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## Abstract

This study investigates the impact of R&D subsidies on R&D investment during the past financial crisis. We conduct a treatment effects analysis and show that R&D subsidies increased R&D spending among subsidized small and medium sized firms in Germany during the crisis years. In the first crisis year, the additionality effect induced by public support was, however, smaller than in other years. This temporary decrease may be caused by an altered innovation subsidy scheme in crisis years or by a different innovation investment behavior of the subsidy recipients. We do not find support for the countercyclical innovation subsidy scheme having caused the smaller additionality effect and conclude that it is likely to be driven by subsidy recipient behavior.



**Keywords:** R&D, Subsidies, Policy Evaluation, Financial Crisis, Treatment Effects

**JEL Classification:** C14, C21, G01, H50, O38


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# 1. INTRODUCTION

The global economic crisis of 2008 has hit OECD countries severely. Unemployment has reached a post-war height of 8.5% in October 2009, GDP declined by 4% (OECD, 2012a) and long-term investments like innovation expenditure decreased significantly in a range of countries including Canada, Sweden and the UK (OECD, 2012b, Filipetti and Archibugi, 2011, Archibugi et al., 2013).

It is well understood that private sector research and development (R&D) is a main factor of sustainable growth of industrialized economies so that even a short-term decline or stagnation of private R&D activities can have detrimental consequences in the long run (Grossman and Helpman, 1991, Aghion and Howitt, 1998). Policymakers in many industrialized countries, including Austria, Denmark and Sweden, reacted immediately and enhanced R&D spending in order to prevent negative long-term consequences of a short-term decrease in R&D investment (OECD, 2012b). In Germany, government spending on R&D increased by 9% in 2009 as compared to 2007. Between 2010 and 2013 the federal government invested an additional €12 billion in key areas of education and research (OECD, 2012b). With these initiatives Germany "ranks in a league of its own" against an overall pro-cyclical behavior of public science and technology budgets in OECD countries (Makkonen, 2013). Overall, Germany belongs to the few countries that experienced a weak increase in R&D despite of the crisis. Business enterprise expenditure on R&D increased by 3% in 2009 as compared to 2007 (OECD, 2012b).

This study aims at evaluating the role of public R&D support during the past economic crisis. Policymakers are well aware of the importance of private sector R&D and also of the fact that private R&D spending is lower than socially desirable, even in boom periods. Private R&D

investment is below the social optimum because R&D has the characteristics of a public good and generates positive external effects which cannot be internalized (Arrow, 1962). In response, projects that would benefit society but do not cover the private cost are not realized. Governments subsidize R&D in order to make such R&D projects attractive to the private sector.

It is an empirical question whether public funding of private R&D projects leads to an increase of R&D in the economy as intended by innovation policy. Due to low application costs virtually all firms have incentives to submit an application for R&D subsidies, including firms that would be able to conduct their R&D projects with own financial means. In the case of a successful application, subsidized firms have incentives to substitute private R&D expenses with public funds. If the majority of subsidized firms would use public funds to replace private R&D expenses, innovation policy would not stimulate additional private R&D and a "crowding out effect" of private R&D investment would occur.[2]

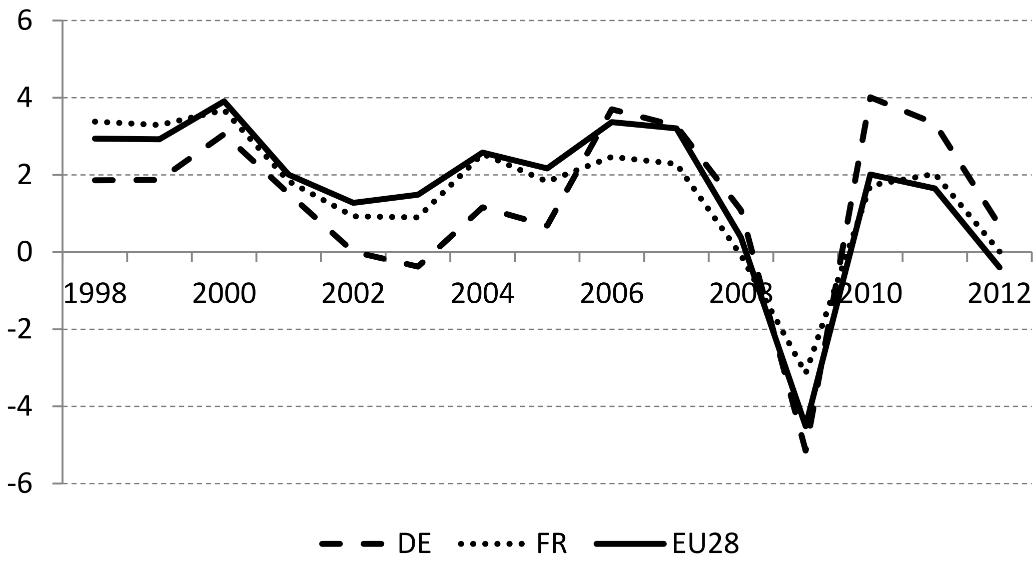
Public support for R&D activities is particularly important in times of an economic downturn. With investment in R&D being risky and returns being uncertain and long-term, firms facing financial constraints due to recessions are likely to reduce their investment in R&D (Schumpeter, 1939, Freeman et al., 1982). The consequences for the economy and for the long-term competitiveness and profitability of the firms themselves can be detrimental. A means to mitigate these consequences is to smooth R&D investment by innovation policy. During an economic downturn, incentives for subsidized firms to use the public funds to substitute private investment are, however, significant. Firms have to cope with the consequences of a crisis so that the likelihood of a crowding out effect is higher. In addition, it

[2] A crowding out effect can be rejected for the vast majority of R&D subsidy programs worldwide (see Zuniga-Vicente et al., 2014, for a recent survey).

has been shown that the responsiveness of companies to policy initiatives is weaker in times of economic uncertainty (Bloom et al., 2007, Bloom, 2008). This is because uncertainty increases the real option value of investments making firms more cautious with regards to their R&D investment decision during recessions.

Based on firm-level data for Germany, we investigate the effects of the German Federal Ministry for Education and Research's (BMBF) public R&D subsidy program on firms' R&D investment in the crisis period. We focus on small and medium-sized enterprises (SMEs) because these firms are expected to be more vulnerable during an economic downturn than large enterprises. The sample covers the period of 2006-2010, with 2009 marking the beginning of the crisis period in Germany as illustrated in Figure 1. Our analysis answers the following questions: First, we analyze whether R&D subsidies lead to an additionality effect in terms of R&D investment or whether there is evidence for a crowding out effect. Our empirical results from a non-parametric propensity score matching indicate that R&D subsidies lead to an additionality effect in all crisis and non-crisis years. Second, we investigate whether R&D subsidies have a different effect in the crisis period than in non-crisis years. Our results show that the effect of subsidies in the crisis year 2009 is - although positive - significantly smaller than in all other years. The smaller additionality effect in the crisis year can be indicative of a different behavior of subsidy recipients or of an altered innovation policy during the crisis. The budget of the BMBF increased by about 9% in 2009 compared to 2008, which enabled the ministry to subsidize more firms. The additionally funded firms that only qualify for funding because of the budget increase might be of worse quality than the subsidy recipients of non-crisis years. A decrease of the average quality of the subsidized companies could cause a lower additionality effect. An alternative explanation for the lower additionality effect could be that firms invest less in R&D during the crisis because they face a reduced demand for products and services and higher incentives to substitute private with public funds. In the last part of the analysis, we hence investigate whether the smaller additionality effect in the crisis year 2009 is related to an altered innovation subsidy scheme. We do not find support for firms subsidized in the crisis being of worse quality than subsidized firms in pre-crisis years. Hence, we reject the hypothesis that an altered innovation policy caused the decrease in the magnitude of the additionality effect of the crisis. This leaves us with the alternative explanation that subsidized firms invest less in R&D because they have to cope with the consequences of the crisis. Although the average additionality effect per firm is smaller in the first crisis year, the counter-cyclical innovation policy is likely to have had a stabilizing effect because it helped SMEs to pay the wages of R&D workers and allowed them to start new projects.

Figure 1 – Real GDP growth




Source: Eurostat. Own calculations.

The remainder of the paper is organized as follows. The next section surveys related literature. Section 3 presents the empirical strategy. The data set is described in section 4. The results are discussed in section 5. The last section concludes.

# 2. LITERATURE REVIEW

## Innovation Expenditure during Economic Downturns

The economic literature has developed different views on the impact of an economic downturn on innovation activities. One line of research advocates counter-cyclical behavior of R&D investment. In times of an economic downturn, profitability declines encourage firms to search for measures to improve productivity. At the same time, opportunity costs of reallocating productive assets from manufacturing to R&D are relatively low because of a limited demand for manufacturing (Stiglitz, 1993, Aghion and Saint-Paul, 1998). This is in line with the Schumpeterian notion of creative destruction according to which a crisis opens new opportunities. Systematic innovation can open opportunities for economic activities and set an end to the recession (Schumpeter, 1934).

The contrary perspective suggests that innovation behavior is pro-cyclical. Schmookler (1966) and Shleifer (1986) argue that innovation strongly depends on demand. If demand is low there is no incentive to introduce new products into the market. Further, R&D is often financed by the firm's free cash flow that depends on the company's current success so that financial constraints during an economic downturn reduce investment in R&D (Hall 1992, Himmelberg and Petersen, 1994, Harhoff, 1998, Rafferty and Funk, 2008).

Prior studies mostly report a pro-cyclical innovation investment behavior. Barlevy (2007) shows that R&D behaves pro-cyclical, resulting in inefficient R&D investment during recessions. He suggests that technology leaders should expand their R&D activities during crisis times to disproportionately gain from growth periods. The threat of spillovers to rival innovators which refrain from own innovation activities in crisis periods, however, incentivizes technology leaders to shift the bulk of their R&D investment to upswing periods. Ouyang (2011) examines the opportunity cost hypothesis and finds an asymmetric response of R&D to demand shocks. A positive demand shock causes R&D expenditures to decrease due to rising opportunity costs while a negative demand shock decreases R&D investment due to liquidity constraints. Ouyang (2011) finds that the liquidity constraints effect outweighs the opportunity cost effect resulting in a pro-cyclical R&D investment behavior. Aghion et al. (2010, 2012) and Bovha-Padilla (2009) find evidence that credit constrained firms reveal a higher share of R&D investment during periods of flourishing sales, underpinning the hypothesis of pro-cyclicality.[3] This relationship, however, turns out to be counter-cyclical if firms are not credit constrained. Further empirical evidence on innovation behavior and the business cycle includes Geroski and Walters (1995) who show for the UK that growth Granger-causes innovation activity. Guellec and Ioannidis (1999) find that the burst of the Japanese financial bubble and the German unification (as macroeconomic shocks) had a large negative impact on R&D investment in the respective countries. In contrast to these results, Saint-Paul (1993) does not find support for either a pro- or counter-cyclical investment behavior in R&D. The explanation put forward is that the cash-intensive nature of R&D offsets the opportunity cost effect.

With regards to the global economic crisis, macroeconomic figures show an overall decline of innovation activities across OECD countries, whereby different countries are affected by a different degree (OECD, 2012b). Heterogeneous effects have been found on the firm level as well. Overall, firms' innovation activities declined during the crisis with a few exceptions

[3] Aghion et al. (2010) do not investigate specifically the effect on R&D investment but on long-term investment. They argue, however, that long-term investment could be e.g. R&D investment.

comprising some new, fast growing firms and some firms that were highly innovative before the crisis and sustained a high innovation performance during the crisis (Archibugi et al., 2013). In addition, a few small firms and new entrants show a greater readiness to "swim against the stream" in terms of their innovation strategy after the crisis (Archibugi et al., 2013). For a sample of Latin American countries, Paunov (2012) shows that many firms stopped ongoing R&D projects during the crisis.

## Public Budgets during Recessions

Given that most evidence supports pro-cyclical R&D investment behavior of the private sector the question remains whether and how the government should react. From a Keynesian perspective there is the clear proposition that the government should stabilize the economy by increasing its spending during recessions, reducing taxes and shifting its budget towards a deficit in order to increase consumption (Romer, 1993).

In a neoclassical framework, the optimal co-movement between government consumption and private consumption depends on the degree of substitutability in utility between these two (Arreaza et al., 1999, Lane, 2003a). If public and private consumption are substitutes, government consumption would be expected to behave counter-cyclically. In case of complementarity, a pro-cyclical pattern would be expected. If public and private consumption are separable in utility, the government should seek to perfectly smooth government consumption over the business cycle.

Empirical evidence supports a pro-cyclical behavior of government spending in OECD countries (Arreaza et al., 1999, Lane 2003a,b, Abbott and Jones, 2012). This is explained by dispersed political power and output volatility (Lane 2003a, Abbott and Jones, 2011, 2012). With focus on public science and technology budgets and the past financial crisis, Makkonen

(2012) reports a pro-cyclical behavior for the majority of countries in the European Union. The new member states were affected most, while some countries showed a counter-cyclical behavior increasing their science and technology budgets during the crisis. The largest percentage increase in budgets took place in Germany, Luxembourg, Denmark, Estonia and Portugal (Makkonen, 2012). Countries including Austria, Germany, Denmark and Sweden reacted to the crisis with targeted R&D initiatives (OECD, 2012b). The German government increased R&D spending by 9% in 2009 as compared to 2007. An additional €12 billion were devoted to key areas of education and research between 2010 and 2013 (OECD, 2012b). The empirical part of this paper will investigate the effect of such a counter-cyclical science and technology policy during the crisis with focus on a direct project R&D subsidy program.

## R&D Subsidy Programs

In times of downturn and upswing, governments across the world spend significant amounts of money on public initiatives to foster private innovation activities to stimulate economic growth and national competitiveness. The success of these policy measures is ex ante unclear and has to be evaluated ex post since there is an incentive for subsidy recipients to replace private R&D investment with public funds. A vast literature of ex post evaluation studies exists for various R&D subsidy programs in different countries.[4] Early surveys are provided by David et al. (2000) and Klette et al. (2000). The majority of the surveyed studies find that R&D subsidies lead to an additionality effect.

[4] E.g. for Finland (Czarnitzki et al., 2007, Takalo et al. 2008), Flanders (Aerts and Czarnitzki, 2005, Aerts and Schmitt, 2008, Czarnitzki and Lopes Bento, 2013), France (Duguet, 2004), Germany (Czarnitzki and Fier, 2002, Almus and Czarnitzki, 2003, Hussinger, 2008), Israel (Lach, 2002), Italy (Cerulli and Poti, 2010), Canada (Berube and Mohnen, 2009), Luxembourg (Czarnitzki and Lopes Bento, 2012), Spain (Busom, 2000, Gonzales et al., 2005, Gonzales and Pazo, 2008, Gelabert et al., 2008), the AMT (advanced manufacturing technologies) program in Switzerland (Arvanitis et al., 2002), the U.S. SBIR program (Wallsten, 2000) and the U.S. chemical industry (Finger, 2008), South Africa (Czarnitzki and Lopes Bento, 2012) and Latin America (Hall and Maffioli, 2008). Most of these studies can rule out a full crowding out effect.

The early literature up to the year 2000 is critiqued for disregarding a potential selection bias of participating firms into R&D subsidy programs. On the one hand, more innovative companies are more likely to apply for R&D subsidies. On the other hand, these companies can be more likely to receive the public funds if the government follows a “picking the winner” strategy. A simple comparison of subsidized and non-subsidized firms would hence lead to biased results. The literature since 2000 as surveyed by Cerulli (2010) and Zuniga-Vincente et al. (2014) takes the selection problem into account.[5] Also after selection is accounted for, most evaluation studies report a positive effect of the subsidy on the subsidized firms’ R&D expenses.[6]

The previous literature does not pay attention to the business cycle when evaluating the effects of R&D subsidy schemes. A notable exception is a recent contribution by Paunov (2012). Paunov (2012) studies the likelihood to stop ongoing R&D projects of firms in eight Latin American countries in response to the global financial crisis. She finds that the likelihood to stop projects correlates negatively with the receipt of public funding. Paunov (2012) concludes that public funding schemes are an important means to foster counter-cyclical investment behavior. Her analysis does not account for a potential selection bias.

A distantly related study investigates the effects of subsidies on R&D investment in the presence of market uncertainty (Czarnitzki and Toole, 2007). While the economic uncertainty that firms face during an economic downturn is not the same as product market uncertainty, it

[5] Prominent methods that allow controlling for a selection bias are matching estimators (e.g. Czarnitzki and Fier, 2002, Almus and Czarnitzki, 2003, Czarnitzki et al., 2007, for heterogeneous treatments), instrumental variables methods (e.g. Wallsten, 2000) and selection models (e.g. Busom, 2000, Hussinger, 2008, for semiparametric versions). Gonzales et al. (2005) and Takalo et al. (2008) develop structural models to access the effect of subsidies on the subsidized firms.

[6] Exceptions are Busom (2000), who finds a partial crowding out effect for Spain and Wallsten (2000), who reports a substitutive effect of subsidies for the U.S. SBIR program. Gelabert et al. (2008) find differences in the effectiveness of public subsidies depending on the level of appropriation in the firm’s industry.

is still an interesting finding that R&D subsidies reduce the negative effect of product market uncertainty on R&D investment.

# 3. METHODOLOGY

## Empirical Strategy

Our empirical approach has three different parts. The first part evaluates the effectiveness of R&D subsidies. In the second part of the analysis we compare the effect of subsidies in the crisis period to non-crisis years. In the last part of the analysis, we investigate whether the altered subsidy scheme in the crisis years has led to different effects of subsidies in crisis and non-crisis years.

## Part 1: Effectiveness of R&D Subsidies

The aim of our policy evaluation is to assess the average effect of the public subsidy on the R&D spending of the subsidized companies. Since a simple comparison between treated (subsidized) and non-treated (non-subsidized) companies is likely to be biased due to selection problems,[7] our empirical approach aims at investigating what the treated observations would have spent on R&D if they would not have received the subsidy, i.e. the counterfactual situation. This average treatment effect on the treated (ATT) is defined as follows:

$$(1)\ ATT = E(Y_1 - Y_0|S = 1) = E(Y_1|S = 1) - E(Y_0|S = 1)$$

where $Y_1$ is the R&D spending of the companies having received a treatment and $Y_0$ is the R&D spending of companies that did not receive a subsidy and $S$ depicts the actual treatment (=subsidy) status. This equation illustrates a missing data problem: while we can

[7] For details see Blundell and Costa Dias (2008).

observe $(Y_1|S = 1)$, i.e. the R&D spending of a subsidized firm, we cannot observe what the subsidized firm $(S = 1)$ would have spent on R&D without the subsidy $(Y_0|S = 1)$. Constructing a valid proxy for the counterfactual situation is the main issue in empirical policy program evaluation. Since it is usually not possible to conduct real experiments, econometric techniques have been developed that aim at proxying the counterfactual situation. Econometric techniques serving to overcome this problem comprise difference-in-difference (DID) estimations, control function approaches (selection models), instrumental variable (IV) estimations, matching techniques and regression discontinuity designs.

The DID approach requires panel data with observations before and after (or while) the treatment. Since more than 50% of the firms in our sample are only observed once, we have to disregard the DID approach. The reliability of selection models and IV estimators rests on the availability of at least one valid exclusion restriction or instrumental variable. In our case it is difficult to find an exclusion restriction or instrumental variable that is motivated by economic theory and impacts the likelihood to receive public R&D funding, but does not correlate with the R&D expenditure of the company. Therefore, we choose a matching method. The intuition behind the matching approach is to proxy the counterfactual situation, i.e. the investment of a treated company in the absence of the treatment, by the investment of the most similar non-treated observation. Functional form assumptions and distributional assumptions about the error terms are not required.

We apply a nearest neighbor propensity score matching. In practice, this means that we match each subsidy recipient with the single most similar company in the control group of the non-subsidized firms. The pairs are chosen based on the similarity in the estimated probability of receiving a subsidy, i.e. the propensity score. Matching on the propensity score avoids a "curse of dimensionality" because all information is bundled in the propensity score which is then used as the single matching argument (see Rosenbaum and Rubin, 1983). In addition, we require that the selected control observation is observed in the same year as the treated observation. This is crucial for our analysis because we are interested in comparing treatment effects across years in the second part of the empirical analysis. We further demand that the control observations are located in the same geographical area in Germany by distinguishing between Eastern and Western German companies. We do this because the funding likelihood as well as the infrastructure for innovation differs between the two regions.

The matching estimator's main disadvantage is its reliance on the conditional independence assumption (CIA). This means that the assignment to treatment has to be independent of the outcomes, in our case the R&D investment, conditional on a set of observable characteristics $(X)$ (Rubin, 1977):

(2) $Y_1, Y_0 \perp S|X$

with $Y_1$ being the outcome of treated companies, $Y_0$ being the outcome of non-treated companies and $S$ representing the actual treatment status. The CIA is satisfied if all information that affect the treatment assignment and the outcome is included in $X$. If so, the observed non-treated outcome $E(Y_0|S=0)$ is a valid proxy for the unobservable counterfactual outcome $E(Y_0|S=1)$. Unfortunately, it is not possible to formally test the CIA. However, we are confident that our rich set of control variables suffices for the CIA.[8]

A further requirement of the matching method is that there has to be sufficient overlap between the treated and the control group in terms of their propensity to receive a public subsidy (common support). In order to guarantee common support, we calculate the minimum

[8] Similar control variables have been used in a variety of studies that evaluate the effects of R&D subsidies based on similar datasets employing a matching approach (e.g.Czarnitzki and Fier, 2002, Almus and Czarnitzki, 2003, Czarnitzki et al., 2007, Czarnitzki and Lopes Bento, 2013).

and the maximum of the propensity scores of the potential control group, and delete observations on treated firms with probabilities larger than the maximum and smaller than the minimum in the potential control group.

If the CIA and the common support are fulfilled, the ATT will be identified and consistently estimated by estimating the following equation:

(3) $ATT = (Y_1|S = 1) - E(Y_0|S = 0)$

The details of our matching procedure are depicted in Table 1.

Table 1 – Matching protocol

1. Specify and estimate a probit model to obtain the propensity score $\hat{P}(X)$.
2. Restrict the sample to common support: delete all observations on treated firms with probabilities larger than the maximum and smaller than the minimum in the potential control group (this step is also performed for other observed characteristics that are used in addition to the propensity score as matching arguments).
3. Choose one observation from the subsample of treated firms.
4. Calculate the Mahalanobis distance between this firm and all non-treated firms in order to find the most similar control observation: $M_{ij} = (Z_j - Z_j)'\Omega^{-1}(Z_j - Z_j)$

   Z contains the propensity score, the year and a dummy that indicates whether the company is located in Eastern Germany or not. $\Omega$ is the empirical covariance matrix of the matching arguments based on the sample of potential controls.
5. Select the observation with the minimum distance from the remaining control group (do not remove the selected controls from the pool of potential controls, so that it can be used again).
6. Repeat steps 3-5 for all observations on treated firms.
7. Use the matched comparison group to calculate the average treatment effect on the treated as mean difference of the matched samples: $\widehat{ATT} = \frac{1}{n^1}(\sum Y_i^1 - \sum \hat{Y}_i^0)$ where $\hat{Y}_i^0$ is the counterfactual for firm $i$ and $n^1$ is the sample size of the treated firms. Note that the same observation may appear more than once in the group of controls.
8. The ordinary t-statistic on mean differences is biased as we perform sampling with replacement. That is why we correct standard errors by applying Lechner's (2001) estimator for an asymptotic approximation of the standard errors.

## Part 2: Effectiveness of R&D Subsidies in Crisis and Non-Crisis Years

After having identified the ATT that shows whether the R&D subsidy led to additional R&D investment by the subsidized companies, we investigate whether the effect of subsidies differs in crisis and non-crisis years. In order to do so we run a regression of the ATT on a set of time dummies *d*.

(4) $\widehat{ATT} = \propto \ + \sum_t \ \beta_t d_t + u$

The estimated coefficients of the year dummies indicate whether the treatment effects differ in times of crisis. There are two different possible scenarios. On the one hand, one can expect that the subsidies are more effective in the crisis years because firms face more severe financial constraints so that the subsidy increases R&D investment substantially. On the other hand, a lower treatment effect can occur in crisis years if firms match the public funds with less private investments than they would have made in non-crisis years. The latter effect would be in line with a prediction from real option theory which state that the responsiveness of companies to policy initiatives is weaker in times of economic uncertainty because uncertainty increases the real option value of investments so that firms become more cautious with regards to their R&D investment decision during recessions (Bloom et al., 2007, Bloom, 2008).

## Part 3: Explanations for Possible Different Effects of R&D Subsidies in Crisis and Non-Crisis Years

In the final part of the analysis we investigate explanations for the potential differences of the effectiveness of R&D subsidy schemes in crisis and non-crisis years in the German context. Such differences can be motivated by (a) a different funding policy in crisis times or (b) a different behavior of grant recipients in crisis times:

(a) During the past crisis direct project funding has been increased in terms of amounts and number of projects funded. This can have implications on the ATT in crisis years because if more projects are funded the average quality of the recipient is likely to be lower than in non-crisis years which could in turn lead to a lower ATT.

(b) Subsidy recipients face financial constraints during the crisis. In response, they might invest less into the subsidized R&D project than they would have spent in non-crisis years.

We aim at analyzing whether the change in innovation policy influenced the effect of R&D subsidies in times of crisis. We do so by comparing first time subsidized firms in crisis and non-crisis years. In case a lower subsidy effect is caused by a lower quality of funded firms during the crisis years, we should find a significant difference between these groups of firms in terms of success predictors like firm size or patent stock. If we do not find evidence for an effect of an altered subsidy scheme on the quality of the subsidy recipients, hypothesis (b) is supported.

# 4. DATA, VARIABLE DEFINITION AND DESCRIPTIVE STATISTICS

To empirically examine a potential additionality effect of R&D subsidies, we construct a database which consists of firm level information and their subsidy records. The firm level dataset is the Mannheim Innovation Panel (MIP), which is an annual survey conducted by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry for Education Research (BMBF) since 1993. The MIP is the German contribution to the European Commission’s Community Innovation Survey (CIS) and provides us with most of the company characteristics.

Information on the Federal Government's project funding is taken from BMBF's PROFI database. It contains information on all non-military R&D projects funded by the BMBF. The BMBF funding is the largest source of public R&D funds for the business sector in Germany and accounts for more than 80% of the total public R&D funding of the business sector. The direct project funding program is open to all firms located in Germany. The official application form requires detailed information on the company and its planned R&D projects. There is a peer review process according to which grants are assigned as "matching grants" to the selected projects, which means that applicants have to contribute at least 50% to the subsidized projects. The government sponsors at most 50% as is prescribed in the funding guidelines of the European Commission (1996) and in German regulations (BMBF and BMWi, 2001).

Further data sources comprise the European Patent Office (EPO) which provides us with firms' patent applications since 1979, the credit rating agency Creditreform and the Center for Economic Studies (ifo). The ifo conducts a business cycle survey on a monthly base. Every month, close to 7000 (2500) enterprises operating in the industry (services) sector are surveyed on their assessment of the actual and future business situation.[9] Based on this information the ifo publishes a yearly business cycle indicator which we use in order to account for the business climate in specific industries before and during the crisis. Additional firm information is retrieved from the largest credit rating agency in Germany, Creditreform, which provides us with firm age information and a credit rating indicator that proxies the firms' financial fitness.

The final sample covers the years 2006 – 2010 so that we cover the pre-crisis and the crisis period. We restricted the sample to firms with more than 4 employees and less than 250

[9] We downloaded ifo's business cycle indicator from Thomson Reuters' Datastream, the world's largest financial database.

employees since SMEs are more sensitive to the business cycle. Our sample includes manufacturing as well as business related service sectors. The final sample consists of 7843 firm-year observations out of which 801 received a R&D subsidy from the BMBF.

### Treatment Variable

We measure treatment by a binary indicator that takes on the value 1 if a firm had been subsidized by BMBF in the respective year. The indicator takes on the value 0 if a firm had not received any R&D subsidy at all in the respective year, neither from the EU nor from the Federal Government nor from other sources. Thus, our control group solely consists of non-subsidized firms, allowing us to rule out side-effects from other subsidy programs.

### Outcome Variables

We test the hypothesis of additionality for six outcome variables in order to show robustness of the results with regards to different definitions of the dependent variable. *RD* depicts a firm's total R&D expenditure, which is measured in million EUR. *PRIVRD* is defined as the private R&D investment, i.e. *RD* minus the subsidy received. Since these variables are distributed askew, we employ *RDINT* (*RD* over sales) as well as *PRIVRDINT* (*PRIVRD* over sales) as additional dependent variables. In addition, we define *RDEMP* (*RD* over number of employees) and *PRIVRDEMP* (*PRIVRD* over number of employees) as alternative measures for the R&D intensity.

### Control Variables

Our control variables encompass firm size as measured by the log of the number of full time employees, *lemp*. We allow for a possible non-linear relationship by including the square term of the log of employees, *lemp2*. We expect that R&D expenditure correlates with firm size and that, thus, larger firms are also more likely to apply for subsidies and to receive a grant if the government is following a "picking the winner" strategy. The logarithmic specification is chosen because of the skew distribution of the firm size variable.

If a firm is part of an enterprise group, this membership can increase the accessibility to innovation capacity and also to information on governmental programs probably resulting in a higher likelihood to apply for a subsidy. Further, governmental evaluators could be prone to subsidize firms that belong to a network of firms, being aware of potential knowledge spillovers within the enterprise group due to the subsidized project. We control for firms belonging to a firm group with a binary variable, *group*. Firms with a foreign headquarter, *foreign*, could, in contrast, be less likely to receive funding because the government might want to induce economic effects in the own country. The binary variable *east* indicates whether a firm is located in Eastern Germany or in the Western part of the country. East German firms could be more likely to receive a subsidy as this region is still in a catch-up process with regards to Western Germany. The log of firm age, *lage*, covers potential firm age effects.

Firms competing in foreign markets are more innovative than others (Arnold and Hussinger, 2005). Therefore, we also expect export-oriented firms to apply more frequently for R&D subsidies. Our binary dummy *export* indicates whether a firm has export sales or not.

To further account for a firm's innovation potential and a "picking the winner" strategy of the government, we control for a firm's past success in creating new knowledge by accounting for its patent stock. To construct the patent stock, we use patent applications from 1979 onwards which have been filed at the EPO. The indicator is calculated as a depreciated sum of all these patent applications until t-1 plus the (non-depreciated) applications in t. The depreciation rate is set to 0.15 as is common in the literature (see e.g. Hall, 1990, Griliches and Mairesse, 1984). Due to collinearity concerns with firm size, the patent stock is divided by the number of employees, *patemp*.

To cover potential financial restrictions a firm might have, particularly during the crisis period, we include Creditreform's credit rating index, *credit*.[10] This is an index representing a firm's solvency. The index ranges from 100 to 600. The higher the index, the lower is the credit rating and the ability to attract debt capital. Firms that have more problems to attract external finance might be more likely to apply for subsidization.

Another characteristic to be considered is the business climate of the industry the firm takes an active part in. SMEs usually participate only in one or a few product markets. In case of economic downturns, these firms may not have the opportunity to compensate a serious decrease in demand in one of their few markets. We control for the business climate the companies are facing by including ifo's index for business situations, *busit*. The business situation indicator ranges from -100 to +100, indicating a positive or negative change compared to the previous period, respectively. We translated the ifo's industry classification to the NACE industry classification at a 2- to 4-digit level using the most disaggregated industry level.

To avoid potential endogeneity, we lagged all time-variant explanatory variables and consider *group, foreign, east* as time-invariant and *lage* as truly exogenous.

### Descriptive Statistics

Table 2 shows descriptive statistics, comparing the variables' mean values for non-subsidized and subsidized firms. The significant t-tests indicate systematic differences between subsidized and non-subsidized firms. For example, subsidized firms score higher on all R&D

[10] We also employ a missing value correction. The missing values of *credit* are set to zero. An additional binary dummy, *creditmiss*, that takes on the value 1 if *credit* equals zero, is included in the estimations.

input measures, they have more patents per employee, more employees and are more likely to be exporters. Further, subsidized firms are younger and are more frequently located in Eastern Germany.

Table 2 – Descriptive statistics

| Variables | Unsubsidized irms N = 7042 | | Subsidized firms N = 801 | | t-test |
|---|---|---|---|---|---|
| | Mean | Std.dev. | Mean | Std.dev. | |
| Covariates | | | | | |
| patemp | 0.002 | 0.017 | 0.021 | 0.073 | *** |
| lemp | 3.174 | 1.107 | 3.502 | 1.083 | *** |
| lemp2 | 11.302 | 7.451 | 13.434 | 7.673 | *** |
| foreign | 0.050 | 0.218 | 0.079 | 0.269 | *** |
| export | 0.470 | 0.499 | 0.845 | 0.362 | *** |
| group | 0.195 | 0.396 | 0.262 | 0.440 | *** |
| lage | 3.117 | 0.838 | 2.689 | 0.717 | *** |
| busit | 12.251 | 29.643 | 17.209 | 33.301 | *** |
| credit | 225.648 | 65.554 | 225.533 | 51.684 | |
| east | 0.338 | 0.473 | 0.404 | 0.491 | *** |
| Outcome variables | | | | | |
| RD | 0.040 | 0.281 | 0.406 | 0.759 | *** |
| PRIVRD | 0.040 | 0.281 | 0.324 | 0.703 | *** |
| RDINT | 0.005 | 0.027 | 0.096 | 0.150 | *** |
| PRIVRDINT | 0.005 | 0.027 | 0.062 | 0.114 | *** |
| RDEMP | 0.001 | 0.003 | 0.009 | 0.011 | *** |
| PRIVRDEMP | 0.001 | 0.003 | 0.006 | 0.010 | *** |

Note: * p<0.1; ** p<0.05; *** p<0.01; the missing value dummy of the credit rating indicator as well as the industry and time dummies are not reported here; N represents the number of observations.

Subsidized firms on average reveal a higher business situation index which describes that the industries of the subsidy recipients have experienced a larger upswing as compared to the previous period than the industries of non-subsidized companies. This suggests that firms are more likely to apply for and receive a subsidy if the industry is in an upswing. Further, the credit rating between non-subsidized firms and subsidized firms does not differ significantly. A value of about 225 means a “good financial standing”.

Note that most of the differences hint at a “picking the winner” strategy of the government when deciding on subsidy recipients. An exception is the difference with regards to firm location in Eastern or Western Germany. The higher share of subsidized companies in the formerly socialist part of the country indicates that the subsidy scheme also aims at fostering firms in the region with a comparatively weak infrastructure.

# 5. EMPIRICAL RESULTS

### Funding Propensity

As described in section 3, we employ a matching method to identify the causal effect of the subsidy treatment. Thus, we have to find non-treated (non-subsidized) observations with the most similar characteristics to the treated (subsidized) observations. We determine the so-called nearest neighbors based on the propensity score, i.e. the likelihood of receiving a subsidy. Therefore, we estimate a probit model for the receipt of public subsidies. Table 3 shows the estimation results. Apart from the dummy indicating membership of a firm group, the dummy indicating a foreign headquarter and the business situation, each variable reveals significant effects with the expected sign.

Table 3 – Probit estimation

| | Coefficients | Standard errors |
|---|---|---|
| patemp | 6.435*** | 0.7 |
| lemp | 0.296** | 0.137 |
| lemp2 | -0.024 | 0.02 |
| foreign | -0.046 | 0.099 |
| export | 0.894*** | 0.061 |
| group | -0.098 | 0.065 |
| lage | -0.341*** | 0.033 |
| busit | 0.002 | 0.001 |
| credit | -0.001** | 0.001 |
| east | 0.246*** | 0.049 |
| constant | -1.104*** | 0.293 |
| Number of observations: | 7843 | |
| McFadden's R2: | 0.27 | |
| Log-likelihood: | -1899.98 | |
| Test on joint significance of | | |
| Time dummies: | chi2(4) = 74.21*** | |
| Industry dummies: | chi2(6) = 309.2*** | |

Note: * p<0.1; ** p<0.05; *** p<0.01; the missing value dummy of the credit rating indicator is not reported here but is negatively significant.

## Average Treatment Effects on the Treated

In a second step, we determine twin observations for non-subsidized firms for each subsidized firm based on the propensity score and the additional two matching arguments – location in Eastern Germany and year of observation. Due to the common support criterion we have to drop two observations for which we cannot determine appropriate control observations.

Table 4 shows the mean values for treated observations and controls after the matching. There no longer exist significant differences between the treated and the non-treated observations with regards to the control variables indicating that our matching specification is valid. Significant differences in the mean values of the outcome variables persist and can be given a causal interpretation after the matching.

The subsidized firms reveal a higher R&D activity independent of the definition of the outcome variable. Thus, we find an overall positive ATT signaling that firms increased their R&D spending due to the subsidy. We can reject a crowding out. The ATT equals 0.224 (0.141) million EUR in terms of R&D (private R&D) expenditures. The ATT in terms of R&D (private R&D) over sales corresponds to 7.6% (4.3%) points. For R&D intensity as defined by R&D over employment the ATT amounts to 0.7% (0.4%) points for R&D (private R&D).

Table 4 – Matching results

| Variables | Unsubsidized firms N = 799 | Subsidized firms N = 799 | t-test | p-value |
|---|---|---|---|---|
| | Mean | Mean | | |
| Covariates | | | | |
| patemp | 0.016 | 0.018 | | 0.622 |
| lemp | 3.582 | 3.502 | | 0.237 |
| lemp2 | 14.099 | 13.436 | | 0.161 |
| foreign | 0.085 | 0.079 | | 0.708 |
| export | 0.862 | 0.845 | | 0.409 |
| group | 0.294 | 0.262 | | 0.232 |
| lage | 2.684 | 2.688 | | 0.920 |
| busit | 17.919 | 17.205 | | 0.723 |
| credit | 225.924 | 225.461 | | 0.883 |
| east | 0.404 | 0.406 | | 0.966 |
| Outcome variables | | | | |
| RD | 0.177 | 0.401 | *** | 0.000 |
| PRIVRD | 0.177 | 0.318 | *** | 0.000 |
| RDINT | 0.020 | 0.096 | *** | 0.000 |
| PRIVRDINT | 0.020 | 0.063 | *** | 0.000 |
| RDEMP | 0.002 | 0.009 | *** | 0.000 |
| PRIVRDEMP | 0.002 | 0.006 | *** | 0.000 |

Note: * p<0.1; ** p<0.05; *** p<0.01; the missing value dummy of the credit rating indicator as well as the industry and time dummies are not reported here.

## Average Treatment Effects in the Course of Time

In this sub-section we investigate potential changes of the average treatment effect on the treated over time. Table 5 presents the results of OLS regressions of the ATT on a set of year dummies. This model's constant represents the ATT of the year 2006, our year of comparison. Table 5 shows that the ATTs in 2006 are positive and significant as expected. As compared to 2006, the ATT in 2009 is significantly lower while the further year dummies are not statistically significant. This suggests that the beginning of the crisis period had a significant negative effect on the ATT.

Table 5 – OLS results

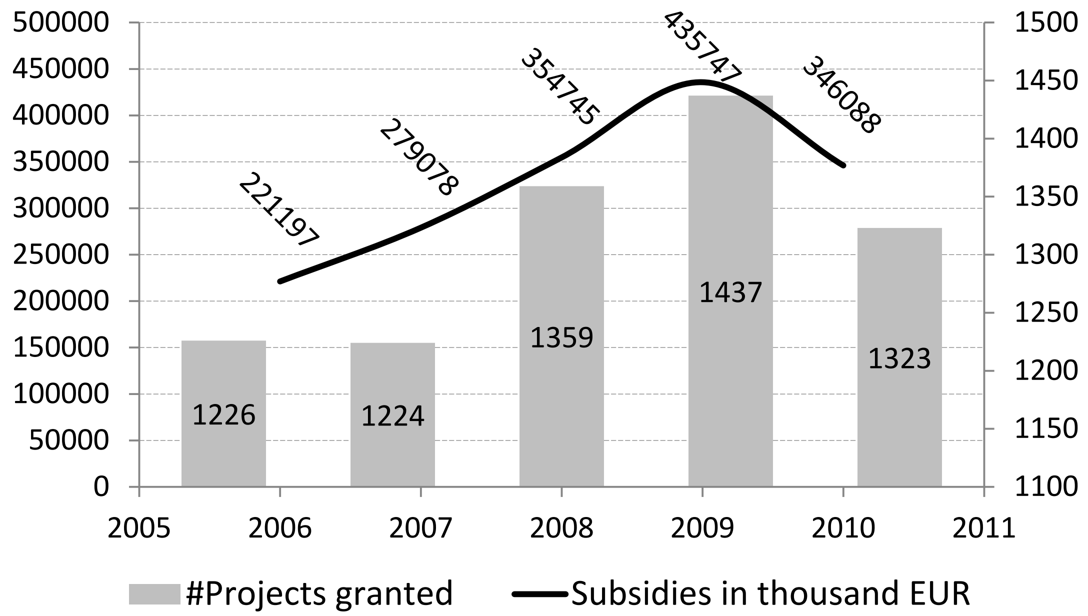
| | RD | PRIVRD | RDINT | PRIVRDINT | RDEMP | PRIVRDEMP |
|---|---|---|---|---|---|---|
| 2007 | -0.18 | -0.167 | -0.004 | -0.009 | -0.001 | -0.001 |
| | -0.125 | -0.122 | -0.018 | -0.015 | -0.001 | -0.001 |
| 2008 | 0.045 | 0.069 | -0.027 | -0.016 | -0.001 | 0.000 |
| | -0.098 | -0.094 | -0.018 | -0.017 | -0.001 | -0.001 |
| 2009 | **-0.179*** | **-0.149*** | **-0.042***** | **-0.033**** | **-0.003**** | **-0.003**** |
| | -0.092 | -0.09 | -0.015 | -0.014 | -0.001 | -0.001 |
| 2010 | -0.102 | -0.092 | 0.001 | -0.005 | 0.000 | 0.000 |
| | -0.094 | -0.092 | -0.017 | -0.014 | -0.001 | -0.001 |
| constant | **0.312***** | **0.215***** | **0.089***** | **0.054***** | **0.007***** | **0.005***** |
| | -0.071 | -0.068 | -0.012 | -0.011 | -0.001 | -0.001 |
| N: | 799 | 799 | 799 | 799 | 799 | 799 |
| $R^2$: | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

Note: * p<0.1; ** p<0.05; *** p<0.01; standard errors are clustered at the firm level.

## Potential Explanations for the Difference

As mentioned in section 3, the significantly lower ATT could be due to a changed funding policy during the crisis or due to an altered firm behavior. Figure 2 depicts the allocation policy of the BMBF for SMEs over the observed period. In 2006, 1226 projects were granted with an overall amount of about 221 million EUR. During the crisis, this amount corresponded to 435 million EUR for 1437 granted projects. This shows that the BMBF increased the number of projects granted as well as the total amount in 2009. In 2010, pre-crisis levels are achieved. The peak of 2009 could imply that the BMBF subsidized firms of lower average quality than in the pre-crisis years. If so, this should be visible in the funding probability.

Figure 2 – Funding development for SMEs




Source: BMBF's PROFI database. Own calculations.

In order to provide a formal test for potential quality differences of subsidy recipients before and during the crisis, Table 6 presents a probit regression of our control variables on a binary dummy variable. The dummy takes on the value 1 if the regarded firm has been subsidized by the BMBF for the first time before the crisis of 2009, it takes on the value 0 if the regarded firm has been subsidized by the BMBF for the first time after the crisis started. If a first time subsidy recipient before and during the crisis differed, we would see significant differences in the firm characteristics. The regression results, however, do not uncover systematic differences between first time subsidy recipients in both periods rejecting the hypothesis of a quality difference of subsidy recipients. The only significant difference is the business situation but the estimated coefficient as well as the marginal effect (not presented here) are negligibly small.

Table 6 – Probit of first time funded firms

| | Coefficients | Standard errors |
|---|---|---|
| patemp | -0.707 | 0.702 |
| lemp | 0.232 | 0.365 |
| lemp2 | -0.031 | 0.051 |
| foreign | -0.199 | 0.252 |
| export | 0.020 | 0.187 |
| group | 0.124 | 0.177 |
| lage | -0.034 | 0.092 |
| busit | 0.005*** | 0.002 |
| credit | 0.000 | 0.002 |
| east | 0.180 | 0.129 |
| constant | 1.160 | 0.826 |
| Number of observations: | 801 | |
| McFadden's R2: | 0.05 | |
| Log-likelihood: | -277.36 | |
| Test on joint significance of Industry dummies: | chi2(6) = 8.88 | |

Note: * p<0.1; ** p<0.05; *** p<0.01; the missing value dummy of the credit rating indicator as well as the industry are not reported here. We left out the time dummies in this regression as including them does not change the results but leaves us with about 40% less observations.

Therefore, we reject that the lower ATT in the crisis year 2009 is caused by systematic differences between subsidy recipients before and during the crisis. The alternative explanation for the lower ATT is that it is induced by firms' investment behavior. Firms had to cope with the negative consequences of the financial crisis. They may have allocated the funds that they would have spent on R&D projects to more urgently needed fields during the crisis. According to Rammer (2011), firms that indicated the most severe effects of the crisis have been R&D active firms. Since most of the firms in the sample, which received a subsidy in the past, are R&D active firms it seems to be reasonable that these firms required financial means to service debt, satisfy long-term orders or to preserve research capacities, e.g. R&D employment.

# 6. CONCLUSION

We explore the effects of R&D subsidies during the global financial crisis. In response to the crisis, most OECD countries experienced a decrease in employment figures and long-run investments such as the investment in R&D. This can have detrimental long-term consequences because innovation is one of the major drivers of sustainable growth and wealth of industrialized countries. Among the OECD countries, Germany stands out with a slight increase in R&D activities from 2007 until 2009. Germany is also one of the countries that employed a counter-cyclical innovation policy to counteract the crisis effects.

Our study examines the effects of R&D subsidies on firms' R&D spending during the financial crisis. We start by investigating the average treatment effect on the treated (ATT) of direct R&D subsidies in Germany during the period 2006-2010. Using propensity score nearest neighbor matching, we find an overall positive ATT over the observed period. This means that even in the crisis years R&D subsidies have stimulated additional R&D investment by the private sector. Further results show that the ATT was - although positive and significant - lower in the crisis year of 2009. In search for an explanation for this lower additionality effect, we investigate whether the expansion of the German subsidy program during the crisis year 2009 has led to the smaller ATT or whether the smaller effect is caused by a different investment behavior of subsidy recipients in the first crisis year. The extension of the subsidy program might have caused the average quality of the subsidy recipients to be lower than in the pre-crisis years. This, in turn, could have lowered the average success of the subsidy program. In order to test this possibility we compare first time subsidy recipients before and during the crisis. The results show that there are no systematic differences between these groups of firms. Hence, we conclude that the smaller effect of the R&D subsidy program is not caused by the extension of the subsidy program in the crisis years but that it is caused by firm behavior. Firms may have shifted funds that they would have spent on R&D in non-crisis years to more urgent needs, such as keeping their stock of employees.

The countercyclical innovation policy of the German government is likely to have had a stabilizing effect for the innovation investment behavior of SMEs helping them to pay the wages of R&D workers and to start new projects. The decrease in the ATT lasted only for one year after which SMEs recovered from the first shock of the crisis and returned to normal R&D investment behavior.

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