errors of the t-statistics are based on the approximation by Lechner (2001) that accounts for sampling with replacement in the selected control group. The control variables as well as the propensity score are not significantly different between the treated and selected control groups after matching.

Table 3: Comparison of R&D efforts after the matching for subsamples depending on the size of DPF grant

Treatment group	DPF firms	Control firms	DPF firms	Control firms	DPF firms	Control firms
	DPF grant in EURO (absolute grant size)					
	Small		Medium		Large	
total R&D	2.2680	2.4805	2.9918	2.2435	4.5666	4.1657
ln(total R&D)	-0.7106	-0.8645	-0.5172	-1.0048***	0.4645	-0.1455***
ln(total R&Dint)	1.1776	0.9493*	1.7149	1.2126***	1.8754	1.4618***
private R&D	2.2487	2.4805	2.9270	2.2435	4.2606	4.1657
ln(private R&D)	-0.9470	-0.8645	-0.8866	-1.0048	0.1097	-0.1455
ln(privateR&Dint)	0.9411	0.9493	1.3455	1.2126	1.4219	1.4618
no. ob obs.	434	434	434	434	436	436
DPF grant in EURO/total R&D (relative grant size)						
	Low		Middle		High	
total R&D	7.5741	6.8211	1.7530	1.6880	0.3635	1.1811***
ln(total R&D)	1.2125	0.6859***	-0.3096	-0.8596***	-1.6758	-1.7383
ln(total R&Dint)	1.4276	0.9066***	1.5859	1.0214***	1.7468	1.5697
private R&D	7.5046	6.8211	1.5851	1.6880	0.2149	1.1811***
ln(private R&D)	1.1963	0.6859***	-0.4398	-0.8596***	-2.5864	-1.7383***
ln(privateR&Dint)	1.4115	0.9066***	1.4556	1.0214***	0.8317	1.5697***
no. ob obs.	432	432	430	430	436	436

Note: Mean values are shown. Blue numbers indicate that the mean value of DPF firms is smaller than the mean value of control firms. *** (**, *) indicate significance level of 1% (5%, 10%) of the two-sided t-tests on mean equality between the firms with DPF and the selected control group. The standard errors of the t-statistics are based on the approximation by Lechner (2001) that accounts for sampling with replacement in the selected control group. All control variables as well as the propensity score are not significantly different between the two groups after matching.

DPF grants do not displace private R&D investments, no crowding-out of private R&D expenditures. But it also does not have a complementary effect, i.e. it does not induce additional company-funded R&D activities. The results for the whole sample differ from previous studies focusing on the DPF scheme since no robust stimulating effects are found on average. However, full and partial crowding-out hypothesis can be rejected here as well. They spend the amount of the grant additionally on R&D but do not increase further R&D expenditures besides the grant. Whether the difference to prior analysis is due to other effects in recent years or due to conceptual differences, is still to investigate. Furthermore, the results suggest that the stable pattern does not lead to a lower effectiveness of the instrument. Effects of the grants for first-time and frequent participants do not differ. For both groups, neither crowding-out nor additional effects are found for privately-financed R&D expenditures.

Effects depending on the absolute grant size, i.e. the amount of the grant, are similar to those for the whole sample. Effects do not vary with grant size. In contrast, the impact is dependent on the relative grant size. Relative small and medium-sized grants have a stimulating effect on firm's privately financed R&D expenditures. In contrast, relative large grants crowd out private R&D spending. The findings do not support the financial constraint argument for large projects.

[...]

6 Conclusions

In this study the participation pattern of firms within the German R&D funding scheme, the DPF scheme, is linked to the effects of the subsidies on firm's input.

This paper provides evidence on the fact that for the effectiveness of the instrument the relative size of the grant, i.e. amount of the grant in relation to the overall R&D expenditures, is relevant. In particular relative small and medium-sized grants are suitable to increase the scope of firms' R&D plans. For firms with only a few R&D activities DPF grants account for a high share of their R&D activities and cannot be assumed to have a stimulating effects.

Due to the 50% rule of the funding, also in cases where no partial crowding-out is found, a reallocation of the private R&D expenditures might have occurred, since the own-funded share is directed towards the funded project and not elsewhere.

The amount of subsidies from other institutions, like regional or European programs, is not considered as this data is not available. Therefore, results might be biased due to effects from those programs. But at least treated and control firms have the same subsidy status in these two schemes and therefore the bias should not be too severe.

[...]

References

- Aerts, K. and D. Czarnitzki (2006), *The Impact of Public R&D-Funding in Flanders*, IWT Study No. 54, Brussels.
- Aerts, K., D. Czarnitzki and A. Fier (2007), Evaluación econométrica de las políticas públicas de I+D: situación actual, in: Heijs, J. and M. Buesa (Eds.), *Cooperación en innovación en España y el papel de las ayudas públicas*, Instituto de Estudios Fiscales, Madrid, 79-104.
- Aerts, K. and T. Schmidt (2008), Two for the price of one? Additionality effects of R&D subsidies: A comparison between Flanders and Germany, *Research Policy* 37 (5), 806-822.
- Almus, M. and D. Czarnitzki (2003), The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany, *Journal of Business and Economic Statistics* 21(2), 226-236.
- Angrist, J.D. (1998), Estimating the Labor Market Impact of Voluntary Military Service Using Social Security Data on Military Applicants, *Econometrica* 66 (2), 249-288.
- Aschhoff, B. (2008), *Who Gets the Money? The Dynamics of R&D Project Subsidies in Germany*, ZEW Discussion Paper No. 08-018, Mannheim.
- Blundell, R. and M. Costa Dias (2000), Evaluation Methods for Non-Experimental Data, *Fiscal Studies* 21(4), 427-468.
- BMBF (2006a), *Bundesbericht Forschung 2006*, Bonn/Berlin.
- BMBF (2006b), *Die Hightech-Strategie für Deutschland*, Bonn/Berlin.
- Czarnitzki, D. (2001), Die Auswirkungen der Forschungs- und Technologiepolitik auf die Innovationsaktivitäten ostdeutscher Unternehmen, *Schmollers Jahrbuch – Zeitschrift für Wirtschafts- und Sozialwissenschaften* 121(4), 1-22.
- Czarnitzki, D. (2006), Research and Development in Small and Medium-Sized Enterprises: the Role of Financial Constraints and Public Funding, *Scottish Journal of Political Economy* 53(3), 335-257.
- Czarnitzki, D., B. Ebersberger and A. Fier (2007), The Relationship between R&D Collaboration, Subsidies and R&D performance: Empirical Evidence from Finland and Germany, *Journal of Applied Econometrics* 22(7), 1347-1366.
- Czarnitzki, D. and A. Fier (2002), Do Innovation Subsidies Crowd out Private Investment? Evidence from the German Service Sector, *Konjunkturpolitik - Applied Economics Quarterly* 48(1), 1-25.
- Czarnitzki, D. and K. Hussinger (2004), *The Link between R&D Subsidies, R&D Spending and Technological Performance*, ZEW Discussion Paper No. 04-56, Mannheim.
- Czarnitzki, D. and G. Licht (2006), Additionality of Public R&D Grants in a Transition Economy: The Case of Eastern Germany, *Economics of Transition* 14(1), 101-131.
- Czarnitzki, D. and A.A. Toole (2007), Business R&D and the interplay of R&D subsidies and product market uncertainty, *Review of Industrial Organization* 31(3), 169-181.

- David, P.A., B.H. Hall and A.A. Toole (2000), Is public R&D a complement or substitute for private R&D? A review of the econometric evidence, *Research Policy* 29(4-5), 497-529.
- Duguet, E. (2004), Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non-experimental data, *Revue d'Economie Politique*, 114(2), 263-292.
- EconStats (2009), GDP deflator, <http://www.econstats.com/weo/V005.htm>.
- Fier, A. (2002), *Staatliche Förderung industrieller Forschung in Deutschland*, ZEW Wirtschaftsanalysen Vol. 62, Baden-Baden.
- González, X. and C. Pazó (2008), Do Public Subsidies Stimulate Private R&D Spending?, *Research Policy* 37, 371-389.
- González, X., J. Jaumandreu and C. Pazó (2005), Barriers to innovation and subsidy effectiveness, *RAND Journal of Economics* 36(4), 930-950.
- Görg, H. and E. Strobl (2007), The Effect of R&D Subsidies on Private R&D, *Economica* 74, 215-234.
- Heckman, J.J., H. Ichimura and P.E. Todd (1997), Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Programme, *Review of Economic Studies* 64, 605-654.
- Heckman, J.J., H. Ichimura, J.A. Smith and P. Todd (1998a), Characterizing Selection Bias using Experimental Data, *Econometrica* 66 (5), 1017-1098.
- Heckman, J., H. Ichimura and J. Smith (1998b), Matching as an Econometric Evaluation Estimator, *Review of Economic Studies* 65, 261-294.
- Heckman, J., R.J. LaLonde and J.A. Smith (1999), The economics and econometrics of active labour market programs, in: Ashenfelter, O. and D. Card (eds.), *Handbook of labour economics* 3, Amsterdam, 1866-2097.
- Herrera, L. and J. Heijs (2007), Difusión y adicionalidad de las ayudas públicas a la innovación, *Revista de Economía Aplicada* 44, 177-197.
- Kaiser, U. (2006), Private R&D and public subsidies: microeconomic evidence from Denmark, *Danish Journal of Economics*, 144(1), 1-17.
- Klette, T.J., J. Møen and Z. Griliches (2000), Do subsidies to commercial R&D reduce market failures? Microeconomic evaluation studies, *Research Policy* 29(4-5), 471-495.
- Lach, S. (2002), Do R&D subsidies stimulate or displace private R&D? Evidence from Israel, *Journal of Industrial Economics* 50(4), 369-390.
- Lechner, M. (1998), *Training the East German labour force: microeconomic evaluations of continuous vocational training after unification*, Heidelberg.
- Lechner, M. (1999), Earnings and Employment Effects of Continuous Off-the-Job Training in East Germany After Unification, *Journal of Business & Economic Statistics* 17(1), 74-90.
- Lechner, M. (2000), An evaluation of public-sector-sponsored continuous vocational training programs in East Germany, *Journal of Human Resources* 35(2), 347-375.

- Lechner, M. (2001), Identification and Estimation of Causal Effects of Multiple Treatments under the Conditional Independence Assumption, in: Lechner, M. and F. Pfeiffer (eds.), *Econometric Evaluation of Labour Market Policies*, Heidelberg, 43-58.
- Lööf, H. and A. Heshmati (2007), The Impact of Public Funds on Private R&D Investment: New Evidence from a Firm Level innovation Study, in Heshmati A., Y-B. Sohn and Y-R. Kim (Eds.) *Commercialization and Transfer of Technology: Major Country Case Studies*, Nova Science Publishers, pp. 77-96.
- OECD (1993), Proposed Standard Practice for Surveys of Research and Experimental Development – Frascati Manual, Paris.
- Rammer, C., B. Peters, T. Schmidt, B. Aschhoff, T. Doherr and H. Niggemann (2005), *Innovationen in Deutschland*, ZEW Wirtschaftsanalysen Vol. 78, Baden-Baden.
- Rosenbaum, P.R. and D.B. Rubin (1983), The central role of the propensity score in observational studies for causal effects, *Biometrika* 70, 41-55.
- Rubin, D.B. (1977), Assignment to treatment group on the basis of a covariate, *Journal of Educational and Behavioral Statistics* 2, 1-26.
- Rubin, D.B. (1990), Formal mode of statistical inference for causal effects, *Journal of Statistical Planning and Inference* 25(3), 279-292.
- Streicher, G., A. Schibany and N. Gretzmacher (2004), *Input additionality effects of R&D subsidies in Austria*, TIP Working Paper, 04-03, Vienna.
- Suetens, S. (2002), *R&D subsidies and production effects of R&D personnel: evidence from the Flemish region*, CESIT Discussion Paper 2002/03, Antwerp.
- Wallsten, S. (2000), The effect of government-industry R&D programs on private R&D: the case of the small business innovation research program, *Rand Journal of Economic* 1, 82-100

Appendix

Table 4: Matching protocol

Step 1	Specify and estimate a probit model to obtain the propensity scores. Calculate the propensity score of receiving a DPF grant for each firm.
Step 2	Restrict the sample to common support: delete all treated observations whose probability is higher than the maximum or less than the minimum probability of the potential control group.
Step 3	Estimate the counterfactual expectations of the outcome variables (R&D and R&D intensity for total and privately financed R&D). For each participant i the following steps are performed: <ul style="list-style-type: none"> a) Choose one observations of the participants and delete it from that pool. b) Find an observation in the sample of the pool of non-participants that is as close as possible to the one chosen in Step a) in terms of the propensity scores, Sub_EU, Sub_regional, employees (ln), and Patent_stock_dev. Closeness is based on the Mahalanobis distance. Do not remove the selected controls from the pool of potential controls, so that it can be used again. c) Repeat a) and b) until no observation of the participants is left. d) Using the matched comparison group formed in c), compute the average effect on the treated as the sample mean difference of the matched observations. Note that the same observation may appear more than once in that group.
Step 4	Calculating the (two-sided) t-test on mean equality in the treated and non-treated groups. Since sampling with replacement is applied correct the standard errors using the approximation by Lechner (2001).

Table 5: Summary statistics of control variables

	Mean	Std. Dev.	Min	Max
Sub_EU	0.095	0.293	0	1
Sub_regional	0.203	0.402	0	1
Sub_supply(profiv)	3.367	1.989	0.26	7.5
ln(Employees)	4.502	1.561	0	9.20
ln(Age)	2.722	1.210	-0.69	5.32
R&D_con	0.698	0.459	0	1
Qualification	0.239	0.253	0	1
Patent_stock_dev	0.984	3.881	0	95.88
Group_national	0.386	0.487	0	1
Group_foreign	0.114	0.318	0	1
East	0.331	0.471	0	1
Low tech ma.	0.114	0.317	0	1
Medium-low tech ma.	0.233	0.423	0	1
Medium-high tech ma.	0.319	0.466	0	1
High tech ma.	0.158	0.365	0	1
Low tech services	0.084	0.277	0	1
High tech services	0.092	0.289	0	1

(9,701 obs.)

Table 6: Propensity to receive DPF, probit regression results (marginal effects)

	DPF	First DPF	Frequent	Absolute DPF size			Relative DPF size		
	dy/dx (Std.Err.)	dy/dx (Std.Err.)	dy/dx (Std.Err.)	Small dy/dx (Std.Err.)	Medium dy/dx (Std.Err.)	Large dy/dx (Std.Err.)	Low dy/dx (Std.Err.)	Middle dy/dx (Std.Err.)	High dy/dx (Std.Err.)
Sub_EU ^o	0.134*** (0.021)	0.023** (0.010)	0.06*** (0.013)	0.037*** (0.012)	0.041*** (0.012)	0.062*** (0.013)	0.024*** (0.008)	0.051*** (0.012)	0.062*** (0.014)
Sub_regional ^o	0.058*** (0.013)	0.006 (0.006)	0.023*** (0.006)	0.031*** (0.009)	0.017** (0.007)	0.013** (0.005)	0.020*** (0.006)	0.028*** (0.008)	0.013** (0.006)
Sub_supply	0.011** (0.005)	0.002 (0.002)	0.003 (0.002)	0.004 (0.003)	0.005** (0.003)	0.002 (0.002)	0.002 (0.001)	0.003 (0.002)	0.004* (0.002)
ln(Employees)	0.029*** (0.004)	0.009*** (0.002)	0.008*** (0.001)	0.009*** (0.002)	0.006*** (0.002)	0.011*** (0.002)	0.012*** (0.001)	0.01*** (0.002)	-0.003 (0.002)
ln(Age)	0.006 (0.004)	-0.001 (0.002)	0.003** (0.001)	0.000 (0.002)	0.005** (0.002)	0.002 (0.001)	0.001 (0.001)	0.001 (0.002)	0.003 (0.002)
R&D_con ^o	0.076*** (0.008)	0.026*** (0.004)	0.019*** (0.003)	0.021*** (0.005)	0.034*** (0.005)	0.020*** (0.003)	0.014*** (0.003)	0.028*** (0.004)	0.021*** (0.004)
Qualification	0.19*** (0.023)	0.052*** (0.011)	0.051*** (0.008)	0.057*** (0.013)	0.057*** (0.012)	0.063*** (0.009)	0.036*** (0.007)	0.064*** (0.011)	0.052*** (0.010)
Patent_stock_dev	0.004*** (0.001)	0.001* (0.000)	0.001*** (0.000)	0.002*** (0.001)	0.001*** (0.001)	0.001** (0.000)	0.001*** (0.000)	0.001* (0.000)	0.000 (0.001)
Group_national ^o	-0.015 (0.009)	-0.006 (0.004)	-0.002 (0.003)	-0.004 (0.005)	-0.007 (0.005)	-0.003 (0.003)	0.004 (0.003)	-0.005 (0.005)	-0.013*** (0.004)
Group_foreign ^o	-0.012 (0.014)	-0.013** (0.005)	0.001 (0.005)	-0.009 (0.007)	-0.008 (0.007)	0.001 (0.005)	0.002 (0.004)	0.001 (0.008)	-0.013** (0.006)
East ^o	-0.003 (0.012)	0.004 (0.005)	-0.002 (0.004)	-0.008 (0.006)	0.003 (0.006)	0.001 (0.004)	-0.008*** (0.003)	0.001 (0.006)	0.007 (0.005)
Wald chi2 all	639.436***	261.116***	385.418***	262.159***	292.950***	423.224***	408.672***	318.939***	367.679***
Log likelihood	-3,127.421	-1,382.129	-1,232.041	-1,547.299	-1,503.389	-1,261.793	-1,205.911	-1,459.676	-1,421.187
Mc Fadden's R2	0.184	0.127	0.273	0.106	0.133	0.273	0.303	0.158	0.182
No. ob obs.	9,701	8,782	8,818	8,830	8,831	8,832	8,830	8,831	8,832

Note: ^o dy/dx is for discrete change of dummy variable from 0 to 1. *** (**, *) indicate significance level of 1% (5%, 10%). Standard errors are clustered by firm. Sector and year dummy variables are included in the regressions but not shown.