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R&D Subsidies in a Crisis

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Abstract

Policymakers are aware of the fact that research and development (R&D) expenditure by the public sector is below the social optimum. This is the reason for subsidizing firms? R&D projects with public funds. Due to these policy interventions, firms are able to realize innovative projects they would not have been able to conduct otherwise. However, firms might also substitute private R&D expenses with the public funds so that the public funds would not stimulate additional private R&D. A ?crowding out effect? would occur. A large body of economic literature documents a positive causal (additionality) effect of R&D subsidies on firms? R&D investment, rejecting the hypothesis of full crowding-out. What remains unexplored is the efficacy of subsidies in times of crisis. One could imagine a different causal effect of subsidies in periods of stable growing economies compared to recession periods, let alone depression periods. The recent economic crisis in 2009 caused severe decreases in firm sales. A firm?s sales level, however, is indicative of the amount of (extra) money a firm is able to spend on R&D. The recent crisis in 2009 thus might have led subsidized firms to hold back additional R&D investment to be better able to cope with the implications of the crisis.

Based on firm-level data on German small and medium-sized enterprises, this study investigates the causal effects of the German Federal Ministry for Education and Research?s (BMBF) public R&D subsidy program on firms? R&D investment (as measured by the log of R&D expenditures, the intensity of R&D expenditures, the log of net R&D expenditures and the intensity of net R&D expenditures). The sample covers the period of 2006-2010, with 2009 being the beginning of the crisis period in Germany. This study tests whether R&D subsidies have a different effect in the crisis period than in non-crisis years. Propensity score nearest neighbor matching results indicate an overall additionality effect. Additionality is also found for every individual year. This means that we do not find evidence for a crowding-out effect in the crisis year but that the subsidy increased the average firm?s R&D investment level. The effect of subsidies in 2009, however, is found to be smaller than in all other periods. On the one hand, this could indicate a relative crowding out in the crisis year as compared to the benchmark years. On the other hand, the BMBF increased the amount of funded projects during the crisis. To counteract the effects of the crisis, the budget of the BMBF was

increased by about 9% in 2009 compared to 2008. This boost enabled the ministry to subsidize more firms than in 2008. Preliminary tests indicate that the smaller additionality effect in the crisis year is driven by the ministry?s changed subsidy policy.

R&D Subsidies in a Crisis[1]

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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 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 dip may be caused by an altered innovation policy in crisis years or by different behavior of the subsidy recipients in times of crises. We do not find support for an altered innovation policy having caused the smaller additionality effect and conclude it is likely to be driven by subsidy recipient behavior.

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 investments in innovation decreased significantly in a range of countries including Canada, Sweden and the UK (OECD, 2012b, Filipetti and Archibugi, 2011, Archibugi et al., 2013). Germany belongs to the countries that experienced a weak increase in research and development (R&D) despite of the crisis. Business enterprise expenditure on R&D increased by 3% in 2009 as compared to 2007 (OECD, 2012b).

It is well understood that private sector R&D is a main factor of sustainable growth of industrialized economies so that even a short-term decline or a 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 support in order to prevent negative long-term consequences of a dip 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).

This study aims at evaluating the role of public R&D support in times of economic crises. 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 companies are reluctant to invest in R&D 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. In order to make such R&D projects attractive to the private sector governments subsidize R&D.

The question whether public funding leads to an increase of R&D in the economy as intended by innovation policy is an empirical one. It is inexpensive and easy for firms to apply for public funding so that virtually all firms have incentives to submit an application, including firms that would be able to conduct their R&D projects with own financial means. When having been successful, 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 especially important in times of an economic downturn. Investment in R&D is risky and returns are uncertain and long-term so that firms facing financial constraints due to recessions are likely to reduce their investment in R&D (Schumpeter, 1939, Freeman et al., 1982). 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 smoothen R&D investment by innovation policy in crisis times.   In times of crisis, incentives for subsidized firms to use the public funds to substitute private investment are,

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[2] A crowding out effect can be rejected for the vast majority of R&D subsidy programs worldwide (see Zuniga-Vicente et al., 2012, for a recent survey).

however, significant. Firms have to cope with the consequences of the crises so that the likelihood of a crowding out effect is higher in crisis years.

Based on firm-level data for small and medium-sized enterprises (SME) in 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. The sample covers the period of 2006-2010, with 2009 marking the beginning of the crisis period in Germany. Our empirical 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. Empirical results from a non-parametric propensity score matching indicate that R&D subsidies lead to additionality effects 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 for a different behavior of subsidy recipients in years of crises or for 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 might be bad risks that only qualify for funding because of the budget increase. A decrease of the average quality of the subsidized companies could cause a lower additionality effect. At the same time, firms faced a reduced demand for products and services and higher incentives to substitute private with public funds. The lower additionality effect could, hence, also be caused by the behavior of the subsidized firms. In the last part of the analysis, we investigate whether the smaller additionality effect in the crisis year 2009 is related to altered innovation policy or altered

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firm behavior. We do not find support for firms subsidized in the crises being worse risks than subsidized firms in pre-crises years. Pre-crisis and crisis subsidized firms do not differ significantly in terms of their characteristics. Hence, we reject the hypothesis that an altered innovation policy caused the dip in the magnitude of the additionality effect of the crisis which 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.

The remainder of the paper is organized as follows. The next section surveys related literature and describes two scenarios of R&D expenditures in crisis times. The next section presents the methodology. The data set is described in section 4. The empirical strategy and the results are discussed in section 5. The last section concludes.

2. LITERATURE REVIEW

Innovation in time of crisis

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 in times of an economic downturn 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. According to Schmookler (1966) and Shleifer (1986), 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). Barlevy (2007) also proves R&D to be pro-cyclical, resulting in inefficient R&D investment during recessions. Accordingly, during economic downturns technology leaders could expand their R&D activities to disproportionately gain from growth periods. This long-term focus, however, increases the risk of spillovers to rival innovators, which refrain from own innovation activities. As a result, technology leaders invest more in R&D during upswing periods. Ouyang (2011) examines the opportunity cost hypothesis and finds an asymmetric response of R&D to demand shocks. According to that, 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. The liquidity constraint effect outweighs the opportunity cost effect, resulting in a pro-cyclical R&D investment. Geroski and Walters (1995) 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.

Some empirical evidence on the cyclicality of R&D investment is mixed. Saint-Paul (1993) does not find support for either a pro- or counter-cyclical behavior in R&D. The explanation put forward is that the cash-intensive nature of R&D offsets the opportunity cost effect. More recent

contributions examine the role of credit constraints. 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.

With regards to the global economic crisis, macroeconomic figures show a 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 new, fast growing firms and firms that were highly innovative before the crisis and sustained a high innovation performance during the crisis (Archibugi et al., 2013). Firms with an innovation strategy aiming at exploration are better able to cope with the crisis as well (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. Interestingly in the context of this study is that she shows that the likelihood to stop projects is significantly lower for firms that received public subsidies.

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[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.

Evaluation of R&D Subsidy Programs

Governments worldwide spend significant amounts on public initiatives to foster private innovation activities in order to stimulate economic growth and national competitiveness. The success of these policy measures is ex ante unclear and has to be evaluated ex post. 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 finds that R&D subsidies lead to an additionality effect. A criticism of the early literature until 2000 is that they disregard a potential selection bias of participating firms into R&D subsidy programs. One the one hand, more innovative companies are more likely to apply for R&D subsidies. On the other, 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. (2013) 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.[6]

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[4] E.g. for Finland (Czarnitzki et al., 2007, Takalo et al. 2008), Flanders (Aerts and Czarnitzki, 2005, Aerts and Schmitt, 2008), 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), Luxemburg (Czarnitzki and Lopes Bento, 2010), Spain (Busom, 2000, Gonzales et al., 2005, Gonzales and Pazo, 2008, Gelabert et al., 2008), the ATM (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, 2010) and Latin America (Hall and Maffioli, 2008). Most of these studies can rule out a full crowding out effect.

[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 in 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.

3. METHODOLOGY

Empirical Strategy

Our empirical approach has three different parts. The first part evaluates the effectiveness of R&D subsidies in times of crises. We investigate whether public funding has a positive impact on R&D expenditure in times of crises. In that second part of the analysis we compare the effect of subsidies in the crisis period to the additionality generated by R&D subsidies in non-crisis years. In the last part of the analysis, we try to find explanations for differences of subsidy effects in crisis and non-crisis years.

Part 1: Effectiveness of R&D Subsidies in Times of Crises

The aim of a policy evaluation is to measure the effect of the observed treatment. In our case, that is the estimation of the difference in an R&D outcome variable between the treated (=subsidized) observations and the treated observations if they would not had been treated. This average treatment effect on the treated (ATT) reads:

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

where Y_1 is the treated and Y_0 is the non-treated outcome and S depicts the treatment (=subsidy) status (1 – treated, 0 – non-treated). By this equation, the missing data problem underlying the evaluations of policy programs becomes obvious. The unambiguous identification of a policy intervention effect requires knowledge about the unobserved counterfactual outcome. That is the outcome of participants had they not been affected by the intervention. In the above equation that is the last term. Neglecting or failing to convincingly account for this missing data problem leads

to the prior mentioned selection bias.[7] Thus, constructing the correct counterfactual situation is the main issue in program evaluation.

Econometric techniques 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 observed firms are only observed once, we disregard the DID approach. The reliability of selection models and IV estimations rests on the availability of at least one valid exclusion restriction. In our case it is difficult to find one.

Therefore, we choose the matching method. The motivation for it is to replicate the treated observations among the non-treated observations. A functional form or distributional assumptions about the error terms are not required. The matching estimator's main disadvantage is its dependence on two strong assumptions. First, the assignment to treatment is independent of the outcomes conditional on a set of observable characteristics (X). Rubin (1977) proposed this so called conditional independence assumption (CIA) and it reads:

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

with Y_1 being the treated outcome, Y_0 is the non-treated outcome and S represents the treatment status. The CIA will be satisfied if all information that affect the treatment assignment and the outcome is included in X. If so, the treated and non-treated observations with similar values in the observables are comparable with respect to the non-treated outcome. That means, the observed

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

non-treated outcome $E(Y_0|S = 0)$ is a valid substitute for the required (unobserved) counterfactual outcome. Second, it is assumed that for given X the probability of treatment is bounded away from zero and one (common support). There has to be enough overlap between the treated and the non-treated group so that:

(3) $0 < P(S = 1|X) < 1$

The fulfillment of (2) and (3) ensures the identification and the consistent estimation of ATT as:

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

The matching approach has one serious drawback, the dimensionality of X. The more dimensions are included, the more difficult it becomes to find a matched non-treated observation. Rosenbaum and Rubin (1983) suggest to eliminate this "curse of dimensionality" by matching on the propensity score $P(X)$, that is the probability of participation. Our analysis is based on a variation of propensity score matching, the nearest neighbor matching. That is, each treated observation is matched to the closest non-treated observation. The pairs are chosen based on the estimated treatment probability, the same year and the same location in Germany. 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 and delete it from that pool

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. Ω 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. Using the matched comparison group to calculate the average treatment effect on the treated as mean difference of the matched samples: $ATT = \frac{1}{n^1}\left(\sum Y_i^1 - \sum \hat{Y}_i^0\right)$ 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 that group in that group.

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 we investigate whether the effect of subsidies is different 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.

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

The estimated coefficients of the year dummies indicate whether the treatment effects differ in times of crisis.

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

In the final part of the analysis we further investigate potential differences between crisis and non-crisis years. 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 the 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 lead to a lower ATT.

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

In the last part of the analysis we aim at providing support for a change in innovation policy causing a potentially lower 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 effects would be caused by a broader funding focus we should find that the first time funded firms in crisis years are worse risk than the first time funded firms in non-crisis years.

4. DATA AND VARIABLE SPECIFICATION

To empirically examine a potential additionality effect of BMBF's R&D subsidy program we constructed a database by linking the Mannheim Innovation Panel (MIP) with the PROFI database. The MIP 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 EU'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 non-military R&D project funding of the Federal Ministry of Economics and Technology (BMWi) and of the BMBF. Further data sources comprise the European Patent Office (EPO) for including information on firms' patent applications and the Center for Economic Studies (ifo) for obtaining a business cycle indicator. 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 questioned on their assessment of the actual and future business situation.[8] Moreover, the largest credit rating agency in Germany, Creditreform, provides us with firm age and a credit rating indicator.

The final sample covers the years 2006 – 2010 so that we could cover the pre- and the crisis period. We restricted the sample to firms with more than 4 employees and less than 250 employees to get a representative sample of small and medium-sized enterprises in Germany. Our sample includes manufacturing as well as business related services sectors. The final sample consists of 7843 firm-year observations out of which 801 received a R&D subsidy from the BMBF.

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[8] Note: we downloaded ifo's business cycle indicator via Thomson Reuters' Datastream, the world's largest financial database.

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 gotten any R&D subsidy at all in the respective year, neither from the EU nor from the Federal Government or from other sources. Thus, our control group solely consists of pure non-subsidized firms, allowing us to rule out side-effects from other subsidy programs.

Outcome Variables

We test the hypothesis of additionality on four outcome variables. *RD* measures a firm's R&D expenditure, which is private R&D investment plus the amount of subsidies received. *PRIVRD* is defined as the private R&D investment. Since these measures are skewed, we also estimate the effect for *RDINT* (*RD* over sales) as well as for *PRIVRDINT* (*PRIVRD* over sales). As a robustness check, we consider a less volatile measure for the denominator as is sales. Thus, we include *RDEMP* (*RD* over number of employees) and *PRIVRDEMP* (*PRIVRD* over number of employees) as alternative calculation of the intensity.

Control Variables

Our control variables encompass the log of the number of employees, *lemp*. We also control for a possible non-linear relationship by including the square of the log of employees, *lemp2*. Controlling for firm size implies that larger firms are more likely to conduct innovation activities, thus, are more likely to apply for subsidies. If a firm is part of an enterprise group, *group*, its membership increases the accessibility to information on governmental programs, probably resulting in more frequent subsidy applications. Further, governmental evaluators could be more 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. However, firms with a foreign headquarter, *foreign*, could be less likely to receive a funding because the government might want to induce economic effects in the own country. Moreover, if a SME should be owned by a large multinational it would no longer qualify for subsidy sub-programs designed for SMEs in Germany. The binary dummy *east* indicates whether a firm is located in Eastern Germany or in the Western part. Eastern German firms are probably more likely to receive a subsidy as this region is still in a catch-up process to Western Germany. The log of firm age, *lage*, covers potential age effects as younger firms are expected to be more innovative.

Successfully competing on foreign markets requires being more innovative than others in the longer term. Therefore, we expect export-oriented firms to apply more frequently for R&D subsidies. Our binary dummy *export* indicates whether a firm is internationally competing or not. A considerable concern is a potential picking-the-winner strategy of the Government. Firms are able to translate R&D input into technological change. The Government might want to get the most out of its funding. Thus, it could be more inclined to subsidize firms that have already proven their ability in transforming money into technology in the past. Therefore, we control for a firm's ability to create new knowledge by including its patent stock. To construct the patent stock we use patent applications from 1979 on, which have been filed at the EPO. The indicator is measured as a depreciated sum of all these 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,

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credit.[9] This is an index representing a firm's solvency. The index ranges from 100 to 600. The higher the index is the lower the credit rating and the ability to attract debt capital. Firms that have more problems to externally finance are more likely to apply for subsidization. Another characteristic the Government might consider in allocating subsidies is the state of the industry the firm is active in. Small and medium-sized enterprises 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. Therefore, fluctuations in the business cycle could have a larger impact on SMEs than on large firms. Accordingly, we assume SMEs to be more likely to apply for subsidies during downturns. We control for it by including ifo's business situation, *bussit*. That is a balance ranging from -100 to +100, indicating a positive and negative change compared to the previous period, respectively. The ifo does not completely classify its branches according to NACE but has to some extent its own classification. Translating these branches to NACE leads to an indicator that is measured at a 2- to 4-digit level. To avoid potential endogeneity, we lagged the time-variant explanatory variables and consider *group, foreign, east* as time-invariant and *lage* as truly exogenous.

Table 2 shows descriptive statistics, comparing the variables' values for non-subsidized and subsidized firms. The significant differences of the t-test strongly indicate a potential selection between subsidized and non-subsidized firms. For example, subsidized firms do have more patents per employee, more employees and are more export-oriented. Further, subsidized firms are younger and are more frequently located in Eastern Germany.

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[9] We also perform 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.

Table 2 – Descriptive Statistics

Variables	Unsubsidized firms 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 values of the credit rating indicator as well as the industry and time dummies are not reported here.

Subsidized firms on average reveal a larger balance of business situation. That means, the industries the subsidized firms are operating in, seem to be more volatile. Subsidized firms are mostly R&D conducting firms. These firms are usually export-oriented. Due to the crisis, the drop in worldwide demand had specifically deteriorated R&D conducting firms' balance sheets (Rammer, 2011). When the worldwide demand began to accelerate again in the end of 2009 / beginning of 2010, export-oriented firms' balance sheets improved. The credit rating between non-subsidized firms and subsidized firms does not differ significantly. A value of about 225

means a "good financial standing". Thus, small and medium-sized enterprises in Germany should not have had problems in getting external financing over the observed period, on average. One might argue that the crisis in 2009 in particular led to a credit crunch in Germany. An examination in 2009 conducted by the German central bank, Deutsche Bundesbank, however, does not find a severe credit crunch in Germany (Bundesbank, 2009).

5. ECONOMETRIC RESULTS

Participation Decision

As mentioned in section 3, identifying the causal effect of a treatment requires finding the correct counterfactual outcome. Thus, we have to find non-treated (=non-subsidized) observations, which have the same or similar characteristics as the treated (=subsidized) observations. We do this by estimating a probit model to obtain the propensity score of each observation. This score represents the likelihood of a subsidy receipt. Table 3 shows that apart from the group and the foreign dummy and the business situation every variable reveals strong significant effects with the expected sign. Based on this score and the other two matching arguments – east and year – we are able to select a twin-firm out of the non-treated firms for each treated firm. Due to common support, however, two observations drop out.

Average Treatment Effects on the Treated

In a second step, we only consider the selected non-treated observations and the respective treated observations. According to Table 4, there no longer exist significant differences in the control variables between the treated and the non-treated observations. There are, however, still significant differences in the mean values of the outcome variables, as expected.

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 R-Squared:	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 values of the credit rating indicator is not reported here but is negatively significant.

The subsidized firms reveal a higher R&D activity in any of these outcome variables. Thus, we find an overall positive average treatment effect on the treated. There was no overall crowding-out but additionality of BMBF's subsidy program during the observed period. The average treatment effect on the treated quantifies for R&D (private R&D) expenditures as 0.224 (0.141) Mio. EUR. The ATT in terms of R&D (private R&D) intensity is 7.6% (4.3%) points. The alternative measured intensity amounts to 0.7% (0.4%) points for R&D (private R&D). In the next sub-section we present the development of the ATT during the observed period.

Table 4 – Matching Results

Variables	Unsubsidized firms N = 7042	Subsidized firms N = 801	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 values 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 would like to show the changes of the average treatment effects on the treated over the time. Table 4 discloses an overall (positive) ATT. So that if one examines the ATT over a longer period, on still finds that public R&D subsidies generate additionality effects.

Table 5 presents the results of OLS regressions of the year dummies on the respective average treatment effects on the treated. This table's constant represents the ATT of the year 2006, our

year of comparison. As one can clearly see, we find the ATTs in 2006 to be positively significant, as expected. By this table you can compare all ATTs of the respective years with the ATTs of our year of comparison, 2006. For example, the additionality effect of R&D expenditure in 2008 is 0.312-0.045 = 0.267 Mio. EUR. This additionality effect is still positive, however, it is by 0.045 Mio. EUR lower than in 2006 but this difference is not significant. By this procedure you can check every ATT. You won't find any negative ATT in this table. A considerable result is the significant negative differences of 2009's ATTs. As said before, the ATTs are positive, however, in 2009 all are significantly lower than in 2006. Thus, one could conclude that a crisis period does have a significant negative effect on average treatment effects on the treated.

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 (2006)	**0.312*****	**0.215*****	**0.089*****	**0.054*****	**0.007*****	**0.005*****
	-0.071	-0.068	-0.012	-0.011	-0.001	-0.001
Number of observations:	799	799	799	799	799	799
R-Squared:	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.

Explanations for the Difference

As mentioned in section 3, the significant lower ATTs could be due to a changed funding policy during the crisis or due to a changed firm behavior during the crisis. Figure 1 depicts the allocation policy of the BMBF for small and medium-sized enterprises over the observed period.

Figure 1 – Funding Policy
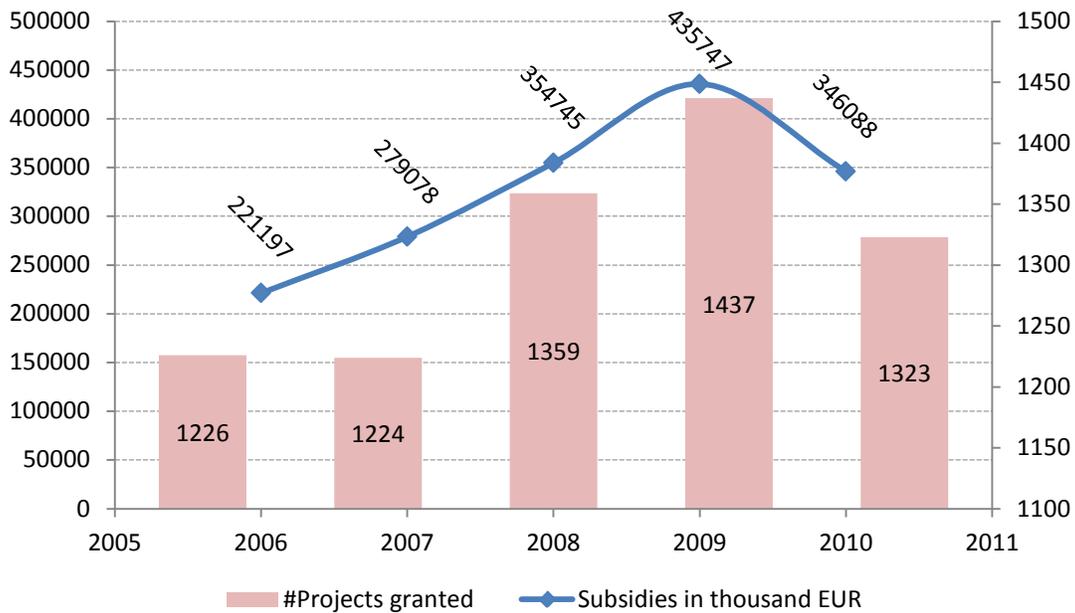
In 2006, 1226 projects were granted with an overall amount of about 221 Mio. EUR. In the crisis, this amounts to 435 Mio. EUR for 1437 granted projects. So the BMBF increased the number of projects granted as well as the overall sum of the granted amount until 2009. In 2010, pre-crisis levels are achieved. The peak of 2009 could mean that the BMBF might have subsidized firms of lower average quality than in the pre-crisis years. If so, we should see that in the funding probability. Table 6 presents a probit regression of our control variables on a dummy that takes on the value 1 if the regarded firm has been subsidized by the BMBF the first time before the

crisis of 2009, it takes on the value 0 if the regarded firm has been subsidized by the BMBF the first time after the crisis started in 2008. If a firm that has been subsidized by the BMBF the first time during the crisis was different from the other firms, we would on average see significant differences in the control variables. So that we could say that these "crisis-firms" have been worse risks. In the sense that the BMBF might have started to subsidize any firm, no matter how promising it is. We see, however, that the pre-crisis first time funded firms do not differ significantly from the crisis first time funded firms. The only significant difference is the business situation but the effect is quite small.[10]

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 R-Squared:	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 values 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.

_____

[10] We have not reported the marginal effects but the coefficients. The marginal effect of the business situation, however, is quite small.

Therefore, we presume that the lower ATTs are not because of the BMBF has chosen bad risks, on average. Our explanation for the lower ATT is that it is induced by the firms themselves. Firms had to cope with the negative consequences of the financial crisis. They may have allocated the additional money they usually would have spent on R&D projects to more needed fields. According to Rammer (2011), firms that indicated the most severe effects of the crisis have been R&D active firms. Most of the firms in the sample, which received a subsidy in the past, are R&D active firms. Thus, it seems to be reasonable that such firms rather needed financial means to service debt, satisfy long-term orders or to preserve research capacities, e.g. employees (know how).

6. CONCLUSION

Our study examines the average treatment effect on the treated (ATT) of the BMBF's subsidy program during the period of 2006 and 2010. While many papers have examined the ATTs of different subsidy programs of different countries, none of these is particularly focused on the effect of the recent financial crisis. Thus, we present first evidence on the ATT before and during the crisis. While using propensity score nearest neighbor matching, we find an overall positive ATT over the observed period, which might not be surprising. Our OLS regressions of time dummy variables on the different ATTs reveal a more surprising result. All ATTs are positive in every year. In the crisis year of 2009, however, we find negatively significant ATTs. This means that in 2009 there has been a significantly lower additionality effect of the subsidy program. By showing Figure 1 and Table 6 we conclude that the BMBF's subsidy program has not changed in terms of the selected risks, over the years. We presume that the firms shifted the money they

usually would have spent in addition to the subsidy on the respective research project to more urgent fields. For example to preserve the stock of employees (know how).

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