Powerful or Powerless?
The impact of public R&D grants on SMEs in Germany

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(draft version)

Abstract

In the last decade considerable innovations in risky and challenging technologies have been significantly spurred by small and medium sized enterprises (SMEs). However, small firms always complain about shortages of capital, in particular for carrying out research and development and innovation. Since the short 1990's technology hype European's policy makers are rediscovering the fact that small high-techs are crucial for strengthening national economic performance. This study describes how R&D policy has changed to stimulate R&D activities in SMEs in Germany. It investigates public R&D project funding schemes and evaluates private investments and patenting behaviour. Applying a Mahalanobis metric-matching approach we find evidence that funded SMEs increase their private R&D investments. Moreover, we observe higher patent activities in publicly funded SMEs compared to its controls.

Keywords: SME, Public Funding, Innovation, Policy Evaluation

JEL-Codes: G24, O31, O38, H32, C20, C24

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1. Introduction

Entrepreneurs of small and medium-sized enterprises (SMEs) always complain about shortages of capital in either their period of start-up or growth. Shortages of track records, niche market orientation, uncertainties in technology and the rapid development of markets prevent many investors from making significant investments. Even worse, the statistics on bankruptcies and closures of SMEs confirm a restrained general strategy and determine the typical behaviour of the most important investors in Europe: the banks. Limited tangible assets reduce SMEs' chances of receiving collateral-based lending from retail banks which is still the predominant source of financing for European SMEs.

These imperfections in capital markets are the predominantly features of the debate on SME development constraints. The existence of the 'equity gap', i.e. a market failure in the adequate provision of external start-up-, seed- and risk capital, has been part of related economic literature for years. These financing difficulties are worse for SMEs looking for R&D capital. In this respect, individual SMEs enter a vicious circle: exceptional technology is a necessary condition for market awareness and fast growth, but it is particularly vulnerable to financial constraints. In the case of new technologies, initial investment costs, particularly those related to R&D, incurred before having revenues in prospect. Moreover, intangible skills do not satisfy any creditors. Since the high-tech boom of the 1990s, which has reduced temporarily European investors' caution in new technologies and has proven the technological power of SMEs, large investment sums today remain undisbursed in funds of venture capital companies or banks.

However, SMEs are known as a driving force for economic wealth. While large pan-European companies in traditional industries have partially shifted production and employment into growing markets like China, multinationals have not fully met the expectations of governments in Europe. Within the sector of small businesses, technology-driven SMEs represent an attractive focus for policy makers. They are seen as offering significant benefits in key areas of policy interest: employment creation, innovation, sales growth and regional development.

SMEs have become an integral part of the European Commission's technological policy as evidenced in 'More Research for Europe – Towards 3% of GDP' (European Commission 2002) and 'Investing in Research: An Action Plan for Europe' (European Commission 2003). The EU as well as national governments have started similar activities to foster SMEs' capabilities, stimulate SMEs to carry out R&D and encourage capital markets to invest in new technologies. Along these lines, the German federal government has started an initiative entitled 'Innovation and Future Technologies for Medium-Sized Companies – High-Tech Master Plan' in the year 2004 (BMBF/BMWA 2004). The aim of this concept is to extend the range of research programs, which is to offer new incentives for SMEs, assign priority in research promotion and open new sources of financing.

In this study we ask whether Germany's R&D policy and its main tool, public R&D project funding, is adequate to foster effectively technology-based SMEs. First, we give a brief overview of economic theory and the rationales of public policy. The theory is linked to recent publications from authorities who illustrate the common argumentation of policy makers and their objectives in fostering small enterprises. In the second section we analyse the significant change of the German federal government's funding policy, preferring large companies in the 1980s and moving to SMEs in the 1990s. The use of the federal government's official R&D project database offers new insights into policy decisions and gives evidence of the increasing attention paid to SMEs. In the empirical section we describe the data and the econometrics applied, following with a presentation of the results of a Mahalanobis metric matching. Our unique merger of firm-level databases allows us to explore the impact of public funding on R&D expenditure on the input side, as well as on patent activities on the output side. Furthermore, we split the sample to control for different types of SMEs according to European statistics on firm size (European Commission, 2005).

2. R&D policy and measuring the impact

The importance of SMEs for the economic health of modern industries is shown in several studies (cf. Nelson 1959, Arrow 1962, Cohen/Levinthal 1990). In particular new technology-based firms (NTBFs) are small in size and often cited as a major contributor to employment and the creation of innovation (Birch 1979, Storey 1994, Acs/Audretsch 1988, Audretsch 1995). High-technology SMEs are significantly more innovative, which is shown by their involvement in radical technological innovations; they grow more rapidly both economically and with respect to sales; they are less vulnerable to closure and employ more highly-skilled scientific and managerial staff (cf. Storey/Tether 1998, Keeble et al. 1998). However, technology-driven SMEs often complain about a lack of financing regarding R&D investment capital (Kamien/Schwartz 1982, Holstrom 1989) and fail to implement effective protection for their invention (Anton/Yao 1994).

Starting with Arrow's (1962) work, economists have realised that investment in R&D differs substantially from other types of investment, e.g. in physical assets. R&D can be seen as the creation of knowledge and information. Unlike investment in physical assets, returns on the creation of knowledge cannot be fully appropriated by the generating firm because of typical characteristics of public goods. When such knowledge leaks out of a firm, competitors can benefit from it and build on the knowledge created by the original investor. Due to these positive externalities, the social returns on R&D are higher than the private returns, but firms will only conduct R&D projects with positive expected private returns. Since there may be projects that could possibly generate high social returns but would not cover the private costs involved, market failure occurs and the level of R&D activities in the economy is below the socially desirable level.

In addition to this market failure, R&D is more difficult to finance than other types of investment. Due to its intangible character, it does not offer any collateral in credit negotiations. Furthermore, the inherent risk of failure associated with each project leads to the fact that potential investors are reluctant to finance such investments – they have even less information about the expected returns than the firm. This problem of asymmetric information, in addition to market failure due to positive externalities, decreases the level of R&D in the economy even further (cf. Akerlof 1970, Stiglitz/Dasgupta 1971). To overcome such market failures, governments use a variety of policy instruments to enhance technological progress.

Empirical studies considering R&D policy instruments *and* firm size are rare because necessary company data, innovation data, funding data and sometimes patent data is almost non-existent for individual firms. Although sophisticated and improved evaluation methodologies have been developed, necessary data on publicly funded firms and, even more importantly, on a large sample of 'controls' (non-funded firms) is not available. It is particularly hard to survey SMEs, which are in general not keen to offer company insights to third parties. Recent econometric analyses taking SMEs into account have almost exclusively been carried out in the evaluation of the Small Business Innovation Research (SBIR) program and the Advanced Technology Program (ATP) in the USA.

Lerner (1999) examined the long-term performance of high-technology firms receiving funds from the U.S. Department of Defense's SBIR program and compared the growth of the recipients to a set of matching firms. Wallsten (2000) tested whether the SBIR program increases innovative activity by assembling a dataset consisting of firms that have been publicly funded, firms that have applied for grants but were rejected and firms that were eligible to apply but did not. Finally, he found evidence that the grants 'crowd out firm-financed R&D spending dollar for dollar'. Audretsch et al. (2002) evaluated the net economic benefits associated with the SBIR program in a case-based analysis and found positive results with regard to stimulating technological innovation and increasing private-sector commercialisation derived from federal R&D. Gans/Stern (2003) used SBIR data and utilize a test based on the relationship between industry-level private venture-capital financing and discovered that the performance of government-subsidized project performance is correlated. Their principal finding was that subsidized project performance is higher in industrial segments with higher rates of private venture investments.

Powell (2002) assesses participation, strategies, and progress of firms engaged in technology development within the U.S. Department of Commerce's ATP program. The focus was on the performance of small firms (fewer 500 employees) in winning ATP awards compared with medium-to-large firms. The study suggests that, at a time when most of the firms are still in the R&D phase, 'small firms funded by the ATP are progressing at a pace at least equivalent to larger firms and engaging in collaborative and other commercialization activities needed for business success and economic impact'. Almost 39 percent of publicly funded small firms filed for a patent compared to 31 percent of larger firms (ATP 2004).

The only (broad) empirical analysis outside the U.S. was carried out by Lach (2002), who used data on Israeli manufacturing firms. Lach found evidence that public R&D subsidies were stimulating company-financed R&D expenditures in small firms.

In the forthcoming analysis, we use a large survey and an official, authority-based, firm-level dataset to evaluate the impact of public R&D grants on SMEs in Germany. We focus our analysis on SMEs which have been publicly funded by Germany's federal ministries in the years 1996 to 2003 within the government's direct R&D project funding schemes.

3. Patterns of small-business R&D project funding in Germany

Since the mid-1970s, one of the most important instruments of the German federal government in stimulating, strengthening and financing R&D activities have been direct project subsidies, which have been almost exclusively provided by the Federal Ministry of Education and Research (BMBF) and of Economics and Labour (BMWA). The allocation of the subsidies is carried out in a framework of 21 broad civilian technology areas, such as biotechnology or production engineering, which are downsized in several schemes provided by different procedures and varying amounts of money. In general all programs are open to science, industry and related R&D performers within certain requirements. Project management agencies ('Projekttraeger') support the Germany's federal ministries in their preparation and implementation of programs providing financial support for research.[1] Project-management agencies express R&D project funding recommendations and are partly authorised to make decisions on R&D project funding on behalf of the federal government. They assist the ministries in funding concepts, advise potential applicants seeking support for research and offer consulting in the exploitation of patents and licences.

The funding received by the business enterprise sector under the BMBF's direct project funding schemes amounted to a total of EUR 413 million[2] in 2003. Supporting SMEs is one of the R&D funding priorities of the Federal Government in the business enterprise sector: 'The Federal Government makes special efforts to support small and medium-sized companies, which are the backbone of Germany's economy' (BMBF 2005). In 2003 small and medium-sized firms receive EUR 160 million – which is a plus of 96 percent compared to 1995. Public funding is given relative to the expenditures which the specific R&D project involves, and business enterprise applicants in general have to cover at least 50 percent of the expenditures.

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[1] Germany currently operates 16 project-management agencies. For instance, the Project Management Organisation Juelich (PTJ) has a staff of about 325 at three locations and administers grants of about EUR 619 million per year.

[2] Contract research is not taken into account. Deflated time series amounts (1995=100).

The scope of this study involves *direct R&D project awards* offered to the business enterprise sector to *small and medium-sized firms*. For the funding scheme of the government SMEs are defined as companies with annual sales of less than EUR 100 million. Additionally, the direct or indirect ownership of companies with annual sales greater than EUR 100 million has to be smaller than 50 percent. This definition corresponds to the one found on the application form for R&D subsidies from the BMBF and is not as restrictive as the definition by the European commission.

(a) Awards funding

Within 1995 to 2003 the public R&D funding awards dedicated to SMEs almost doubled: the total amount of direct R&D project subsidies allocated by the BMBF to SMEs increased almost continuously from EUR 82 million in 1995 to EUR 160 million in 2003, whereas the pattern of the amount received by larger firms is not as clear within this time period and is with EUR 253 million in 2003 slightly above the level of 1995. Consequently, the share of direct project subsidies to SMEs increased from about 26 percent to 39 percent over the covered time period (see Fig. 1).[3]

Figure 1: Awards funding (1995-2003)

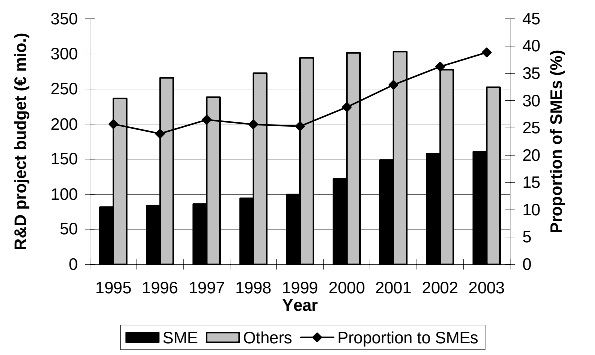
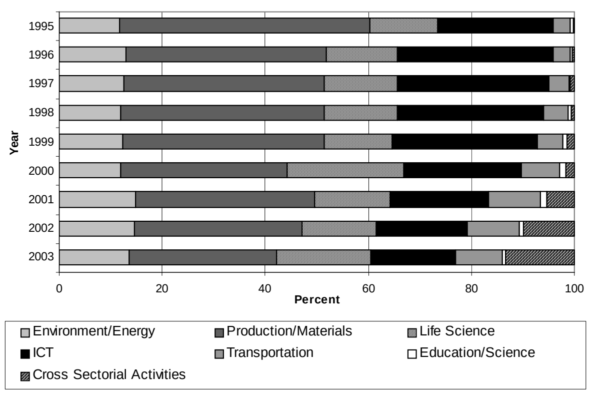


Figure 2: Technology area funding (1995-2003)



Source: Calculation by ZEW based on the German federal government's database, PROFI (2004)

(b) Technology area funding

Categorizing the SMEs by technology area[4] for each year from 1995 to 2003, a gradual shift becomes apparent: The largest part of the funded SMEs (29%) is active in the research field of production/materials. However, its importance fell from a considerable level of 49 percent in 1995 and hence the distribution of the funded companies is more balanced throughout the technology areas, today. In the same time period, the proportion of cross-sector activities increased remarkably by 13 percentage points, whereas in 1995 this group

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[3] All amounts are deflated to 1995 price levels.

[4] The funding areas are aggregated as follows: environment/energy; production/materials; life science; transportation; education/science, and cross-sectional activities (cf. BMBF 2004).

was basically non-existent. Although the government stresses a focus on special technology areas, this development gives evidence for policy makers endeavour to stimulate the exchange of knowledge not just within but also between technology fields (see Fig. 2).

(c) Total number of awardees

The total number of business enterprise awardees increased from 1,539 in 1995 up to 2,700 in 2003. In this period of time the number of publicly funded SMEs doubled (see Fig. 3). Today, about 1,900 distinct SMEs are receiving direct R&D project funding. In comparison, the number of publicly funded larger firms in the business sector only increased by 34 percent in the same time period. Thus, not only the number of SMEs shows a positive trend; the proportion of SMEs also rose from 61 percent (1995) to 70 percent (2003).

Figure 3: Total number of awardees (1995 - 2003)

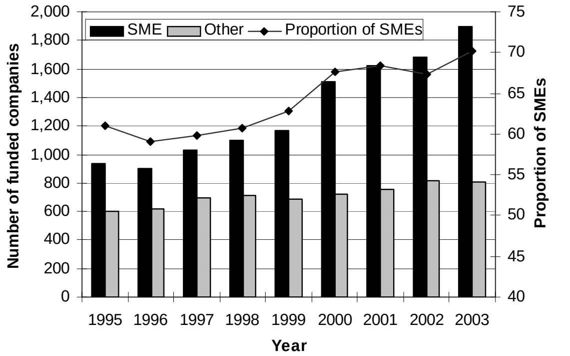
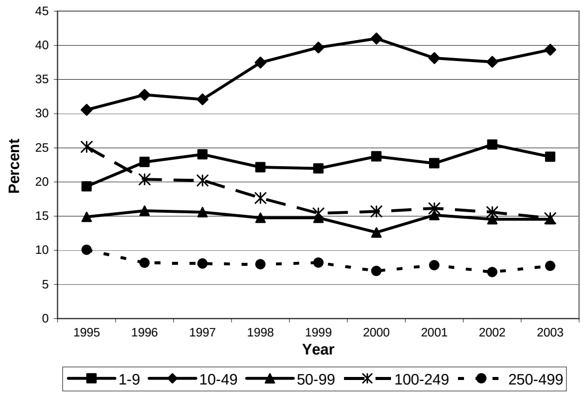


Figure 4: Firm size of SME awardees (1995 - 2003)



Source: Calculation by ZEW based on the German federal government's database, PROFI (2004)

(d) Firm size of SME awardees

Taking a more detailed look at funded SMEs, a change in their structure regarding firm size becomes observable: the proportion of firms with up to 49 employees in particular increased from 1995 to 2003. The smallest companies (1-49 employees) account for 63 percent of all funded SMEs in 2003 (1995: 50 %). This increase is borne by the SMEs with more than 100 employees, the proportion of which fell to 22 percent of all funded SMEs in 2003 (1995: 35%). The proportion of companies of 50 to 99 employees is unchanged. IN this context we really find that government's funding policy appears to be directing more and more funding to smaller firms.

Overall, the importance of small and medium-sized companies within direct R&D funding increases steadily with respect to the number of publicly funded firms and the amount dedicated to them. Against the background of these development economists and policy evaluators are interested whether this innovation policy strategy is sensible. Today, it is clear from case study research what sort of impact of public R&D funding is related to innovative activities in small firms. Since these companies in particular are in the focus of the German federal government, it is substantial to know whether R&D funding help SMEs to overcome liquidity gaps concerning R&D expenditures. The forthcoming evaluation investigates whether direct R&D funding effectively stimulates or crowds out private investment within SMEs and if these investments lead to any output, such as patents.

4. Empirical Study

Concepts of measuring R&D program's impact

In his day, Kuznets (1962) stated, 'perhaps the greatest obstacle to understanding the role of innovation in economic processes has been the lack of meaningful measures of innovative inputs and outputs'. From the initial evaluation studies on the relationship between publicly funded and private R&D by Blank/Stigler (1957), it becomes clear that policy evaluation has to clarify the terminology used. To be able to analyse a policy instrument and judge its performance, it is necessary to agree on the scope and a set of indicators. Relating to economic literature, it is important to distinguish the evaluation scope of success between private and social value (Nelson/Romer 1996). In the first place, private value is conventionally measured by sales, growth or employees, but there are good reasons to believe that this underestimates the social level because of significant externalities (Griliches 1992, Jaffe 1996).

It is evident that the term 'measuring the success' is not sufficient because success relates to different indicators dependent on different perspectives concerning a policy measure: Policy makers may see a high number of participants as a success indicator; firms may assess profits; consumers may judge new products or lower prices as indicative of success. Nevertheless, these cases illustrate that 'additionalities' or 'returns on tax payers' investments' are usually expected – compared to the situation of non-public intervention (cf. Griliches 1995, Lach 2002).

Today, a battery of analytical tools to measure program effectiveness, including statistical analyses, case studies, surveys, stories etc. is used. Recent evaluation programs usually involve four categories of measurements: program-inputs, -outputs, -outcomes, and longer-term impacts (e.g. ATP 2004). In the recent study, we only focus on the categories of program inputs and outputs:

(i) *Program-inputs* derived from additional budget/investments because of the cost/sharing request, convening additional staff, the acquirement of equipment or facilities conditional for the R&D project etc. Related to SME's mentioned lack of R&D liquidity we focus our analysis on firm's R&D expenditure by the question: Do financial public R&D resources foster financial inputs related to business R&D resources? In this particular context, these resources are public R&D project grants meant to encourage investments (input) in R&D projects carried out by industry. In several OECD countries, this R&D policy tool is a direct financial stimulus, using matching grants to share public and private R&D risks (and to avoid misuse); in other words, the government and firms co-finance R&D projects conducted in the business sector. In evaluation terms, the category of measuring inputs analyses whether public R&D grants (partly) substitute or complement private R&D investment (cf. David et al. 2000).

(ii) *Program-outputs* include new collaborative R&D partnerships, publications, patents, prototypes etc. In this study we focus on patents and hence our analysis is characterised by the question: Do public R&D funding foster patent activities related to business R&D processes? The term output is used in the context if a certain policy stimuli (public funding) and a company output (patent activity) is related? From a public perspective, the kind and, possibly, the degree of the output is the efficiency score.

Problems of measuring 'causal effects'

The impact of R&D funding policies has been of interest in related economic literature for decades. Empirical analysis always tries to determine the effects of public R&D intervention. Recent studies show that in particular receiving public grants does not happen by chance, but rather is subject to different selection processes: (i) a firm's decision to apply for a R&D grant (participation probability), and (ii) a government or funding agency's decision to affirm an R&D funding request (funding probability). Applying firms have passed through varying stages, such as familiarising themselves with the R&D funding program in question, deciding to participate in the program, conceptualising an R&D project plan as well as a planned utilization plan, and dealing with bureaucratic requirements (entry in the company register, balance sheets). On the other hand, the government, its agencies and funding applicants as distinct actors are often in a principal-agent relationship (Laffont/Tirole 1993, Tirole 1994). Governments may follow a 'picking the winner' strategy in order to succeed in politics with the most powerful and promising applicants (Downs 1957).

Firms face different likelihoods of applying for funding depending, among other things, on their access to information, their experience, the lobby group they belong to, or on the number of R&D projects they conduct. Firms with more projects and experience are able to apply more often for public R&D funds because of economies of scale and scope. On the other hand, policy makers and public funding agencies might tend to decide in favour of recent technological trends or well-known applying firms due to the promise of more public attention. In any case, the probability of applying for funding and of being awarded is distributed purely by chance. The estimation of this probability is a crucial part of this analysis's consideration of selectivity. For this reason, we first estimate a probit model using different firm characteristics to analyse funding probability (Greene, 1997).

In the impact analysis of program's inputs and prgram's outputs, we will observe systematic differences between publicly funded firms and non-supported firms. However, we will take into account that a simple comparison of the mean impacts of the subsidies may lead to severely biased results. The questions we pose relevant to program-input and program-output are:

– *What is the amount of R&D expenditure a publicly funded SME would have spent without its subsidies*?

– *Do publicly funded SMEs apply for additional patent applications due to granted subsidies?*

In this context, the problem occurs that such situations – involving counterfactual circumstances – are not observable. Hence, in order to make a reliable estimation of the impact of public R&D funding, econometric methods have been established to infer this situation. Econometric models were developed and first used in the evaluation of labor market economics to estimate the 'treatment effect' in the case of a non-random selection of treatments. This approach is transferred to the evaluation of SMEs in this study.

Data

The data used in the following empirical analysis have been carefully merged on the basis of company names and addresses from four different databases: (i) general company data (turnover, employees, industry code, etc.) stem from the Mannheim Foundation Panel (MUP); (ii) company innovation data (R&D expenditure, new products/processes, etc.) have been surveyed within the Mannheim Innovation Panel (MIP); (iii) public R&D funding data belong to the official R&D project database of the German federal government; and (iv) patent data were added to our study by the German Patent and Trademark Office (cf. Appendix). The final database contains 6,244 SMEs surveyed in the MUP and MIP between 1996 and 2003. The definition of an SME is based on the recommendation of the European Commission (see European Commission, 2005) and identifies companies with less than 250 employees and a turnover smaller than EUR 40 million as SMEs. Additionally, the direct or indirect ownership of companies with annual sales greater than EUR 40 million has to be smaller than 25 percent. Altogether, 303 SMEs (4.9% of the total) did receive R&D project funding (PROFI) from project management agencies. This relation is quite similar to the overall R&D project funding share of innovative companies in Germany, which is about eight percent. In our analyses, we also split the SMEs into categories containing smallest/small and medium-sized companies, respectively. The smallest and small-sized companies include SMEs with less than 50 employees and turnover smaller than EUR 10 million. The remaining SMEs are medium-sized.

Operationalisation of variables

Indicators of public funding activity

The core variable of the analysis in this study is the public funding status (*PFS*) and indicates whether a firm received public research funding from the German federal government or not. Furthermore, we use the public funding amount (*PFA*), which is the sum of the total R&D project funding per company (in millions of euros).

Indicators of input and output additionality

The European Community Innovation Survey (CIS) records firms' R&D expenditures, which is described in detail in the questionnaire. R&D managers were asked to estimate the amount of expenditures they typically allocated for intramural (in-house) as well as for extramural R&D. Intramural R&D is defined as ‘creative work undertaken within the enterprise to increase the stock of knowledge and its use to devise new and improved products and processes (including software development)’, while extramural R&D is ‘performed by other companies or public research organizations and purchased by the enterprise’ (Survey-Questionnaire of the CIS, cf. Appendix). In the analysis, we use total R&D expenditures as the sum of intra- and extramural R&D expenditures (*RDE*, in millions of euros) and as an intensity (*RDINT*), which is the particular proportion to turnover. These variables represent SMEs' financial efforts in carrying out R&D activities.

Patents are still a common measure of innovation output (Griliches 1990, Hagedoorn/Cloodt 2003).[5] With regard to time, highly standardized patent applications are closely associated with the R&D process and hence pose fewer assignment problems between R&D input and -output than alternative indicators. However, many patents have very little economic value which also varies unpredictably (Hall 2000, Hall et al. 2004). SMEs in particular do not patent all their inventions, relying instead on other mechanisms to protect their intellectual property. SMEs are often afraid of high patent-application costs and shrink from lengthy and expensive litigations in the case of patent infringements by foreign or large companies. In the recent context of German funding procedures, we are confident in measuring patent activities immediately attributable to public funding because companies are advised or even forced to utilize their R&D results by governmental officials. In our analysis, we use two lead patent indicators: the dummy variable *DPAT* indicates whether a firm applied for at least one patent in the following year (*DPAT*=1) and the variable *NPAT* displays the number of patent application in the following year.

Company and market characteristics

Since Schumpeter’s hypothesis and Scherer’s analysis that ‘size is conductive to vigorous conduct of R&D’, empirical studies have found ambiguous results in relating R&D and innovation activities to firm size (Schumpeter 1942, Scherer 1982, Acs/Audretsch 1991, Cohen et al. 1987). Cohen (1995) reviewed the empirical studies of the oft-quoted Schumpeterian notion that large firms are more eager to innovate, gaining from improved capital market access, economies of scale and scope, and complementarities in implementing innovation marketing. In our analysis, we use firm size in terms of thousands of employees (*EMP*). The squared term (*EMP2*) is used to capture possible non-log-linear functional forms. We consider firm’s age using *AGE* to differentiate SMEs' access to capital markets and lack

[5] Hagedoorn and Cloodt (2003) analyse how different indicators describe the innovativeness of firms and point out that patents "could be a more than acceptable indicator of innovative output".

of financial capacity. Moreover, age might be an indicator of a firm's experiences with government funding schemes or of reliability – from the funding agencies' point of view – and could thus be an indicator of the probability of participation in public support programs. As discussed above, SMEs have to face several technological and market risks, and the lack of a track record is among the foremost obstacles to R&D and innovation. Such a lack of resources is often considered an 'innovation barrier' by medium-sized industrial firms in particular. A number of studies (Toivanen/Niinnen 2000, Czarnitzki 2000) provide evidence that restrictions in credit financing of research and development have an immediate effect on firms' R&D intensities. We use the CREDITREFORM credit rating index (*CRIDX*) in order to verify capital market restrictions. The credit rating index is frequently used in Germany, for instance, by suppliers, banks and insurance companies, to identify risks. It can assume values between 100 and 600 risk points, with increased risk indicated by higher numbers. In response to innovation pressure produced by globalized markets and competitors, it is widely accepted that firms which export their products have more R&D and innovation activities. We use the amount of firms' exports as intensity (*EXPINT*) to control for foreign businesses. Moreover, we calculate a patent stock *PATS* and *PATS2* (*PATS squared*) per employee from the time series of patent applications in the German patent database by: $PATS_{it}$= 0.85 x $PATS_{i,t-1}$ + $PATAP_{t,}$ where *PATAP* is the number of patent applications and 0.85 is a depreciation rate (Hall, 1990). All regressions include a dummy which denotes Eastern German firms, as these may face different circumstances due to the ongoing transformation process of the Eastern German economy (*EAST*). Finally, we capture industry-specific impacts and year-specific effects by including industry (*IND1-IND11*) and time dummies (*Y1996-Y2003*) in all regression (cf. Appendix).

Table 1: Descriptive Statistics (6,244 obs.)

	non-funded firms				funded firms			
Variable	mean	std. dev.	min.	max.	mean	std. dev.	min.	max.
PFS	0	0	0	0	1	0	1	1
PFA	0	0	0	0	0.09	0.11	0.00	0.68
RDE	0.04	0.22	0	8	0.64	2.08	0.01	29.55
RDINT	0.01	0.13	0	8.57	0.32	1.25	0.00	20
DPAT	0.16	0.37	0	1	0.26	0.44	0	1
NPAT[a)]	0.01	0.18	0	9	0.09	0.32	0	3
EMP	0.04	0.05	0.00	0.25	0.05	0.06	0.00	0.25
LNAGE	2.83	1.04	-9.21	6.79	2.41	0.84	0.69	4.85
EXPINT	0.08	0.17	0	1	0.22	0.25	0	1
PATS	0.00	0.02	0	1	0.02	0.05	0	0.51
CRIDX	2.31	0.61	1	6	2.31	0.44	1.52	6
EAST	0.35	0.48	0	1	0.49	0.50	0	1
# of obs.		5,941				303		

Note: Eleven industry dummies and eight time dummies are included in all regressions but not presented here. For correlation matrix of variables see appendix.
[a)] 5,033 observations for non-funded firms and 245 observations for funded firms

Mahalanobis Metric-Matching Approach

In order to correct for selection bias, a matching approach is applied to identify the treatment effects.[6] The treatment in our context is receiving R&D subsidies. The advantages of this method is that we neither have to assume any functional form for the outcome equation (R&D or patent activities) nor is a distributional assumption regarding the error terms of the selection equation and the outcome equation necessary. The disadvantage is that it only controls for observed heterogeneity among treated and untreated firms. We want to measure the average treatment effect for the program participants θ^1, which can be expressed as

$$E\left(\theta^1\right) = E\left(Y^1 | I = 1\right) - E\left(Y^0 | I = 1\right) \qquad (1)$$

where $I = 1$ indicates the participant group, Y^1 denotes the value of the outcome variable in the case of participation and Y^0 of non-participation. However, Y^1 and Y^0 cannot be simultaneously observed for the same individual firms. The situation $E\left(Y^0 | I = 1\right)$ is not observable by design and has to be estimated. In econometric literature, this is usually called the counterfactual situation (cf.. Heckman et al. 1998, 1999 for an overview of evaluation econometrics). In order to apply the matching approach, it is necessary to make the conditional independence assumption (CIA) introduced by Rubin (1977):

$$Y^1, Y^0 \perp I | X \, , \qquad (2)$$

i.e. conditional upon observable characteristics, participation and the potential outcome variable are statistically independent. Given this assumption, one can build a control group of non-participants which strongly resembles the participant group in important characteristics:

$$E\left(Y^0 | I = 1, X\right) = E\left(Y^0 | I = 0, X\right) \qquad (3)$$

and thus the effect of participating in public policy schemes can be estimated as

$$E\left(\theta^1\right) = E\left(Y^1 | I = 1, X\right) - E\left(Y^0 | I = 0, X\right) \qquad (4)$$

Given the CIA assumption, one can compare the outcome of the participating group with the outcome of the selected control group which, having similar characteristics in X, serves as an estimate for the counterfactual situation. Remaining differences in the outcome between both groups can thus be assigned to the treatment (Heckman et al. 1997).

In the related literature, there are several approaches to constructing the control group. The idea of matching is to balance the sample of program participants and comparable non-

[6] There are other approaches, such as difference-in-difference estimation, where participants and non-participants are compared before and after treatment; this is not applicable in our case (see Heckman et al. 1999).

participants. The matching estimator creates a sample of participating firms that is comparable to the sample of non-participating firms, whereas comparability relates to a set of *a priori* defined characteristics (*X*). Supposing *X* contains only one variable, it would be intuitive to look for a control observation that has exactly the same value in *X* as the corresponding participant. However, if the number of matching criteria is large, it would hardly be possible to find any such observation. Therefore, Rosenbaum and Rubin (1983) developed propensity score matching. The idea is to estimate the propensity score of participation for the whole sample and find pairs of participants and non-participants that have the same probability value of participation. Usually, one does not perform an exact matching but the popular 'nearest neighbor' matching, i.e. after the estimation of a (probit) regression model of the participation dummy based on important criteria, one selects the control observation with the estimated probability value closest to the participant. Using this propensity score, one reduces the multidimensional problem of several matching criteria to one single measure of distance. However, since we are matching firms, it is appealing to use not only the propensity score but other firm characteristics like firm size as well. This ensures that we only compare participants with non-participants with similar propensity scores *and* sizes. Otherwise, the matching might not be meaningful.

In this study, a nearest-neighbor matching based on the Mahalanobis metric is used to choose the matched partner (see Heckman et al., 1999)[7]. The weight w_{ij} represents the comparison between participant *i* and non-participant *j* and increases with similarity. The weights w_{ij} sum up to one. The estimated treatment effect for participant *i* is

$$\theta_i^1 = Y_i^1 - \sum_j w_{ij} Y_j^0 \qquad (5)$$

Within the framework of the nearest-neighbour matching, the non-participant *j* which is the closest neighbour to *i* is selected. Applying the Mahalanobis metric, the distance to minimize is

$$MD_{ij} = \left(x_i - x_j\right)' \sum\nolimits_0^{-1} \left(x_i - x_j\right) \ldots..(6)$$

with $\sum_0$ being the sample covariance matrix of the comparison group. The weight w_{ij} for the resulting nearest neighbour is set to one, and zero otherwise.

Lechner (1998) introduced a modification of the propensity score matching, as one often wants to insert additional variables, e.g. firm size, directly into the matching function. In this case, instead of a single X (propensity score), other characteristics of the firms considered

[7] Many different procedures enable matching of treatment and control groups. Most practical procedures are based on the propensity score method developed by Rosenbaum and Rubin (1979), Rubin (1985) and Dehejia and Wahba (1998). There are many applications of these approaches (e.g. Hujer et al. ,1998).

may also be employed in X and are thus taken into account for the calculation of the Mahalanobis distance.

In this study, we specify both a tobit and a probit model in order to estimate the propensity score. In the first case, the dependent variable is the amount of subsidies; in the second, mere participation in any funding scheme is used. Additionally, we include firm size (number of employees), location (Eastern/Western Germany) and the knowledge within the firm (patent stock per employee) in the calculation of the Mahalanobis distance.

5. Empirical results

To estimate the probability of participating in direct project R&D funding schemes, we execute different tobit regression models related either to our dataset of all SMEs or the two subsamples of smallest/small firms and medium-sized firms.[8] In contrast to similar estimations that involve carrying out probit estimations, we take into account the exact amount of public funds an SME received within its R&D grant. We assume a particular importance of funding amounts because firms might participate in R&D funding applications simply because the award is worthwhile in terms of financial support. Otherwise, German entrepreneurs seem to be saying, ‘I prefer to find a certain customer and I would rather not complete all the bureaucratic procedures for small grants’. Moreover, instead of ready-to-market applications, the German federal government aims to address fundamental research activities which produce spillovers. Such ‘basic research’ is even more expansive because of its risks and long-term execution. From this point of view and because of their own bureaucratic efforts, funding agencies might prefer expensive R&D funding applications.

The results are given in Table 2: Participation probability increases with firm size (EMP), but is inverse-U-shaped (*EMP2*), which shows that the probability decreases if the number of employees exceeds a particular amount. Medium-sized firms – which contain 50 to 249 employees according to the European Commission’s recommendation – are not significant in the tobit model. Age (*LNAGE*) is significantly negative and proves a tendency of less established and younger SMEs to participate in public funding schemes. As expected, internationalised enterprises have a higher probability of applying/achieving R&D funds (*EXP*). Moreover, we do observe a significant influence of the patent-stock variable (PATS, PATS2), which explains the importance of cumulative know-how within a firm and with respect to public funding opportunities. The credit-rating index (*CRIDX*) is not significant. It remains so when we split the sample of SMEs into smallest/small firms and medium-sized firms. Hence, the probability of participating in R&D funding schemes is not dependent on creditworthiness in the case of SMEs. This would be a result in favour of public funding, showing that SMEs that complain about difficulties in external R&D financing are not discriminated against because of their lower liquidity. However, the variable is interpreted

[8] Additionally, we estimated probit models to validate our tobit model results.

carefully because it is a broadly ‘mixed’ variable. The Eastern Germany dummy (*EAST*) has a positive estimated coefficient, which reflects the intense support of the eastern states of Germany. Finally, some high-tech sectors such as ICT and technical services are favoured industries with respect to public support (IND3, IND5, IND6, IND9). We wish to mention that we do not control for different technologies funded in different schemes, such as biotech grants, aeronautic grants, and so on, but recommend controlling for distinctive technologies in further analyses. Even so, we actually find strong correlations between industry dummies and their related technologies in the funding schemes.

Table 2: Tobit regressions on public R&D funding amount

Enterprises	All SMEs		Smallest & small sized		Medium sized	
Dependent Variable	PFA		PFA		PFA	
Exogenous variables	Coefficient (Std.Err.)		Coefficient (Std.Err.)		Coefficient (Std.Err.)	
EMP	1.48 (0.34)	***	2.85 (0.52)	***	0.29 (0.22)	
EMP2	-4.37 (1.61)	***	--		--	
LNAGE	-0.27 (0.01)	***	-0.04 (0.01)	***	--	
EXPINT	0.19 (0.03)	***	0.16 (0.03)	***	0.17 (0.06)	***
PATS	2.83 (0.35)	***	2.25 (0.33)	***	10.27 (2.38)	***
PATS2	-5.11 (0.95)	***	-3.84 (0.84)	***	-92.63 (36.46)	**
CRIDX	-0.01 (0.01)		-0.02 (0.01)		-0.01 (0.02)	
EAST	0.05 (0.01)	***	0.03 (0.01)	**	0.13 (0.03)	***
Log likelihood	-480.41		-253.05		-174.04	
Pseudo R^2	0.41		0.48		0.37	
Number of observations	6,244		3,842		1,644	

Note: *** (**, *) indicate significance levels of 1% (5%, 10%).
Eleven industry dummies and eight time dummies are included in the regressions.
Tobit/Probit regression for program-output see appendix.

Table 3 shows a test concerning the balancing of the variables before and after matching for every specification. Prior to the matching procedure, the t-test reports show that the means of the participants and of the potential control group differ significantly for most variables, including number of employees, age, export intensity, and propensity score. Through the matching, the nearest neighbor is selected as twin for every participant based on the Mahalanobis distance. The matched partners should be equal in their means for all variables to allow a proper control group to be constructed. Since the t-statistics on mean differences do not suggest any rejection of the hypothesis in any specification, this condition is fulfilled and the results can be interpreted. For example, in the tobit approach for all SMEs, the difference in the participants' propensity scores and the potential controls prior to the matching was about 0.227 on average. After the matching procedure, this difference shrank to 0.008, which is statistically equal to zero. The results of the matching sample construction for program-output can be found in the appendix.

Table 3: Results of the matching samples construction (Input Add.)

Enterprises		All SMEs			Smallest & small sized			Medium sized		
		Mean		p-value	Mean		p-value	Mean		p-value
Exogenous variables		treated	control	of t-test a)	treated	control	of t-test a)	treated	control	of t-test a)
pscore	Unmatched	-0.19	-0.39	0.000	-0.14	-0.35	0.000	-0.20	-0.41	0.000
	Matched	-0.19	-0.20	0.608	-0.15	-0.16	0.501	-0.20	-0.22	0.399
EMP	Unmatched	0.05	0.04	0.008	0.02	0.02	0.001	0.11	0.10	0.191
	Matched	0.05	0.05	0.801	0.02	0.02	0.897	0.11	0.11	0.784
EMP2	Unmatched	0.01	0.00	0.021	0.00	0.00	0.001	0.01	0.01	0.123
	Matched	0.01	0.01	0.908	0.00	0.00	0.523	0.02	0.01	0.830
LNAGE	Unmatched	2.41	2.83	0.000	2.16	2.71	0.000	2.83	3.08	0.018
	Matched	2.41	2.29	0.317	2.16	2.18	0.874	2.83	2.89	0.688
EXPINT	Unmatched	0.22	0.08	0.000	0.20	0.06	0.000	0.26	0.14	0.000
	Matched	0.22	0.21	0.661	0.20	0.20	0.851	0.25	0.25	0.855
PATS	Unmatched	0.02	0.00	0.000	0.02	0.00	0.000	0.01	0.00	0.000
	Matched	0.02	0.01	0.765	0.02	0.02	0.908	0.01	0.01	0.718
PATS2	Unmatched	0.00	0.00	0.007	0.00	0.00	0.012	0.00	0.00	0.000
	Matched	0.00	0.00	0.862	0.00	0.00	0.989	0.00	0.00	0.884
CRIDX	Unmatched	2.31	2.31	0.925	2.37	2.39	0.549	2.21	2.14	0.249
	Matched	2.31	2.29	0.698	2.37	2.39	0.813	2.21	2.14	0.398
EAST	Unmatched	0.49	0.35	0.000	0.50	0.37	0.000	0.46	0.29	0.000
	Matched	0.48	0.48	1.000	0.50	0.49	0.931	0.46	0.44	0.718

a) The t-statistic of the two-sided t-test on mean equality is based on the variance approximation by Lechner (2001) which accounts for matching with replacement.

The difference between the funded SMEs and the control group before and after matching concerning propensity score is also shown in Figure 5 and Figure 6.

Figure 5: Kernel density of estimated propensity score for funded SMEs and controls before matching

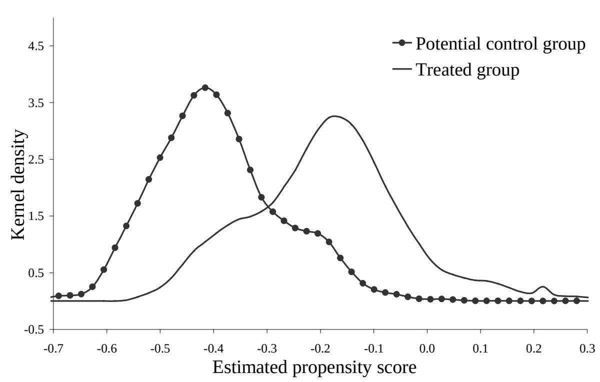
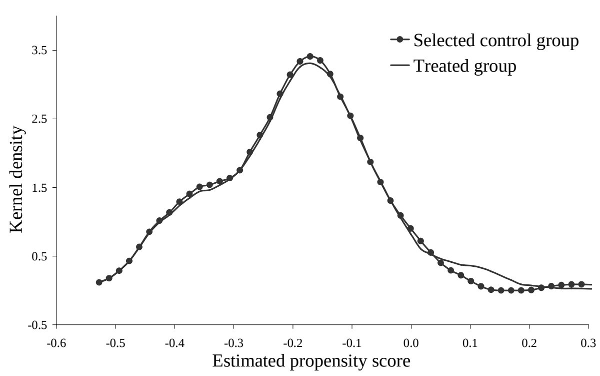


Figure 6: Kernel density of estimated propensity score for funded SMEs and controls after matching



On the basis of the successful matched-sample construction, it is possible to estimate the causal effect of the government funding policy for the recipients of public funding. The average effect is the difference of the outcome variable between the matched groups, i.e. in this study, R&D expenditures and R&D intensity as measures of program-input and propensity to patent in the following year as a measure of program-output. These results are presented in Table 4.

Regarding all SMEs and using the tobit approach to estimate the propensity score, the average R&D expenditures equal EUR 0.63 million for the subsidized firms, whereas the mean R&D expenditures of the selected controls is only about EUR 0.14 million. We conclude that the increase of EUR 0.48 million is due to participation in direct R&D funding programs. A comparable result can be seen in R&D intensity. The mean R&D intensity of the participating firms is 31 percent, while the mean of the corresponding controls is 5 percent. This implies a difference of 26 percentage points. Thus, the hypothesis regarding full crowding-out effects between public and private R&D funds can clearly be ruled out. In conclusion, if a firm takes part in a direct R&D funding scheme, increased R&D efforts can be expected, both in absolute terms and in relation to turnover. Using a probit regression, we reveal similar results that support the finding of positive effects. Similar results apply for smallest/small and medium-sized firms, but differ in size of the effect.

Table 4: Average effect of participation in public innovation schemes

			Treated Mean	Controls Mean	Difference	t-value [a]	
Input							
All SMEs	RDint	Unmatched	0.32	0.01	0.31	17.25	***[b]
		ATT	0.31	0.05	0.26	3.48	***
	RD	Unmatched	0.64	0.04	0.60	20.05	***
		ATT	0.63	0.14	0.48	3.87	***
Smallest & small sized	RDint	Unmatched	0.44	0.01	0.43	15.21	***
		ATT	0.44	0.14	0.30	2.48	***
	RD	Unmatched	0.34	0.02	0.33	31.94	***
		ATT	0.34	0.06	0.28	6.94	***
Medium sized	RDint	Unmatched	0.10	0.01	0.09	20.08	***
		ATT	0.10	0.03	0.07	4.41	***
	RD	Unmatched	1.15	0.10	1.05	11.31	***
		ATT	1.14	0.34	0.80	2.40	**
Output							
All SMEs	DPAT	Unmatched	0.09	0.01	0.08	11.64	***
		ATT	0.08	0.02	0.06	2.96	***
	NPAT	Unmatched	0.09	0.01	0.08	6.30	***
		ATT	0.08	0.02	0.06	2.89	***

a) The t-statistic of the two-sided t-test on mean equality is based on the variance approximation by Lechner (2001) which accounts for matching with replacement.
b) *** (**, *) indicate that the means between both groups differ significantly at the 1% (5%, 10%) level in a two tailed t-test.

Comparing the variable measuring program-output between the two groups, another positive difference becomes obvious. The share of the funded firms which applied for at least one patent in the following year is significantly higher than the corresponding share of the control group. Almost the same result applies for the average number of patent applications in the following year.

6. Conclusions

In European economies entrepreneurs of SMEs always complain about shortages of capital in either their period of start-up or growth. However, SMEs are known as a major policy vehicle for economic wealth. For this reason European and German Governments implement different policy tools to overcome financial gaps aimed to stimulate R&D investments and activities. In the recent study we analyze the most important German R&D policy tool called direct R&D project funding towards SMEs.

To prove the significance of the German R&D project funding instrument, we investigate the Federal Government's R&D policy in this concern between 1995 and 2003 describing the awards funding, technology area funding, total number of awardees, and different firm size of SME awardees. We recognize that SME within direct R&D funding becomes major import: the number of publicly funded firms increases steadily as much as the awarding amounts dedicated to them. Because increasing numbers of SME participation in public R&D policy programs is not a yardstick from economists or policy evaluators point of view, we apply an impact analysis on the program's in- and outputs. We ask which amount of R&D expenditure a publicly funded SME would have spent without its subsidies (input) and whether publicly funded SMEs apply for additional patent applications due to R&D awards (output).

In this context, the empirical problem occurs that such situations – involving counterfactual circumstances – are not observable. Hence, in order to make a reliable estimation of the impact of public R&D funding, we apply a Mahalanobis metric matching approach to estimate the 'treatment effect'. The unique database used for this analysis rely on general company data, CIS company innovation data, a complete survey of the Federal Government's public R&D funding data, and a official patent office database. Finally, 6,244 SMEs are surveyed in their R&D activities and patenting behaviour between 1996 and 2003.

Within the matching approach we first estimate the probability of participating in direct project R&D funding schemes. We execute tobit regression models related to a dataset of all SMEs and two subsamples of smallest/small firms and medium-sized firms. Applying tobit models instead of probit estimations, we take into account the exact amount of public funds an SME received within its R&D award. We assume a particular importance of funding amounts because firms might participate in R&D funding applications simply because the award is worthwhile in terms of financial support.

Table 5 exemplifies the average composition of each euro an SME invests in R&D in our analysis. With respect to all SMEs, in the end we have 303 publicly funded firms and the same number of matched controls. The share of publicly funded R&D as a percentage of total private R&D investments is an average of 33 percent for all SMEs (smallest/small firms: 37%; medium-sized firms: 25%). In this context, we have to consider the cost-sharing condition of matching grants: The BMBF funds a maximum of 50 percent of a firm's total R&D project costs. We do find a considerable funding effect on SMEs' business R&D: EUR

1.00 of publicly funded money causes private investments of EUR 1.35 for all SMEs (smallest/small firms: EUR 1.19; medium-sized firms: EUR 1.80). Thus, the publicly funded euro is completely used for R&D and leads to further investments of about EUR 0.35 (smallest/small firms: EUR 0.19; medium-sized firms: EUR 0.80).

Table 5: Effects of direct R&D project funding of the BMBF on the R&D expenditures

	All SMEs	Smallest/small-sized firms	Medium-sized firms
Number of observations	6,241	3,841	1,643
Privately financed R&D expenditures	EUR 0.70	EUR 0.51	EUR 1.20
Amount of funding (‘Funding-EURO’)[a)]	+ EUR 1.00	+ EUR 1.00	+ EUR 1.00
Private R&D project expenditures (‘Private-EURO’) [b)]	+ EUR 1.00	+ EUR 1.00	+ EUR 1.00
Potential total R&D expenditures	= EUR 2.70	= EUR 2.51	= EUR 3.20
Additional private expenditures for R&D	**+ EUR 0.35**	**+ EUR 0.19**	**+ EUR 0.80**
Observed total R&D expenditures	= EUR 3.04	= EUR 2.69	= EUR 3.99

a) The amount of funding is based on the average proportion of funding to R&D expenditures of all regarded funded firms.

b) Assumption: the R&D expenditures of the funded project are covered equally by the firm and the funding.

We judge the results as an indicator already explained in the US Advanced Technology Program (ATP). The public funding of specific R&D projects in German SMEs provides a ‘stamp of approval’ that attracts capital investment. In the particular context of Germany, we assume that public grants open additional channels of R&D financing or that a firm’s own management is convinced to agree to further R&D investments. In any case, German bank officers and capital markets need information and sometimes just a marginal stimulus to decide to support R&D activities. We are confident that the public funding decision helps SMEs to convince cautious investors. Moreover, it helps individual lenders (e.g. within banks) exculpate themselves to their advisory management when a loan has to be written off or an SME goes bankrupt. In this respect the impact analysis of publicly funded R&D does not find a crowding-out of private R&D investments.

Whether SMEs ultimately benefit from public R&D funding which helps to overcome internal financial obstacles, external restrictions or a mixture of both is still unknown and give rise for further research.

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Appendix

Table 6: The Mahalanobis matching protocol

Step 1	Specify and estimate a probit or tobit model to obtain the propensity scores. Calculating the propensity score of participation for each firm or the score for what amount of subsidies a firm would get.
Step 2	Restrict the sample to common support: delete all observations with probabilities larger than the smallest maximum and smaller than the largest minimum of all sub-samples defined by *S*.
Step 3	Estimate the counterfactual expectations of the outcome variables (R&D, R&D intensity and dummy for patent application.
	For each participant *i* the following steps are performed:
	a) Choose one observations of the participants and delete it from that pool.
	b) Find an observation in the sample of the pool of non-participants that is as close as possible to the one chosen in Step a) in terms of the propensity scores, firm size, location and patentstock per employess. Closeness is based on the Mahalanobis distance. Do not remove the selected controls from the pool of potential controls, so that it can be used again.
	c) Repeat a) and b) until no observation of the non-participants is left.
	d) Using the matched comparison group formed in c), compute the respective conditional expectation by the sample mean. Note that the same observation may appear more than once in that group.
Step 4	Repeat Step 3 for all participants.
Step 5	Compute the estimate of the treatment effects using the results of Step 4.
Step 6	Calculating the t-test for equality of means in the treated and non-treated groups.

Table 7: Description of firm-level databases

In the so called *Mannheim Foundation Panel (MUP)* the ZEW records all companies that were founded in Germany since 1989. It is based on data surveyed by CREDITREFORM, the largest German credit rating company. Based on a co-operation agreement CREDITREFORM transfers biannually its company data to the ZEW, and the institute's researchers are bringing them into a panel structure, carries out quality checks and eliminate double entries. Each new data set will consist of information on recently registered companies, and updates on companies that are already listed in the database (Stahl 1991, Harhoff/Stahl 1992). Information collection from public registers, newspapers, company reports, and in firm interviews is an ongoing process such that the frequency of information updating varies among firms. Company records indicate the firm's location, industry classification, number of employees, legal status, ownership and management details (Prantl 2003). Since June 2000, the Mannheim Foundation Panel is gradually shifting towards a Panel for all German firms. Currently, the total number of company data is almost eight million.

On behalf of the Germany Federal Ministry for Education and Research (BMBF) the ZEW annually gathers data to the innovation behaviour of the German economy. The so called *Mannheimer Innovation Panel (MIP)* is designed to address the same firms each year since 1993. However, the sample is refreshed periodically by newly founded firms in order to substitute enterprises which are closing or left market through mergers. The MIP covers the areas of mining, manufacturing, energy, construction, producer services and distributive services and is representative for Germany. It enables empirical investigations for the German economy in total as well as for single industries. The survey provides detailed information about new products, services and processes, R&D budgets and the expenditures for innovations. In this context the survey serves to cover the technology and economic-political demand for information concerning innovation processes and to indicate starting points for a policy aiming at strengthening innovative competitiveness. Moreover it is the German contribution to the European *Community Innovation Survey (CIS)* which was jointly initiated and implemented by EUROSTAT and the European Commission. The methodology was developed in co-operation with Statistical Offices in the Member States, independent experts and the OECD to collect comparable firm-level data on inputs to, and outputs of, the innovation process across Member States and regions.

The electronic funding catalogue, called *PROFI*[9], of the Federal Government at the Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Economics and Technology (BMWA) provides an overview of all publicly funded R&D projects in Germany. The ZEW is charged with the identification and structural analysis of German SMEs, which participate in this R&D project funding catalogue. The database contains all R&D projects, directly funded in Germany since the 1970s to business and academics. The funding data is classified and analysed to offer policy makers common statistics on the number and type of publicly funded R&D projects and firms. The database is regularly updated and gives detailed information on R&D funding and German firm's R&D activities.

Furthermore, the ZEW is collecting various data sets containing patent data. Usually, it is drawn from the database PATDPA of the *German Patent and Trademark Office (GPTO).* It contains all patent applications filed from 1978. By the end of 2003 around 2.5 million observations were available in a statistical usable format. The data provide information on the characteristics of the patent. Available variables are the date of application, the title of the invention, the name and address of the applicants and inventors, the technological classification (IPC), the references to prior patents (backward citation). Another important patent data set is based on patent applications submitted to the European Patent Office (EPO). Patent applications starting with the year 1978 are included, i.e. the data is available since the inception of the EPO. Due to an administrative publication lag, the patent data are complete up to the application year 2001. However, the data set is updated on an annual basis. At the moment it contains about 1.4 million patent applications.

[9] **PRO**jekt**F**örder-**I**nformationssystem

Table 8: Industries used and regression aggregates

Industry	NACE Rev. 1	Description
IND1	10	Mining of coal and lignite; extraction of peat
	11	Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying
	12	Mining of uranium and thorium ores
	13	Mining of metal ores
	14	Other mining and quarrying
	26	Manufacture of other non-metallic mineral products
	40	Electricity, gas, steam and hot water supply
	41	Collection, purification and distribution of water
	45	Construction
IND2	15	Manufacture of food products and beverages
	16	Manufacture of tobacco products
	17	Manufacture of textiles
	18	Manufacture of wearing apparel; dressing and dyeing of fur
	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
IND3	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	21	Manufacture of pulp, paper and paper products
	22	Publishing, printing and reproduction of recorded media
	36	Manufacture of furniture; manufacturing n.e.c.
	37	Recycling
IND4	23	Manufacture of coke, refined petroleum products and nuclear fuel
	24	Manufacture of chemicals and chemical products
	25	Manufacture of rubber and plastic products
IND5	27	Manufacture of basic metals
	28	Manufacture of fabricated metal products, except machinery and equipment
	29	Manufacture of machinery and equipment n.e.c.
	34	Manufacture of motor vehicles, trailers and semi-trailers
	35	Manufacture of other transport equipment
IND6	30	Manufacture of office machinery and computers
	31	Manufacture of electrical machinery and apparatus n.e.c.
	32	Manufacture of radio, television and communication equipment and apparatus
IND7	33	Manufacture of medical, precision and optical instruments, watches and clocks
IND8	50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
	51	Wholesale trade and commission trade; except of motor vehicles and motorcycles
	52	Retail trade, except of motor vehicles; repair of personal and household goods
IND9	60	Land transport; transport via pipelines
	61	Water transport
	62	Air transport
	63	Supporting and auxiliary transport activities; activities of travel agencies
	641	Post and courier activities
	65	Financial intermediation, except insurance and pension funding
	66	Insurance and pension funding, except compulsory social security
IND10	642	Telecommunications
	72	Computer and related activities
	73	Research and development
	742	Architectural and engineering activities and related technical consultancy
	743	Technical testing and analysis
IND11	741	Legal, accounting, book-keeping and auditing activities; tax consultancy, market research and public opinion polling; business and management consultancy; holdings
	744	Advertising
	745	Labour recruitment and provision of personnel
	746	Investigation and security activities
	747	Industrial cleaning
	748	Miscellaneous business activities n.e.c.
	90	Sewage and refuse disposal, sanitation and similar activities

Table 9: Correlation Matrix (6,244 observation)

	EMP	EMP2	LNAGE	EXPINT	PATS	PATS2	CRIDX
EMP2	0.9401	1					
LNAGE	0.1865	0.1577	1				
EXPINT	0.2138	0.1911	0.0654	1			
PATS	-0.0179	-0.0144	-0.0293	0.0993	1		
PATS2	-0.0213	-0.0144	-0.0132	0.011	0.8713	1	
CRIDX	-0.1742	-0.1290	-0.1714	-0.0513	0.0036	0.0067	1
EAST	-0.0715	-0.0655	-0.3778	-0.1627	0.0015	0.0076	0.1757

Table 10: Tobit/Probit regression on participation/funding amount in public innovation schemes for program-output

Enterprises	All SMEs	All SMEs
Dependent Variable	PFA	PFS
Regression method	Tobit	Probit
Exogenous variables	Coefficient (Std.Dev.)	Coefficient (Std.Dev.)
EMP	1.50 (0.37) ***	6.39 (2.07) ***
EMP2	-4.01 (1.74) **	-14.23 (9.71)
LNAGE	-0.02 (0.01) ***	-0.13 (0.04) ***
EXPINT	0.18 (0.03) ***	1.10 (0.17) ***
PATS	2.87 (0.38) ***	16.49 (2.20) ***
PATS2	-5.09 (1.01) ***	-29.28 (6.24) ***
CRIDX	-0.01 (0.01)	-0.04 (0.07)
EAST	0.06 (0.01) ***	0.31 (0.08) ***
Log likelihood	-386.65	-721.12
Pseudo R2	0.42	0.27
Number of observations	5,278	5,278

Note: *** (**, *) indicate significance levels of 1% (5%, 10%).
Industry and year dummies are included in the regressions.

Table 11: Probit regression on the probability of participation in R&D public funding schemes for program-input

Enterprises	All SMEs	
Dependent Variable	PFS	
Exogenous variables	Coefficient (Std.Dev.)	
EMP	6.23 (1.89)	***
EMP2	-15.98 (8.95)	*
LNAGE	-0.15 (0.03)	***
EXPINT	1.15 (0.15)	***
PATS	15.97 (2.07)	***
PATS2	-28.71 (5.86)	***
CRIDX	-0.09 (0.06)	
EAST	0.31 (0.07)	***
Log likelihood	-894.51	
Pseudo R^2	0.26	
Number of observations	6,244	

Note: *** (**, *) indicate significance levels of 1% (5%, 10%). Industry and year dummies are included in the regressions.

Table 12: Results of the matching samples construction using probit estimation for Input Additionality

Enterprises		All SMEs		
		Mean		p-value
Exogenous variables		treated	control	of t-test [a)]
pscore	Unmatched	-1.00	-2.13	0.000
	Matched	-1.02	-1.06	0.605
EMP	Unmatched	0.05	0.04	0.008
	Matched	0.05	0.05	0.808
EMP2	Unmatched	0.01	0.00	0.021
	Matched	0.01	0.01	0.920
LNAGE	Unmatched	2.41	2.83	0.000
	Matched	2.41	2.28	0.303
EXPINT	Unmatched	0.22	0.08	0.000
	Matched	0.22	0.24	0.360
PATS	Unmatched	0.02	0.00	0.000
	Matched	0.02	0.01	0.755
PATS2	Unmatched	0.00	0.00	0.007
	Matched	0.00	0.00	0.878
CRIDX	Unmatched	2.31	2.31	0.925
	Matched	2.31	2.26	0.243
EAST	Unmatched	0.49	0.35	0.000
	Matched	0.48	0.48	0.886

a) The t-statistic of the two-sided t-test on mean equality is based on the variance approximation by Lechner (2001) which accounts for matching with replacement.

Table 13: Results of the matching samples construction (Output Add.)

Enterprises		All SMEs			All SMEs		
Dependent Variable		PFA			PFS		
Regression method		Tobit			Probit		
		Mean		p-value	Mean		p-value
Exogenous variables		treated	control	of t-test [a)]	treated	control	of t-test [a)]
PSCORE	Unmatched	-0.19	-0.40	0.000	-0.99	-2.18	0.000
	Matched	-0.19	-0.20	0.373	-1.02	-1.07	0.506
EMP	Unmatched	0.06	0.05	0.005	0.06	0.05	0.005
	Matched	0.06	0.05	0.7695	0.06	0.05	0.801
EMP2	Unmatched	0.01	0.00	0.011	0.01	0.00	0.011
	Matched	0.01	0.01	0.894	0.01	0.01	0.894
LNAGE	Unmatched	2.40	2.81	0.000	2.40	2.81	0.000
	Matched	2.341	2.42	0.862	2.41	2.45	0.607
EXPINT	Unmatched	0.21	0.08	0.000	0.21	0.08	0.000
	Matched	0.21	0.20	0.608	0.21	0.23	0.501
PATS	Unmatched	0.02	0.00	0.000	0.02	0.00	0.000
	Matched	0.01	0.01	0.908	0.01	0.01	0.868
PATS2	Unmatched	0.00	0.00	0.036	0.00	0.00	0.036
	Matched	0.00	0.00	0.840	0.00	0.00	0.879
CRIDX	Unmatched	2.32	2.30	0.628	2.32	2.301	0.628
	Matched	2.32	2.32	0.930	2.32	2.27	0.383
EAST	Unmatched	0.49	0.36	0.000	0.49	0.36	0.000
	Matched	0.48	0.48	0.935	0.48	0.48	0.936

a) The t-statistic of the two-sided t-test on mean equality is based on the variance approximation by Lechner (2001) which accounts for matching with replacement.

Table 14: Average effect of participation in public innovation schemes using probit estimation within matching procedure

			Treated Mean	Controls Mean	Difference	t-value a)	
Input Add.							
All SMEs	RDint	Unmatched	0.32	0.01	0.31	17.25	***b)
Probit		ATT	0.31	0.05	0.26	3.52	***
	RD	Unmatched	0.64	0.04	0.60	20.05	***
		ATT	0.62	0.14	0.48	3.86	***
Output Add.							
All SMEs	DPAT	Unmatched	0.09	0.01	0.08	11.64	***
Probit		Matched	0.08	0.02	0.06	2.67	***
	NPAT	Unmatched	0.09	0.01	0.08	6.30	***
		ATT	0.08	0.02	0.05	2.70	***

a) The t-statistic of the two-sided t-test on mean equality is based on the variance approximation by Lechner (2001) which accounts for matching with replacement.
b) *** (**, *) indicate that the means between both groups differ significantly at the 1% (5%, 10%) level in a two tailed t-test.

Table 15: Effects of direct R&D project funding of the BMBF on the R&D expenditures using probit estimation within matching procedure

		All SMEs
Number of observations		6,241
Privately financed R&D expenditures		EUR 0.68
Amount of funding („Funding-EURO“)a)	+	EUR 1.00
Private R&D project expenditures („Private-EURO“) b)	+	EUR 1.00
Potential total R&D expenditures	=	EUR 2.68
Additional private expenditures for R&D	**+**	**EUR 0.35**
Observed total R&D expenditures	=	EUR 3.03

a) The amount of funding is based on the average proportion of funding to R&D expenditures of all regarded funded firms.
b) Assumption: the R&D expenditures of the funded project are covered equally by the firm and the funding.

♦