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Working Paper

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ZEW Discussion Papers, No. 02-04

Provided in cooperation with:
Zentrum für Europäische Wirtschaftsforschung (ZEW)

Suggested citation: Czarnitzki, Dirk; Fier, Andreas (2002) : Do Innovation Subsidies Crowd Out Private Investment? Evidence from the German Service Sector, ZEW Discussion Papers, No. 02-04, http://hdl.handle.net/10419/24802

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published 2002 in: *Applied Economics Quaterly (Konjunkturpolitik)* 48(1), 1-25.

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This Version: August 2002
First Version: January 2002

Abstract

This paper analyses the impact of public innovation subsidies on private innovation expenditure. In the empirical economic literature there is still no common support for the hypothesis of either a complementary or a substitutive relationship between public funding and private investment. We investigate whether firms of the German service sector increase their innovation effort when participating in public policy schemes. Cross-sectional data at the firm level are used to estimate the effect of subsidisation. Applying a non-parametric matching approach we find evidence that the hypothesis of complete crowding-out effects between public and private funds can be rejected.

Keywords: Innovation, Public Innovation Subsidies, Service Sector, Policy Evaluation
JEL-Classification: O31, H32, C20, C24

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* We are grateful to two anonymous referees for helpful comments and Dirk Engel for providing the data of the Mannheim Foundation Panel. Furthermore, we thank the MIP-Team (Thorsten Doherr, Günther Ebling, Sandra Gottschalk, Norbert Janz and Hiltrud Niggemann) for making the innovation data available.

1 Introduction

The discussion about the importance of the German service sector, its contribution to research and development (R&D) and its ability to generate innovations is twofold. On one hand, services are seen as a promising business sector for growth, employment and a source of new technologies. Economists, policy makers and entrepreneurs agree that services play an increasingly dominant role for the whole economy. On the other hand, it is striking that Germany's share of services in business R&D is at the bottom, compared to OECD countries. Services in R&D account for 40 % in Canada, 35 % in Norway and 20 % in the USA just as in the United Kingdom or the Netherlands, but only 5 % in Germany (cf. OECD 1999, 47). In all these countries, the technological performance depends on the ability to transfer knowledge and results from R&D into innovations. The small share of service firms which are involved in business R&D in Germany can be interpreted as a serious gap, which might negatively affect Germany's economic competitiveness in the future. This gap between economic demand and reality leads to the question, whether technology policy can halt these shortcomings by stimulating private innovation activities. In this paper, we investigate whether recent R&D policy schemes contributed significantly to business innovation activities in the service sector or whether policy instruments failed to create more innovation.

Even though new services have a high technological capability, R&D is still mainly carried out by manufacturing. New business services have become possible through technical developments only. Via the internet, software can be expelled and it provides new technological opportunities for products and cooperation among firms. As to this, information and communication technologies (ICT) have become a driving force of many national economies. Countries economically grow together, for example telephone calls, internet communication and journeys into foreign countries become more regular and cheaper. These effects of new technologies in services are very important for export oriented countries like Germany. Industrial relations counsellors, engineers, advertising agencies and other service providers can easily exploit advantages for services both at home and abroad. Moreover, R&D activities of service firms are getting more significant as factor input for manufacturing firms. These industries enlarge and improve their product portfolio by enlarging the use of services, such as call centres, internet links, software support, competent consulting etc. In recent times, complex technologies need to be accompanied by services, which ensure the capability, power and the efficiency of production processes and organisations. Customers of high-tech products expect to buy services in a bundle.

The German government's objective of R&D policy is to create and maintain basic conditions for an innovative economy. In the Government's view the conditions for public research promotion in services and manufacturing are met in those cases where companies are unable to develop certain technologies of considerable general importance on their own or where they cannot do so fast enough or to an adequate extent. Beside fulfilling public needs, the economic rationale of public R&D funding is the existence of market failures associated with R&D. Imperfect appropriability, or the diffusion of knowledge uncontrolled by the inventor, implies that the private rate of return to R&D is lower than its social return. Therefore, the amount invested by firms in research activities in a competitive framework is likely to be below the socially optimal level (Arrow, 1962).

Another argument to justify governmental interventions is the existence of an additional gap between the private rate of return and the cost of capital when the innovation investor and financier are different entities. Recently, Hall (2002) has surveyed the literature on this second argument. She states that "[...] it may still be difficult or costly to finance R&D using capital from sources external to the firm because there is often a wedge between the rate of return required by an entrepreneur investing his own funds and that required by external investors. By this argument, unless an investor is already wealthy, or firms already profitable, some innovations will fail to be provided purely because the cost of external capital is too high, even when they would pass the private returns hurdle if funds were available at a normal interest rate." (Hall, 2002)

Governments can commit funds for stimulating business performed research to reduce the private cost of innovation. In this understanding of governmental R&D policy the service sector is a suitable field of public promotion. Consequently, we analyse whether public funding of R&D activities in the service sector crowds out privately funded innovation activities. We present a matching analysis to estimate the impact of public R&D subsidies on private innovation activities. Beside the funded service firms, this approach uses a control group of companies which did not receive any subsidies. From this potential control group, we construct a matched sample which resembles the subsidised group except for the fact of reception of public innovation subsidies.

First, we give a brief overview of public innovation subsidies in Germany. In the second section, we review the literature and finally the empirical section describes the data, the matching algorithm applied and the results for German service firms.

2 Public Innovation Subsidies in Germany

The German science system has gone to a dynamic development in recent years. Like in all industrialised nations structural changes lead to research-intensive industries and knowledge-intensive services and products. Germany's success depends on the innovative strength of its industry and scientific community. To safeguard its standing in international state-of-the-art technologies, the Federal Government decided to foster education and research, modernise the research landscape and added the funding for R&D projects. The rapid application of new technologies in world markets is seen as the most important task if Germany is to keep pace with other technologically leading countries (cf. BMBF 2000).

Policy makers intend to strengthen innovation activities by three main policy instruments: public (government or university) research, government funding of business performed R&D, and fiscal incentives. While tax credits are not practised in Germany, public funding of R&D projects performed by the business sector is preferred. Project funding is seen as the most important instrument for technology policy because this tool allows to respond flexibly to new challenges. Moreover it is particularly well suited to initiate co-operation between research and business communities, and it fosters quality because of its competitive character. Innovation funding is conducted to enhance the technological prowess of the economy ("pick the winner"), but not to support firms without appropriate R&D capabilities and financial resources.

With respect to the funding procedure, companies or research facilities have to apply for a grant in Germany. The official application form requires detailed information on the company and its planned R&D projects. In principle, Federal Government's grants are given as "matching grants", which means, that applicants have to contribute at least a 50 percent own risk capital to the subsidised projects (cf. Klette/Møen, 1997). Government's 50 percent limit is a maximum, which is prescribed in the funding guidelines of the European Commission (1996) and therefore also in German regulations (cf. BMBF and BMWi 2001).

In fact, public innovation support is a crucial instrument for promoting knowledge creation and technological innovation in Germany. In 1999, the German government and the federal states (Laender) spent approximately € 16 billion on support for R&D. Such support is commonly used to accomplish specific government missions (e.g. defence, health care, environmental protection) and to ensure the generation of fundamental scientific and technological knowledge. Each year about € 2.5 billion of public money is spent to finance business R&D in order to spur industrial innovation and economic growth. The efforts to strengthen R&D activities in the service sector are remarkable. For example, in the project funding more than a quarter of all grants is used for R&D projects related to services. Over time the share of the total R&D business sector budget which has been spent for service projects rose from 8 % in 1982 to 23.5 % in 1997.

3 Public funding of innovations: Review of the Literature

After the US R&D budget was significantly raised during the 1950s, Blank and Stigler (1957) were among the first to question the relationship between publicly funded and private R&D.With a large sample of firms they tested whether a complementary or substitutive relationship between public and private R&D investment existed. In case of a complementary relationship, firms use to extent their innovation activities due to public funding. If full crowding-out effects between public and private funds occur, the private innovation activities remain constant. The implications of such studies are still significant for today's R&D politics because a complementary relationship legitimises public funding whereas substitution is regarded as misallocation.

Over time and along with improved scientific methods it became clear that definite statements regarding the effect of public R&D funding cannot be made. Meanwhile, two main fields of research can be identified which are used to analyse the relationship between public and private R&D investment: qualitative and quantitative research studies. Qualitative data is frequently based on interviews or case-studies within a selected number of firms, whereas quantitative studies count for macro- and microeconomic information on a broad number of companies. David et al. (2000) surveyed macro- and microeconomic studies, focusing on their „net impacts". Only two out of fourteen of these empirical studies indicated substitutive effects on the aggregate level. On the firm-level the results are less clear, i.e. nine out of nineteen find substitutional effects. In summary, macroeconomic studies usually identify a complementary and „good-natured" relationship between public and private R&D expenditure, whereas micro-studies on the firm-level are not able to confirm this effect.

In contrast to macroeconomic studies, the advantage of a microeconomic analysis is that it can allow for detailed influences among several determinants that may have an impact on private R&D activities. Recent microeconometric studies approach the above-mentioned question with firm level or business data provided by ministerial offices, business publishers, statistical offices or own surveys. Based on this data, the impact of the available determinants on private R&D activities is tested by panel or cross-sectional econometric analysis (cf. Klette et al., 2000). Nevertheless, micro firm-level analyses require detailed databases and careful considerations to eliminate misspecifications (cf. Lichtenberg, 1984). In the 1990‘s Busom (2000) and Wallsten (2000) address other serious problems: selectivity, endogeneity and causality. The former, which is also described by Lichtenberg (1987) and Klette/Møen (1997), is linked to the public funding decision. The difficulty of this aspect lies within potential selection bias of the public institution that – depending on the applying firm and the relevant R&D project – decides on the public funding process: "This makes public funding an endogenous variable, and its inclusion in a linear regression will cause inconsistent estimates if it happens to be correlated with the error term" (Busom, 2000: 114). Furthermore, the public institution might support only those firms and R&D projects that are expected to generate extensive economic spillover effects. To estimate the "real" effects of public subsidies it is neccessary to adress the core evaluation question: how much would the recipients have invested, if they had not participated in a public policy scheme?".

In fact, only a few studies on the impact of R&D subsidies attempt to model this counterfactual situation. Busom (2000) explores this problem by applying an econometric selection model. Based on Heckman's (1979) selection model[1], she estimates a probit model on the participation probability. In a second equation, the R&D activity is regressed on several covariates including a selection term which accounts for the different propensities of firms to be publicly funded. The second equation is estimated separately for participants and non-participants. The difference in expected values of R&D expenditure of both groups is due to public funding. Busom concludes that public funding induced more effort for the majority of firms in her sample, but for 30% of participants complete crowding-out effects cannot be ruled out. Lach (2000) investigates the effects of R&D subsidies granted by the Israeli Ministry of Industry and Trade on local manufacturing firms. He applies different estimators,

[1] Heckman's selection model is extended to the "treatment model" (see e.g. Maddala, 1983, section 9.2).

such as the before-after-estimator, the difference-in-difference estimator and different dynamic panel data model.[2] Although Lach finds heterogenous results from different models applied, he finally concludes that subsidies do not crowd out company financed R&D expenditure completely. Their long-run elasticity with respect to R&D subsidies is 0.22. On average an additional dollar of subsidy increases the R&D expenditure by 41 cents in the long run.

The studies mentioned above deal with manufacturing firms. For Germany, Czarnitzki (2001) analyses the effects of innovation subsidies on manufacturing firms located in Eastern Germany. Fier (2002) also studies the behaviour of manufacturing firms, having a closer look at the mission-orientated R&D funding of the German Federal Government. Both studies use a non-parametric matching approach to estimate the counterfactual and conclude that innovation subsidies do not crowd out private investment completely.[3] Today it is still unknown whether same is observable for the service sector. Service firms differ significantly from manufacturers in terms of production technologies used, of the kind of value added and final goods/services traded on markets. Hence, it is interesting whether service firms behave similarly to manufacturing firms. Especially for the growing service sector, there is no evidence for social justification of government spending. We analyse whether public research funding crowds out private investment.

4 Empirical Study

4.1 Construction of matching samples

We want to address the evaluation question: "How much would an enterprise which participated in at least one public policy scheme in 1996 have spent on innovation if it had not received any grants of public sources?" Formally, the average programme effect for the participants θ^1 can be expressed as

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[2] See Heckman et al. (1999) for a comprehensive survey on the econometrics of evaluation and Arellano/Bond (1991) for further details on the dynamic panel data model.

[3] Another interesting study is Almus and Prantl (2002). Using a matching approach, they do not analyse innovation subsidies but grants for young and newly founded firms and estimate the impact on firm survival and growth. The empirical analysis shows significant positive effects of public start-up assistance.

$$E\left(\theta^{1}\right)=E\left(Y^{1} \mid I=1\right)-E\left(Y^{0} \mid I=1\right), \tag{3}$$

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

$$Y^{1}, Y^{0} \perp I \mid x, \tag{4}$$

i.e. conditional on observable characteristics, the 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, then

$$E\left(Y^{0} \mid I=1, x\right)=E\left(Y^{0} \mid I=0, x\right) \tag{5}$$

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

$$E\left(\theta^{1}\right)=E\left(Y^{1} \mid I=1, x\right)-E\left(Y^{0} \mid I=0, x\right). \tag{6}$$

In literature on the matching samples construction one can find several approaches to construct the control group. Supposing x contains only one variable, it would be intuitive to look for an individual as 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 control observation. Therefore, Rosenbaum and Rubin (1983) developed the 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 neighbour" matching, i.e. after the estimation of a (probit) regression model of the participation dummy on important criteria, one selects the control observation with the closest estimated probability value to the participant. Using this propensity score, one reduces the multidimensional problem of several matching criteria to one single measure of distance. However, as we are matching firms it is appealing to use not only the propensity score but also other firm characteristics like size and industry classification. This ensures that we compare participants only with controls of similar size and same industry. Otherwise the matching would possibly not be meaningful. For a better understanding of the matching algorithm, we briefly summarise the procedure applied:

1. Estimation of a probit regression model $I_i = x_i^{'}\beta + \varepsilon_i$ to calculate the (unbounded) propensity score of participation $x_i^{'}\hat{\beta}$ for each firm. x_i is a vector of important factors that determine the participation, β is the parameter vector to be estimated and ε_i is the error term.
2. The sample of size N is divided into the two groups of participating (N^1) and non-participating (N^0) firms. Then the first participant is selected.
3. We calculate the vector

   $$d_{ij} = \left(x_i^{'}\hat{\beta}, z_i\right)^{'} - \left(x_j^{'}\hat{\beta}, z_j\right) \;\; \forall \;\; j = 1, \ldots, N^0,$$

   where z_i is a vector which contains important matching criteria additional to the propensity score. In our case, this is firm size measured as the number of employees.
4. For the i-th participant, we use the vector of N^0 differences calculated in the preceeding step to calculate a one dimensional measure called Mahalanobis distance:

   $$MD_{ij} = d_{ij}^{'}\Omega^{-1}d_{ij} \;\; \forall \;\; j = 1, \ldots, N^0 .$$

   Ω denotes the covariance matrix of the propensity score and the included additional important matching criteria based on the potential control observations.
5. We require that the potential twin which will be selected belongs to the same industry as the i-th participant and hence we drop all observations on non-participants of other industry classifications.
6. The control observation with the smallest value of the Mahalanobis distance is selected as nearest neighbour for the i-th participant. If more than one observation has the same Mahalanobis distance, we draw randomly one of those.
7. We return the selected twin into the pool of potential control observation, i.e. we sample with replacement, and repeat the first six steps for all remaining participants.

8. Finally, the outcome variable, i.e. the innovation activities, of the participant group and the selected control group are compared. We carry out a t-test on mean differences between both groups. If we find a difference being larger than zero, we conclude that public innovation subsidies stimulate private investment.

4.2 Data

In this study, we use data of the "Mannheim Innovation Panel – Services" (MIP-S) which is conducted by the Centre of European Economic Research (ZEW) on behalf of the German Ministry of Education and Research (BMBF). We use the survey of 1997 and 1999 (see Ebling et al., 1999, for a detailed description), i.e. the information provided refers to the calendar year 1996 and 1998.

The MIP-S includes the service sectors as printed in Table 4 in the appendix. However, not every sector on the three digit level contains firms which received public funding in the time period analysed. Thus, we restrict our analysis to those three digit sectors that contain publicly supported firms (see Table 5 in the appendix). For methodological reasons, we restrict our analyses to firms with a maximum of 3,000 employees. The subsequent matching approach is based on the idea that one can compare a treated individual with a non-treated individual which has the same characteristics, i.e. one is looking for "perfect twins". However, larger firms, e.g. the ones with more than 3,000 employees, are really unique and it would not be meaningful to look for twins for companies like these.

Our sample includes 1,084 observations at the firm level. Out of those, 210 firms participated in at least one public innovation programme in 1996 or 1998. Using the MIP-S answers Lichtenberg's (1984) criticism that many studies only deal with large firms. The MIP-S includes firms with at least five employees or more. Our sample median (mean) of employees is 42 (167) for non-supported firms and 55 (188) for the subsidised ones.

4.3 Empirical Considerations

Our main question is whether there is a complementary relationship between private investment and public subsidies or if crowding-out effects occur.

The innovative activity is measured as expenditure on innovation projects at the firm level. The definition of innovation expenditures in the MIP-S is in line with the so-called OSLO-Manual of the OECD and Eurostat (1997).[4] As we use this European standard definition of innovation expenditure, we ensure comparability to other European investigations and meet Lichtenberg's (1987) suggestion for the use of coherent data on innovation.

As a potential outcome variable of the matching procedure, we consider the innovation intensity (*InnoInt*) of firm *i* as the dependent variable in the regressions, i.e. the innovation expenditure (*InnoEx*) divided by sales:

$$InnoInt_i = \frac{InnoEx_i}{Sales_i} \times 100 \,. \qquad (1)$$

For sure, the increase of innovation intensity is not the only aim of public innovation policies but it is an important question whether public funding crowds out private investment.

The participation in at least one public innovation scheme is captured by the dummy variable PF_i which takes the value 1 if firm *i* is a participant and 0 otherwise. With this dummy variable, we are able to differentiate exactly between recipients of public funding and non-recipients. However, we cannot identify different policy schemes which have had different aims, concepts and impacts. Therefore, the results of the empirical analysis is an average effect of various policy instruments. Some might have performed better while others failed.

For the subsequent analysis, it is necessary to estimate the probability of receiving public grants for innovation activities. Therefore, we use several control variables to explain the probability of participation in public innovation programmes. The log of the number of employees (divided by one thousand) *LNEMP* takes account of size effects. To distinguish between the old and new states in Germany, we use a dummy variable *EAST* which indicates if a firm is located in Eastern Germany.[5] Since German reunification in 1990 the government maintains innovation schemes especially for firms located in Eastern Germany in order to foster innovation activities in this underdeveloped region and to improve its technological

[4] We have quoted the definition of innovation expenditure from the OSLO-Manual in the appendix of this study.

[5] The term "new states" or "new Länder" is used synonymous with Eastern Germany, i.e. the five states of the former German Democratic Republic (GDR). "Old states" refers to Western Germany which is the eleven states of the Federal Republic of Germany (FRG).

performance. Thus, it is expected that the probability to participate in public policy schemes is larger for firms from Eastern Germany than for those from the old states in Western Germany.

As to the intention of Federal Government to support the most potential innovations, we include three measures which reflect the “pick the winner” principle: a dummy variable indicating continuous R&D activities (*R&D*) describes firms’ innovation capabilities. Another important feature of a firm is its human capital which is measured by two regressors: on one hand, technical engineers are the main force of R&D capability (absorptive capacity). The variable NSESHARE is the share of employees with a university degree in the field of natural science and engineering (NSE). On the other hand, it may be possible that highly qualified personnel in the field of business administration (BA) aims to improve the financial situation of their firm. These employees may focus on the fund raising for innovative projects, while technical personnel is important for the “innovation know-how”. Hence, it is more likely that firms with skilled employees in business administration (or jurisprudence) file more applications for public innovation schemes than other firms. We include BASHARE (university graduates of business administration/economics, jurisprudence, humanities and social science as share of all employees) in the regression to capture this effect. It is noteworthy that a possible endogeneity problem would occur if the human capital measures are contemporaneously correlated with the participation in a public innovation scheme. As the receipt of grants may influence the personnel structure of a firm, we use lagged values, i.e. the shares of graduates prior to the period under review.

Following Lerner (1999) we include the population density of the district (*DPD*) where the firm is located. Lerner constructs matching samples based on industry classification, sales levels and geographical proximity of firms. This implies that two matched firms are acting in the same market, i.e. in the same commodity market and in the same geographical market. Two firms in the same market and of same size are comparable units. We use the population density of districts because we prefer to compare firms in similar surroundings, instead of geographical proximity only. Suppose for a firm located in Berlin one cannot find a match in the city itself. Then, we want to compare it preferably with one which is located in similar cities like Hamburg or Munich rather than with one located in the rural areas of Brandenburg which surround Berlin. Moreover, we add the firms‘ age to the regression equations because some policy schemes are directly addressed to younger firms or new firm foundations. We use an inverse relationship (1/*AGE*) because some firms are quite old and a linear specification may not fit this circumstance very well. Moreover, governments often pursue the idea of supporting key technologies in order to keep track with technological progress and take one of the first places in the world's technology race. We try to capture this goal by the growth rates of firms foundations (*FF*) on the NACE[6] three digit industry level (NC3)

$$GRFF_{t,NC3} = \frac{FF_{t,NC3} - FF_{t-1,NC3}}{FF_{t-1,NC3}} \quad (2)$$

This variable is taken from the „Mannheim Foundation Panels" of the ZEW. *GRFF* marks the sectoral dynamics of the national economy. Note that *GRFF* also differentiates between Eastern and Western Germany. This takes account of the special situation of the transition economy of the new states. If the sectoral growth rates are increasing, we expect that firms in these up-and-coming sectors are more likely to be considered by the government. For example, today there are many initiatives to foster information and communication technologies or biotechnology but less for energy supply as in the 1970's and early 1980's.

Finally, the model contains a legal form dummy variable *LFD* which takes the value one for joint-stock companies or firms with limited liability; *LFD = 0* otherwise. The legal forms with limited liability indicate more reliable receipt of public funds. Joint-stock companies and firms with limited liability are officially registered and fulfil important preconditions for participation in public innovation programmes. Moreover, using legal forms with limited liability owners can minimise their risk up to a certain amount and thus have higher incentives to pursue more risky projects (cf. Stiglitz and Weiss 1981). Hence, they are more likely to enter public innovation schemes. The regression includes a time dummy (for 1998) and five industry dummies adjusting cross-sectional effects (see Table 5 for further information). A correlation matrix of all covariates used can be found in Table 7 in the appendix.

4.4 Empirical results

At first, we estimate a probit regression model on participation in public innovation schemes. The results are given in Table 1. The participation probability does increase with firm size. Larger firms often maintain R&D laboratories or departments, employ more qualified personnel and are, thus, more competent to meet the requirements demanded by government.

[6] NACE is the European standard sectoral industry classification.

As expected, the Eastern Germany dummy has a positive estimated coefficient which reflects the intense support for the new states of Germany.

The degree of appropriability (absorptive capacity) which is often interpreted as a function of market structure, institutional aspects and organisational abilities is of considerable importance. In our regression model, the absorptive capacity of firms is reflected by the R&D dummy and the share of technical and administrative employees: Firms which conduct permanent R&D activities are much more likely to receive public subsidies for innovation than others. Surprisingly, the share of NSE graduates has no impact on participation whereas the share of BA graduates has. In our explanation these people are more familiar with fund raising procedures and more creative in business. As the utilization of public innovation funding involves many administrative hurdles, BA graduates are more willing to deal with these regulations than technological personnel. The result is attractive: If public funds are acquired, this capital is definitely cheaper than the funds raised from private investors who will charge a risk premium.

Moreover, public funding varies among regions in Germany. The districts' population density has a significantly negative impact on participation. This reflects the governmental strategy to support economically underdeveloped or disadvantaged regions. Additionally to the Eastern Germany dummy, this describes the preference of Germany's new states in innovation policy in order to erect a reasonable R&D scene in these regions.

Other variables like age and legal form do not have any significant impact on participation in public policy schemes. In case of firms' age, this may be due to a high correlation among *EAST* and 1/*AGE* (see Table 7). Most companies in the East were newly founded after Germany's reunification. For a subsample of 674 firms, we have also experimented with variables that describe the financial situation: a credit rating and the "highest recommended credit" taken from the Creditreform database. Creditreform is the largest German credit rating agency. However, both the credit rating and the highest recommended credit (measured per employee to reduce size effects) turned out to be insignificant in the regression analysis. As the number of observations would decrease and because the matching results did not change either, we decided to exclude it from our calculations.

Another important factor in explaining the probability of participation in public policy programmes is the industries' dynamics. The variable *GRFF* is not significant in our regression. From this, we draw the conclusion that public R&D funding is not a short-time policy instrument, which follows every technological trend. Especially in the project funding with its high budgets for years, the federal governments' R&D initiatives and funding procedures are carefully developed. It is the government's aim to identify technological gaps and undeveloped R&D-fields with future prospects. The biotech-programme, for example, was already introduced in the 1970s and did not come into being due to the biotech-trend in the 1990s. For this reason, we cannot find a hint that firms in dynamic sectors are more likely to be considered by government.

Table 1: Probit regression on participation in public innovation schemes

	Dependent variable: participation dummy PF_i	
Exogenous variables	Coefficient	z-value
log(number of employees) (*LNEMP)*	.073 **	2.01
Share of graduates of NSE (NSESHARE)	-.163	-.38
Share of business admin. grad. (BASHARE)	.997 ***	3.82
Eastern Germany dummy (*EAST*)	.678 ***	6.03
1/Age	.949	1.56
Dummy for continuous R&D activity (*R&D*)	1.053 ***	8.62
Growth rates of firms foundations (*GRFF*)	-.245	-.58
Districts' population density (*DPD*)	-.108 **	-2.50
Legal form dummy (*LFD*)	.049	.33
Time Dummy for 1998	.180	1.79
Industry dummies (reference class: other business services)		
- Wholesale	-.131	-.67
- Retail trade	-.261	-1.44
- Traffic	-.348 **	-2.29
- ICT Services	-.165	-.90
- Technical Services	-.304	-1.74
Constant term	-1.499 ***	-6.54
Log likelihood	- 424.51	
Pseudo R^2	.2034	
Number of observations	1,084	

Note: *** (**) indicate significance levels of 1% (5%).

Table 2 illustrates the difference between the participant group and the potential control group prior to the matching procedure. The t-test reports that the groups differ in the distribution of several variables: the share of graduates with a degree in business administration, the location in Eastern and Western Germany, firms' age and, very important, their conducted R&D activities (dummy for continuous research) and the propensity scores.

The matching algorithm picks one observation of the potential control group as nearest neighbor for every participant. The matching function includes the estimated propensity score and the districts' population density. After the calculation of the Mahalanobis distance, we require that every potential neighbour belongs to the same industry classification as the corresponding participant. Out of these potential neighbors, the one with the smallest Mahalanobis distance is chosen as twin. After the matching procedure, we have a properly constructed control group, because the t-statistics on mean differences do not suggest any rejection of the hypothesis that the means of both groups are equal. For example, the difference in propensity scores of participants and the potential controls prior to the matching was about 0.79 on average. After the matching procedure this difference has shrunk to -0.077 which is statistically not different from zero.

Table 2: Results of the matching samples construction

	Means of variables by group			
	Participants	Control Group prior to the matching		Matched Controls
Number of employees (in thousands)	.188	.167		.167
Share of graduates of NSE (NSESHARE)	.057	.073		.062
Share of business admin. grad. (BASHARE)	.302	.143	***	.288
Eastern Germany dummy (*EAST*)	.652	.334	***	.562
Age	16.133	22.033	***	16.019
Dummy for continuous R&D activity	.467	.129	***	.481
GRFF	.009	.016		.005
Districts' population density (*DPD*)	1.240	1.310		1.249
Legal Form Dummy (*LFD*)	.890	.860		.914
Estimated propensity score	-.412	-1.202	***	-.489
Number of Observations	210	865		210

*** (**) indicate that the means between the participant group and potential control group or the matched controls respectively differ significantly at the 1% (5%) level in a two tailed t-test.

Note: The distribution over industries is not presented here because the matching algorithm required that a potential control observation is classified in the same industry as the corresponding participant and hence the distribution over industries is exactly the same for the participants and the matched controls.

On the basis of the successful matched sample construction it is possible to estimate the causal effect of innovation policies for the recipients of public funding. The average effect is the difference of the outcome variable, i.e. the innovation intensity, between both groups (cf. equation 6):

$$\bar{\hat{\theta}} = \frac{1}{N^1}\left(\sum_{i=1}^{N^1} Y_i^1 - \sum_{i=1}^{N^1} Y_i^0\right). \tag{7}$$

If $\bar{\hat{\theta}}$ differs significantly from zero, we can conclude that the subsidies do not crowd out private investment completely. The test on the effect is usually carried out by means of a simple t-statistic. In this case, however, the ordinary t-value is biased upwards because it does not take into account that the mean of the outcome variable of the control group is not a result of a random sampling but an estimation: it is based on the estimated propensity scores and the non-parametric matching procedure. Thus, the usual t-statistic may be misleading for the final conclusion. To remove the bias of the t-statistic, we apply the method of bootstrapping, i.e. we simulate the distribution of the mean outcome of the control group by repeated sampling (for a sketch of bootstrapping, see Greene, 2000, p. 173-174 or Efron and Tibshirani 1993 for a comprehensive discussion):

- We draw a random sample with replacement from the original sample. This sample with replacement has the same size as the original one.
- Then we estimate the probit model again and perform a new matching with this sample and record the mean difference of the outcome variable after the procedure.
- The whole process is repeated 200 times.
- Subsequently, we receive a simulated distribution of mean differences between the participants and their controls. This empirical distribution can subsequently be used to calculate a standard error and, thus, t-statistic which is not biased.

Table 3 presents the estimates of the average policy effects $\bar{\hat{\theta}}$ for the sampled service firms. The mean innovation intensity of subsidised firms is 13.7% while the mean of the selected controls is only 8.0%. Thus we conclude that an innovation intensity of 5.7%-points is due to the participation in public innovation programmes. In absolute figures of German DM, the participating firms have invested 3.08 million DM (1.06 million €) on average. The mean of the control group amounts only to 1.5 million DM (0.77 million €).

The hypothesis of full crowding out effects between public and private innovation funds can undoubtedly be ruled out. This result shows that if service firms are considered in public innovation policy schemes, it can be expected that these firms raise their innovation efforts, i.e. they increase the innovation expenditure in relation to their turnover.

Table 3: Average effect of participation in public innovation schemes

	mean of subsidized firms	mean of matched controls	mean difference $\bar{\hat{\theta}}$	t-value	bootstrap t-value
Innovation intensity (in %)	13.693	7.981	5.712 (%-points)	3.537***	3.054***
Innovation expenditure (million DM)	3.079	1.492	1.587	2.308**	2.294**

*** (**) indicate that the means between both groups differ significantly at the 1% (5%) level in a two tailed t-test.

5 Conclusions

This paper analyses the impact of public innovation subsidies on private innovation expenditure of German service firms. Due to the fact that the service sector is believed to be of growing importance in all industrialised economies and is regarded as the driving force of technological performance and the development of know-how, it is interesting whether technology policy grants crowd out private innovation activities. Especially in Germany where the share of services in business R&D is low compared to other OECD countries, it is of particular interest, if the Federal Government's project fundig is able to enhance innovation activitites.

We investigate the relationship between participation in public innovation policy schemes for a sample of 1,084 service companies using a non-parametric matching approach (nearest neighbour). We find that the propensity to enter a public innovation programme depends on the firm size, the absorptive capacity (measured by permanent R&D activity and share of high-skilled employees) and the location of firms. Applying a Mahalanobis metric propensity score matching, we show that the participants of innovation policy schemes have a remarkably higher innovation intensity than other firms: On average, they exhibit an innovation intensity which is almost six percentage points larger.

Therefore, we conclude that public funding of innovation activities in the German service sector has generated additional private investment in the 1990‘s, i.e. the innovation efforts have been fostered.

However, we only observe whether or not a firm has been a recipient of public funding but we do not have information about the amount of funding. Hence, we can rule out complete crowding-out effects between public funds and private investment. Partial substitution of the two financial resources might still have occured. Moreover, we cannot differentiate between several innovation programmes which possibly have had various effects on firms' activities. Thus, our results should be interpreted as broad average of policy instruments with different aims, concepts and impacts. Despite the positive results of this investigation, which confirm governmental innovation funding as a stimulus for private activities, several questions remain open: It is not known, how and to which extent the funding is used in a company. Patent activities of publicly funded projects might be an indicator to estimate the companies innovation output. As to this, further research has to focus on the effects of public innovation funding concerning spillovers, the utilization of R&D results and the economic and social returns of subsidies for society.

Appendix

Definition of innovation expenditure in the OSLO-Manual

"In order to facilitate comparison with R&D expenditure it is recommended that information should be collected on the breakdown by technological product and process (TPP) innovation activity for total TPP innovation expenditure (current and capital expenditure). The following breakdown is recommended:

- R&D expenditure;
- expenditure for the acquisition of disembodied technology and know-how;
- expenditure for the acquisition of embodied technology;
- expenditure for tooling up, industrial engineering, industrial design and production start-up, including other expenditure for pilot plants and prototypes not already included in R&D;
- expenditure for training linked to TPP innovation activities;
- marketing for technologically new or improved products." (OECD/Eurostat, 1997: 87).

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Table 4: Service sectors included in the Mannheim Innovation Panel

NACE Rev. 1	Description
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
51	Wholesale trade and commission trade, except for motor vehicles and motorcycles
52	Retail trade, except for motor vehicles and motorcycles: repair of personal and household goods
60	Land transport; transport via pipelines
61	Water transport
62	Air transport
63	Supporting and auxiliary transport activities; activities of travel agencies
64	Post and telecommunications:
64.1	Post and courier activities
64.2	Telecommunications
65	Financial intermediation, except for insurance and pension funding
66	Insurance and pension funding, except for compulsory social security
67	Activities auxiliary to financial intermediation
70	Real estate activities
71	Renting of machinery and equipment without operator and of personal and household goods
72	Computer and related activities
73	Research and development
74	Other business activities:
74.1	Legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling; business and management consultancy; holdings
74.2	Architectural and engineering activities and related technical consultancy
74.3	Technical testing and analysis
74.4	Advertising
74.5	Labour recruitment and provision of personnel
74.6	Investigation and security activities
74.7	Industrial cleaning
74.8	Miscellaneous business activities n.e.c.
90	Sewage and refuse disposal, sanitation and similar activities

Table 5: Industries used and regression aggregates

Industries	Aggregate
501	Retail trade
502	Retail trade
503	Retail trade
512	Wholesale trade
513	Wholesale trade
514	Wholesale trade
515	Wholesale trade
516	Wholesale trade
517	Wholesale trade
524	Retail trade
527	Retail trade
602	Transport
631	Transport
632	Transport
634	Transport
641	Transport
701	Other services
702	Other services
703	Other services
721	Computer and telecom services
722	Computer and telecom services
723	Computer and telecom services
725	Computer and telecom services
726	Computer and telecom services
731	Technical services
741	Other Services
742	Technical services
743	Technical services
744	Other Services
746	Other Services
747	Other Services
748	Other Services
900	Other Services

Table 6: Descriptive Statistics (1084 observations)

Variable	Mean	Std. dev.	Min.	Max.
Participation dummy (*PF*)	.19	.40	0	1.00
Innovation intensity (in %)	6.72	12.23	.01	93.08
Innovation expenditure (in million DM)	1.572	6.596	.0002	100.00
Number of employees/1000 (*EMP*)	.17	.38	.004	3.00
NSESHARE	.07	.14	0	1.00
BASHARE	.17	.26	0	1.00
R&D	.20	.40	0	1.00
EAST	.40	.49	0	1.00
1/AGE	.10	.09	.005	1.00
LFD	.86	.34	0	1.00
GRFF	.01	.12	-.33	.8
Districts' population density (*DPD*)	1.30	1.24	.041	3.95
Industries:				
Wholesale	.11	.31	0	1.00
Retail Trade	.13	.33	0	1.00
Transport	.16	.37	0	1.00
Computer Services	.13	.33	0	1.00
Technical Services	.17	.37	0	1.00
Other Business Services	.31	.46	0	1.00

Table 7: Correlation matrix of exogenous variables

	LNEMP	*EAST*	*1/AGE*	*R&D*	*GRFF*	*DPD*	*BA-SHARE*
LNEMP	1.00						
EAST	-.12	1.00					
1/AGE	-.20	.49	1.00				
R&D	.10	.03	-.02	1.00			
GRFF	.05	-.15	-.05	.01	1.00		
DPD	.15	-.06	-.03	.13	.09	1.00	
BASHARE	-.12	.17	.21	.35	-.06	.11	1.00
NSESHARE	-.02	-.08	.04	.09	.23	.27	-.04