Additionality of Public R&D Grants in a Transition Economy: the Case of Eastern Germany

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March 2005

Abstract

This paper examines input and output additionality of public R&D subsidies in Western and Eastern German. We estimate the impact of public R&D grants on firm's R&D and innovation inputs. Based on the results of the first step we compare the impact of publicly funded private R&D on innovation output with the output effect of R&D funded out of firm's own pockets. We employ micro-econometric evaluation methods using firm level data derived from the Mannheim Innovation Panel. Our results point toward large degree of additionality of pubic R&D grants with regard to innovation input measured as R&D expenditure and innovation expenditures as well as with regard to innovation outputs measured by patent applications. Input additionality is more pronounced in Eastern German during the transition period than in Western Germany. However, R&D productivity is still larger for the established West-German innovation system than for Eastern Germany. Hence, a regional redistribution of public R&D subsidies might improve the overall innovation output of the German economy.

Keywords: R&D, Innovation, Subsidies, Evaluation of Public Policy
JEL-Classification: C14, C25, H50, O38

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[1] We are indebted to Creditreform for supporting us with credit rating data, to Günther Ebling, Norbert Janz, Bettina Peters and Sandra Gottschalk for careful preparation of the Innovation Survey Data and Thorsten Doherr for augmenting the Innovation Survey data with information on patent applications at the firm level. Significant parts of the paper were written during Dirk Czarnitzki's stay at the University of California at Berkeley. We thank the Volkswagen Stiftung for financial support and Bronwyn H. Hall as well as Guido W. Imbens for their hospitality and their advice.

1. Introduction

Since a couple of years the catching-up process of former East-Germany does not match its expected speed. Labour productivity is still significantly lower in former East Germany than in Western Germany, the unemployment is much higher and the value of regional production falls short of regional consumption (cf. e.g. Burda and Hunt 2001). Hence, based on the convergences speed realised in the first phase of the catching-up process, a significant transfer of income is needed for a much longer time period than expected. Neither the private nor the public sector in Eastern Germany is viable without massive transfers from the western parts of Germany.

In 2004, various critical reviews of the current means of stimulating the catching-up process have been published inducing a wide ranging discussion on how to foster the transition of former East German regions. The Federal Government's 2004 (Bundesregierung 2004) report on the "status of the German unification" claims a rapid expansion in manufacturing. Due to Governments view the stagnating catching-up is primarily caused by the downturn of the business cycle in the last three years. However, the report also suggests a revision of current policy instruments. Based on an appraisal, the current situation and the perspectives for Eastern Germany, the federal government's high level expert group also calls for major revisions of policy approaches (cf. Seitz 2004, Dohnani 2004). This group also raised the question whether the low growth rates of the western regions in the last ten tears is caused by the huge burden of 4% of the regional product implied by financing the transfers to the eastern regions.

The emerging general consensus in economic policy holds that transfers should focus on investments in innovation, research and development. Likewise industry associations as well as many firms claim additional public interventions lamenting their limited financial resources and severe hurdles for bank loans.. Without additional public subsidies for investment, innovation and R&D the private sector in Eastern Germany will not be able to profit from EU enlargement. Corseted between highly productive West-European industries and low wage industries in the new member states, Eastern German firms face a dilemma and rapid productivity gains induced by increased investments in physical and knowledge (R&D) capital seems to be the only way out. However, public subsidies for those types of private investments had been on record levels in East Germany for more than a decade now and many doubt the effectiveness and efficiency of even larger subsidies (e.g. DIW/IAB/IfW/IWH/ZEW 2003).

Against this background the paper examines the effectiveness and efficiency of public R&D grants for private sector R&D projects. We restrict our analysis to those programmes which involve a direct payment to private firms. However, we do not intend to evaluate single programmes but instead we will look at the "average" impact of public R&D subsidies on private R&D. In addition, we examine the link between publicly funded private R&D and R&D funded by firms from their one pockets on the one hand and innovation output on the other. We use the relation between publicly funded R&D

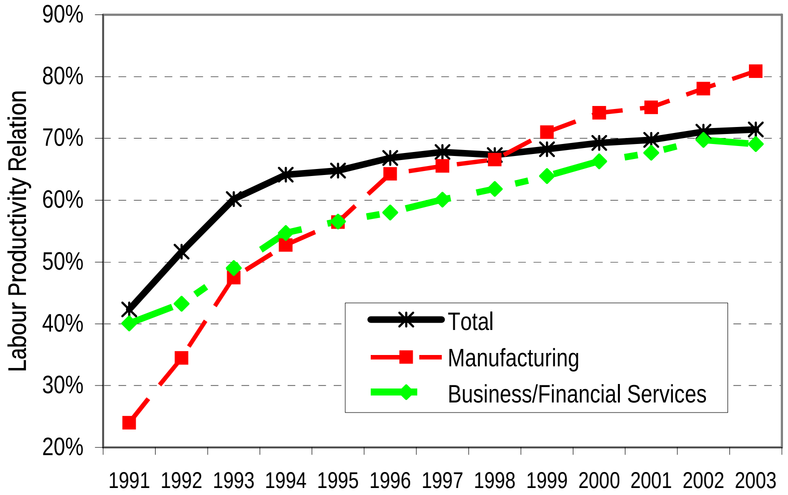
and innovation input and outputs in Western Germany as a benchmark for the impacts of R&D programmes during the first ten years of the transition process in Eastern Germany.

In section 2 we introduce some basic facts about innovation and productivity growth in Eastern Germany. In addition, we highlight some evidence on the credit market squeeze for firms from Eastern Germanyusing Western Germany as a benchmark. Section 3 shortly introduces the method used to examine effectiveness and efficiency of public R&D subsidies. Section 4 describes the data used. In section 5 we look at the impact of public R&D subsidies on private R&D and discuss reasons to explain divergences between Eastern Germany and Western Germany. Section 6 deals with the impact of public subsidies on innovation output. Again, we highlight differences with regard to the impact of R&D subsidies in both parts of Germany. We use the well-known concept of knowledge production function to derive measures for the efficiency of public subsidies with regard to innovation output. Finally, section 7 summarises the results. In addition, taking the current policy discussion as a yardstick, we discuss some implications of our econometric results.

2. Innovation activities and R&D during transition in Germany

Since the fall of the Berlin Wall in 1989, Eastern Germany drastically reduced the huge initial productivity gap. Figure 1 demonstrates the development of the relative labour productivity level in Eastern Germany for the total economy, manufacturing and business services. The figure shows an initially fast productivity catch-up of the Eastern German economy.

Figure 1: Productivity level comparison of Eastern Germany relative to Western Germany (Western Germany = 100%)



Annotation: East Germany comprises the new laender without Berlin. Berlin is also omitted from the West-German data. Berlin is left out because a separation in East-Berlin and West-Berlin is not possible. Labour productivity is calculated as value added in constant prices divided by the number of employees.

Source: Statistische Ämter der Länder (2005), Volkswirtschaftliche Gesamtrechnungen der Länder, Reihe 1, Band 1.

At the macro-level ("total economy") a drastic slow-down of the convergence speed is visible in 1995/1996. This slow-down is less pronounced in manufacturing as well as in the business service and financial service sector. The difference in the development between the overall economy on the one hand and manufacturing and business service on the other hand reflects the fading out of the construction industry based growth in Eastern Germany in the first phase of the transition process.

The continued productivity catching-up of the Eastern German manufacturing is fuelled by extensive investment in new equipment stimulated by generous government subsidies. (cf. Hunt and Burda 2001). So, catching-up in manufacturing was mainly driven by increasing the stock of physical capital. Physical investment per employee resp. investment per output was much higher in Eastern Germany than in Western Germany. In addition, an extensive transfer of know-how and organisational innovation took place via direct investment from Western German and foreign companies (see Burda and Hunt 2001).

The catching-up process is also visible with regard to international competitiveness of Eastern German firms. The terms of increasing export ratios even outperformed the success of Western German firms in international markets. The compound growth rate of exports in the 1996 to 2002 period amounts to 21% p.a. R&D intensive industries take the lead with a 26% annual growth rate in exports. This contributes to significant growth of the R&D intensive industries of 12% p.a. However, there is still a significant gap in export ratios compared to Western Germany. The export to total sales ratio amounts to 41% in Eastern Germany whereas the ratio for Western German R&D intensive manufacturing approaches 55%. (cf. Legler et al. 2004 for details).

The reorganisation of the Eastern German economy was paralleled by an even stronger re-organisation of the (regional) innovation system (see Meske 2000, Leydesdorff and Fritsch 2005). Just after unification the number of R&D personnel in industry dropped considerably. Still today, innovation expenditures as well as R&D expenditures are much lower in Eastern Germany than in Western Germany at the aggregated level. This is depicted in Figure 2.

Both, R&D and innovation intensity[2] declined during the first transition phase mainly due to the rapidly rising value added but also due to the decreasing number of R&D employment in manufacturing which took place until 1993. Since the mid-nineties R&D and innovation intensities increase and the significant gap between Eastern and Western Germany is gradually reducing only. This is notable because the growth rates in manufacturing and business services, which contribute the bulk of R&D and innovation expenses, are larger in Eastern Germany than in Western Germany implying an even larger growth rate of R&D and innovation expenses.

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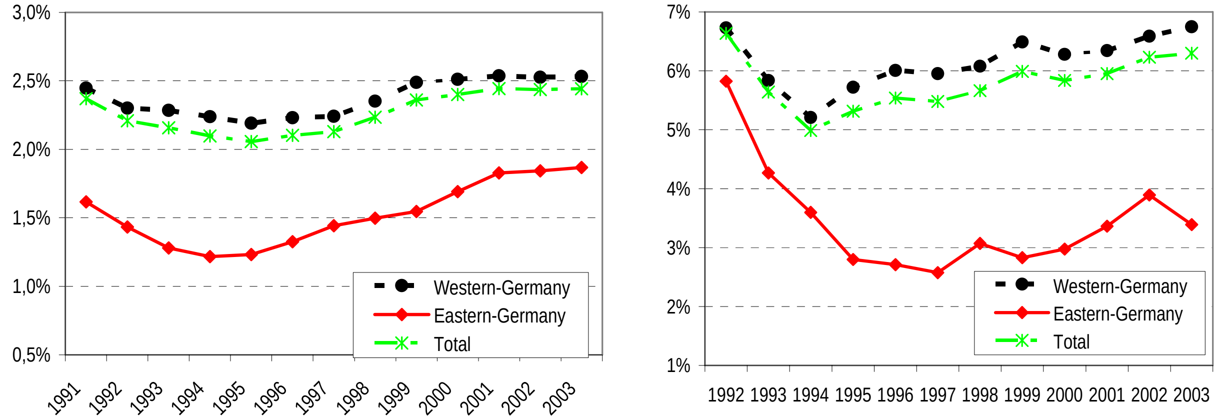
2 Innovation expenditure are defined following the OECD Oslo-Manual. Innovation expenditures comprise R&D expenditure and other expenditure directly related to the generation and implementation of new and improved products and processes e.g. costs of tooling up of new production processes, expenses fort he training of employees, costs of acquisition of IP rights (see OECD and Eurostat 1997 for details).

Figure 2: R&D intensity and innovation intensity of the private sector in Eastern and Western Germany

R&D Intensity = Internal R&D expenditures per Value Added (Private Sector)	**Innovation Intensity = Expenditure on Innovation per Value Added (Private Sector)**



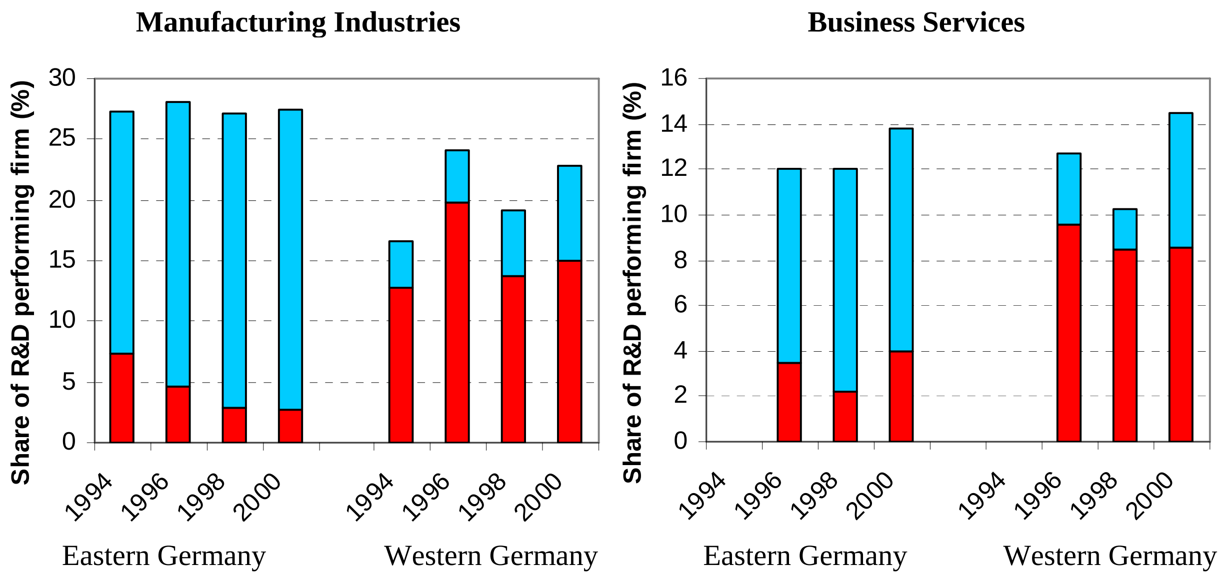
Source: Stifterverband; VGR der Länder
Annotations: Eastern Germany includes Berlin

Source: ZEW, VGR der Länder
Annotations: Eastern Germany includes Berlin; 1993-1996 are partly estimated

Fostering competitiveness of Eastern German firms through stimulating R&D and innovation was a prime goal of economic policy right from the start of the transition period. Various programmes to stimulate private R&D were launched driven by the conviction that Eastern German firms will only survive in the market place if they are able to improve their technological competitiveness. The weak technological base is still a common economic rationale for those programmes. Another widespread conviction is the continual presence of credit squeeze hampering investments in R&D. The numbers in Figure 2 nurture this widely held believes. However, it's well known that R&D and innovation intensities vary considerably by firm size and industry. Taking the structural features of the Eastern German economy into account, Legler et al. (2004) show that the "adjusted" R&D intensity of manufacturing sector in Eastern German is even larger than R&D intensity than in Western Germany.

Data from the German innovation survey show that the share of manufacturing firms engaged in R&D compared to all manufacturing firms is larger in Eastern Germany. 27% of Eastern German firms performed R&D whereas this share amounts only to 23% in Western Germany. As shown in Figure 3 the majority of R&D performers in Eastern Germany get R&D subsidies whereas only 30% of the R&D performers in the West take part in government sponsored R&D programmes.

Figure 3: Share of continuously R&D performing firms with and without public R&D subsidies



Annotation: Figures refer to firms with 5 and more employees
Source: Mannheim Innovation Panel

In addition, R&D intensity (measured as share of R&D workers in total employment) in R&D performing firms in manufacturing and business service is larger in Eastern Germany than in Western Germany. Given this number one immediately supposes that the large R&D intensity and the widespread R&D participation of firms are due to the generous R&D support for Eastern German firms. However, there seems to be some problems with regard to the efficiency of this huge R&D investment. Legler et al. (2004) give some descriptive evidence showing that the ratio of new product sales to innovation expenditure as well as patents to R&D spending are significantly smaller for Eastern German manufacturing than for Western Germany. Against this background the present paper attempts more formal tests for the lower efficiency of R&D and innovation expenditure in Eastern Germany. It adopts a double testing strategy. First, we look at the relationship between publicly funded R&D and privately funded R&D in manufacturing. Second, we compare the gradient of public innovation support on innovation output inboth regions.

3. Methodological Approach

The common objective of public R&D support is to increase the size and the number of R&D projects performed by private sector firms. This is especially true for the present R&D support system in Germany which mainly comes as a grant to specific projects. A tax credit based R&D support is not available. Theoretically, public support aims at projects whose private cost-benefit ratio is small and hence those projects will only be undertaken when public subsidies are available.[3] In order to keep allocation failure at a minimum, Government will only cover a share of the total project cost (as a rule 50%). As a consequence, public support is expected to induce to additional private R&D investment, because due to lower private costs, the private cost-benefit calculation exceedsthe threshold value. This implies that the project selection (by the Government as well as by the firms) is far from random. Government and firms are both interested to conduct the best projects. However, firm's maximise private value whereas the government is interested in maximising the social value. Hence, a comparison of sponsored and non-sponsored projects will not give a reliable indication of the impact of the R&D subsidy. This holds even more when we leave the project level and look at the firm level because firms have an incentive to re-allocate their budget to R&D areas where public support is more likely. Hence, looking at firm level R&D presents a stronger test for the (input) additionality of public R&D support than the project level. Furthermore, firm level tests for the output additionality also take into account negative impacts on R&D productivity resulting from the re-routing effect.

If we observe systematic differences between supported firms and non-supported firms a pure comparison of the mean impact of the subsidy may lead to biased results. The relevant question to ask is e.g. "What is the amount of R&D the company would have spent without the subsidy?" The problem is that this situation – the counterfactual - is not directly observable. Hence, in order to make a reliable guess about the programme impact we have to look for methods which help as to infer the counterfactual situation as good as possible. In the eighties several econometric models were developed to estimate the counterfactual situation and hence to estimate the "treatment effect" in the case of non random selection of the group of treated individual resp. treated firms.[4] For this analysis we choose the matching estimator which is shortly sketched in the following:

Step 1: Impact of R&D subsidies on the R&D input

Our starting point is an question linking the target variable (*Y*) (e.g. private R&D investment) to the policy instrument and a variety of other exogenous factors (*X*) which also influences the target variable (e.g. firm size, industry, region, human capital):

(1)
$$\begin{aligned} Y_i &= g^1\left(X_i\right) + D_i\alpha + u_i\,, \quad \text{if} \quad D_i = 1 \\ Y_i &= g^0\left(X_i\right) + u_i\,, \qquad\qquad \text{if} \quad D_i = 0 \end{aligned}$$

u_t represents as usual a random variable. The impact of policy instrument is measured by α. *D* is a simple dummy variable which take the value 1 if the firm is treated and 0 otherwise. When employing

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3 In order to clarify our argument we neglect from capital market imperfections as a rationale for public subsidies (see Hall 2002). See David et al. (2000) or Klette et al. (2000) for recent surveys on the evaluation of R&D policies.

4 See Heckman et al. (1999), Blundell and Costa Dias (2000, 2002) for surveys.

matching estimators there is no need to make assumptions about the functional form of g^0 and g^1. This is a crucial advantage of the matching approach.

The basic idea of the matching approach is to imitate a “natural” experiment where the treatment is randomly distributed between groups of identical twins. Hence, the task for the matching approach is to find for each treated firm (a firm that receives the public R&D subsidy) an “identical” non-treated firm. Identity here means that treated and non-treated firm have sufficiently similar values with regard to all variable summarised in X. Ideally, X contains all factors (variables) responsible for the participation in the public R&D programme. Depending on the complexity of the decision process perfect “twins” maybe hard to find. Rosenbaum and Rubin (1983) developed an approach to solve "curse of dimensionality" in the twinning problem: the “Propensity Score Matching”. Instead of using all variables contained in X we can use the estimated likelihood of programme participation conditioned on X. The probability of participation P is modelled as a function of X. The twinning process groups firms with a similar estimated probability of programme participation (“nearest neighbour”). The propensity score is estimated by a probit regression. Based on Rubin’s (1977) conditional independence assumption, the counterfactuals for the treated firms can be subsequently estimated by the values of nearest neighbours:

(2) $$E\left(Y^0 \middle| P = X\hat{\beta}, D=1\right) = E\left(Y^0 \middle| P = X\hat{\beta}, D=0\right),$$

where $\hat{\beta}$ represents the estimated coefficients of the probit model for programme participation. Based on the estimated propensity score we find the “nearest neighbour” by the following procedure:

1. Let {(1)} represent the treated firms, {(0)} the non-treated firms
2. Randomly select a firm *i* from {(1)}.
3. Find another firm $j \in$ {(0)} which is closest to *i* in terms of the propensity score *P*.
4. Select firm *j* as a twin to *i*.
5. Repeat steps 2 to 4 for all firms in {(1)}.

When this process is finished the average impact of the programme on the treated (Average Treatment Effect on the Treated "ATT") is calculated by

(3) $$\alpha_{ATT} = \frac{1}{N^1}\sum_{i=1}^{N^1}\left(Y_i^1 - \hat{Y}_i^0\right),$$

N^1 represents the number of treated firms. In addition to the standard propensity score matching, we assume that with regard to a certain number of characteristics have to be identical. We also introduce the restriction that twins must stem from the same industry.

In the empirical analysis we use different measures for innovation inputs in order to increase the robustness of our conclusions. Given data availability in innovation survey data we first explore the impact of public R&D subsidies on the R&D inputs. Secondly, we use the concept of innovation expenditure which comprises R&D and other inputs needed to bring new product to the market resp. use advanced production equipment.[5]

Step 2: Impact of R&D subsidies and privately funded R&D in innovation output

The second step of our analyses asks whether there are productivity differences between government funded R&D and R&D funded out of firm's own pockets. This allows some insights into the efficiency questions with regard to public R&D funding. The point of departure is a typical Griliches type invention production function which links innovation output to innovation input.

We assume that the innovation output of firm *i* (O_i) is a function of R&D inputs and a vector of control variable *Z*. The novel aspect of our approach is its separation of R&D expenditures into two components. In Y_i^0 and $\alpha_i = Y_i^1 - Y_i^0$ that is, in R&D that would have been carried out regardless of the public R&D subsidy (Y_i^0) and in the R&D expenditures induced by public funding ($Y_i^1 - Y_i^0$). The values for Y_i^0 and α_i were calculated as a result of the matching approach. Hence:

(4) $$O_i = f(Y_i^0, \alpha_i, Z_i)$$

Comparing regression resultson Y_i^0 and α give some hints whether there are differentials with regard to the productivity of both types of R&D. We restrict the second step to patent applications as a measure for innovation output because patent applications are quite close in time to the innovation input. Other innovation output indicators, e.g. share of sales with innovative products, cost reduction due to new processes, are not employed here because it usually takes some time until the impact of innovation materializes in those measures. As a consequence, however, we may underestimate the impact of re-routing budgets.

4. Data and Operationalisation

The data used in the analysis were taken from the Mannheim Innovation Panel (MIP)[6], which is collected by ZEW via a mail survey since 1993. The survey encompasses data on R&D- and innovation expenditures, a wide array of firm characteristics (e.g., firm age, industry, turnover, number of employees, exports, firm integration, market structure) and information on whether or not the respondent firms received innovation support from public sources (e.g., the EU, the German federal government, their respective state governments, public banks).

This pool of data is supplemented by information from the German Patent Office on each individual firm's patent applications. Depending on the information of public subsidies four waves of the MIP were used for this study, corresponding to the years 1994, 1996, 1998 and 2000. In the following, the

5 Innovation expenditures are used already by Czarnitzki (2001), and R&D is used by Almus and Czarnitzki (2003) in a similar context.

6 Janz et al. (2001) provide a detailed description of this database.

indicators and values for the endogenous variables (publiclysponsored promotion, R&D and innovation activities, and patent applications) as well as the exogenous variables are introduced. Basic descriptive statistics on sample firm for Western and Eastern Germany and publicly support and non-supported firms can be found in the table A1 to A4 in the appendix. Besides definition this section also gives economic rationales for the use of the set of endogenous variables

Public promotion of R&D

A central variable of this study is the firm support status indicator (*PF*), which takes the value 1 if the firm in question received public research support either from the EU, the federal government or a German state in the observed year.

Expenditures for R&D and innovation

A firm's total R&D expenditures are part of its innovation expenses regardless of their categorization as internal or external. In addition to these expenditures, the R&D expenditure in logs is applied as a dependent variable in order to compensate for the skewness in the distribution of R&D (ln*R&D*). Moreover, R&D intensity is analysed as *R&D / SALES* * 100 . "Innovation expenditures" includes (in addition to R&D expenses) all continuous expenses, such as personnel and material expenditures linked to innovation projects, as well as investments made in development and introduction of new and improved products and/or processes (cf. Eurostat and OECD, 1997). Innovation expenditures thus contain R&D expenses as well as spending related to prototypes, product design, investment in manufacture of new and improved products, introduction of process innovations, market launch costs, license acquisition and patent application expenditures, and further education of employees assigned to innovation projects and similar expenses. The innovation expenditure logarithm (ln*IE*) and innovation intensity (*IE/SALES* * 100) are used, too.

Number of patent applications and propensity to patent

Patents are a common measure of innovation output (cf. Griliches 1990 for an survey). The most important advantages of this indicator are its ready availability and comparatively high standardization. Additionally, a patent application is temporally closely associated with the R&D process, and hence poses fewer assignment problems between R&D input and output than alternative indicators. The main disadvantage of the use of patent applications lies in the fact that many patents have only a tiny economic value. Typically, the value of patents varies dramatically (cf. Hall 2000 and Hall et al., 2005 for overviews). Furthermore, not all companies patent their inventions, relying instead on other mechanisms to protect their intellectual property (e.g. non-disclosure). Despite this caveats, this study uses two patent based measures. The dummy variable $DPAT_{it}$ indicates whether a firm applied for at least one patent in a given year, taking the value 1 if so and zero otherwise. The second measure used is number of annual patent applications PAT_{it}.

Firm size

Increased R&D promotion in the former East German states is in many cases justified by citing the small-business structure of the firms implementing R&D. The related literature presents diverse discussions on the correlation between firm size and R&D or innovation activities. Arguments in favour of the theory that larger firms are more eager to innovate are also manifold (cf. Cohen 1995 for an overview), extending from improved capital market access, economies of scale and scope to complementarities in implementing innovation marketing. Firm size is considered in terms of the number of employee (*EMP*) and is used taking the log (ln*EMP*). Additionally, $(\ln EMP)^2$ is used to capture possible non-log-linear functional forms.

Herfindahl index of firm concentration

Market structure is traditionally regarded in industrial economic studies as an important determinant of innovation activity. As a rule one would expect higher profits in highly concentrated market. The likelihood of state support may also be increased, since fewer companies compete for the available resources. Market concentration is measured by the Herfindahl index for turnover at a three-digit industry level corresponding to the NACE classification (ln*HHI*).

Firm age

Firm age is introduced to capture specific funds available for young firms and specific needs of young firms. As a rule, one refers to young firms' poor access to the capital market and lack of their own financial capacity. Firm age is thus a potentially essential determinant of innovation activity, but also of the probability of participation in public support programs. The firm age (in years) in logs (ln*AGE*) is applied in the regressions.

Export activity

One can assume that firms committed to being internationally competitive have a higher propensity to innovate than others. It is also accepted that expansion of innovation expenditures has mainly occurred in more export-oriented branches in recent years. In response, firms' export activity is measured in the estimations using a dummy variable $DEXP_{it}$, which takes the value 1 when exports were recorded for the respective firm and zero otherwise.

Patent stock (previously accumulated patents)

Patent stock approximates firms' past innovation activity and depicts both previously collected knowledge and otherwise disregarded qualities of innovation. The variable *patent stock* (PS_{it}) corresponds to firm *i*'s number of patent applications (PA_{it}) in year *t* and patent stock in the previous year *t-1*, the latter of which is inserted into the patent stock calculation in year *t* with an "depreciation factor" of 15 percent. This deduction accounts for loss and economic obsolescence of knowledge[7]:

[7] Cf. Griliches and Mairesse (1984) or Hall (1990) for further details.

$$PS_{it} = 0.85 * PS_{it-1} + PA_{it} .$$

The patent information utilized is taken from the DPMA (German Patent and Trademark Office) database and contains data from 1980 on. Patent stocks (*PS*) are calculated firm-specific and are then linked to the MIP firm data. For the year 1979 all firms' *PS* values are set to zero. Depreciating the knowledge stocks over time guarantees that the distortion caused by the initial condition of zerois negligible in the period under review. In the regression analyses the patent stock enters with a one year lag avoiding endogeneity. This variable is also measured logs. In cases where the patent stock is zero it is replaced by the smallest positive value observed in the sample. In order to compensate for the resulting distortion, an additional dummy variable *NoPAT* is introduced, indicating zero patents.

R&D department

An experienced work force, accumulated knowledge and modern capital equipment are important factors in carrying out innovation projects. Established organisational structures simplify the bureaucratic investment typically implied by such ventures. Furthermore, one can also suppose that R&D facilities promote the participation in government programs because of superior information about government programs. R&D departments are natural contact points for scientific institutions looking for partners for collaborative research projects funded by the government. In applying for R&D support R&D facilities can fall back on readily available experience, allowing R&D employees to handle the application with relatively little effort. A dummy variable ($RDDEPT_{it}$) indicates whether a firm has an own R&D department.

Credit rating / access to the capital market

As data from innovation surveys show high costs of innovation, the significant economic risks and a lack of sources of financing rank are among the dominant obstacles to innovation. Lack of financial resources is considered an "innovation barrier" by medium-sized industrial firms in particular. A number of studies (cf. e.g. Toivanen/Niinnen, 2000, Czarnitzki, 2002) provide evidence that restrictions in credit financing of research and development have an immediate effect on firm's R&D intensity. In order to verify capital market restrictions, the CREDITREFORM credit rating index (CR) – used by suppliers, banks, insurance companies, etc. in determining risks involved with clients – is employed. This index can take values between 100 and 600 risk points. The higher the credit rating index the greater the risk. Firms with up to 130 risk points exhibit a excellent rating, while values of 500 and above strongly suggest avoiding any business relationship.

Firm ownership

Holemans and Sleuwaegen (1988) or Janssens and Suetens (2001) point out that technology transfers within company groups represent crucial determinants of the individual member-firms' respective R&D activities. The corresponding literature offers descriptions of widely varying effect channels and –mechanisms displaying no uniformity with respect to direction of that effect. The innovation efficiency of Eastern German firms in particular may indeed benefit from membership in such an association (cf. Czarnitzki, 2005). Along these lines two dummy variables are applied: a binary variable, taking the value 1 when the firm in question belongs to a Western German firm association ($WGROUP_{it}$), and another which takes the value 1 when the parent company of the firm in question is based abroad ($FOREIGN_{it}$). In addition, one should bear in mind that these variables also portray access restraints to public research support. Small firms, for example, do not qualify for the specific SME programs support if they are majority-owned by large firms.

Specific industry and year effects

Additionally, we capture industry specific impacts and year specific effects by including industry and time dummies in all regressions. Porter (1998), for example, identifies with his diamond-scheme the components factor market conditions, demand conditions, related and auxiliary industries and firm strategies as the four main determinants of a nation's competitive advantage. Industry particularities not covered by the other variables are hence accounted for with sector dummies. Changes in the general macroeconomic framework can also have an effect on firms' innovation activity. For instance, a recession can present challenges to parties seeking sufficient capital for R&D projects; changes in the capital market can lead to postponements in firms' investment opportunities as they readjust their factor allocations. In order to control for these and many other possible temporal influences in the regressions, four year dummies are included in all the analyses.

5. Impact of Public R&D Subsidies on Innovation Input

A number of scenarios arise in the empirical analysis. As Czarnitzki (2002) describes, the existence of government funding can engender two different reactions. When such promotion has a stimulating effect on innovation input, one wonders what course the affected firms would have taken had they not received any assistance. On the one hand, the firms' levels of R&D expenditures, for example, might have been lower without support. On the other hand, however, small and medium-sized companies in particular may not have been able to engage in any R&D at all without government subsidies. Eastern German firms would have also abandoned R&D efforts after encountering capital market restrictions. These considerations give rise to two options:

- The initial estimation contains in the potential control group all non-supported firms, regardless of whether they are engaged in R&D or not; this will allow for firms' changing R&D status.
- In the second estimation the control group is limited to firms permanently conducting R&D. This likely underestimates the effect of promotion, as it is assumed implicitly that R&D promotion alone is not able to motivate firms to start R&D activities.

Case I: Government funded R&D performers vs. all other firms

Program participation and difference between supported and non-supported firms

The effect of innovation promotion on innovation input (R&D- and innovation expenditures) is examined first. The probability for participation in Governemnt funded R&D programmes (*PF*) is estimated using a probit model (cf. Table 1). This allows some interesting insights into differences between Eastern and Western Germany. Using firms' patent stock as a measure of earlier innovation success is an essential determinant of receipt of financial support. A clear indicator of a firm's access to R&D capacity or its actual engagement in R&D (an R&D department) is presented by innovation successes, which are documented via preceding patent applications. Conversely, only a small share of Eastern German firms can claim to have innovated successfully using patents; as a result, a problem concerning orientation on innovation history is posed to the promoting entity. As in the Western German states, support programs in the "new" states have focused on the dispersal of firms' knowledge bases. This is made apparent by the fact that the existence of one's own R&D department – not recorded by the patent stock – is decisive in predicting likelihood of receiving public support, a conclusion that could also reflect the contrasting political devices affecting research and technology in the two regions. While Western Germany focuses on direct promotion of specific R&D projects, the East emphasises an indirect approach (e.g. foster R&D personnel).

In essence, the estimation of participation likelihood in Eastern Germany resulted in a specification dependent on firm size, the R&D-department dummy, the NoPAT dummy (indicating whether a firm has never applied for a patent), firm age, export activity and firm integration. Market structure, measured as ln*HHI*, credit rating (ln*CR*) and size of patent stock had no influence on participation in support programs in Eastern Germany and were thus not considered in the final estimation (see Table 1).

As expected, firm size is a significant determinant of public R&D subsidies. In addition, an existing R&D department is one of the most important determinants of support in Eastern Germany. Firms with own R&D departments demonstrate the capacity and competency to successfully carry out R&D projects.

The likelihood of participation declines in Eastern Germany as firm age increases, while in Western Germany firm age has no such influence. This effect may reflect the existence of support programs for young high-tech firms; the application behaviour of firms can potentially change over time, as well. Older firms have better funding alternatives, as external investors can more often rely on experience with such companies than with newly founded firms. As a consequence, established companies able to provide evidence of a successful record have better access to the capital market.

Firms engaged in international competition take part in support programs more often than other firms. This may also mirror a signalling effect. Through their established position on international markets these firms have apparently proven their ability to transform innovation activities into successful products.

Table 1: Probit Regression for Program Participation; All Firms

Dependent Variable: ***PF***	**Eastern Germany**			**Western Germany**		
Exogenous Variable	Coeff.		Std. error	Coeff.		Std. error
ln*EMP*	0.94	***	0.174	0.05		0.106
(ln*EMP*)^2	-0.09	***	0.020	0.02	**	0.010
RDDEPT	1.46	***	0.081	/		
ln*PAT*	/			0.10	***	0.022
NoPat	-0.37	***	0.088	-0.54	***	0.176
LnAGE	-0.18	**	0.077	/		
DEXP	0.44	***	0.076	0.55	***	0.106
FOREIGN	-0.63	***	0.166	-0.21	***	0.080
WGROUP	-0.32	***	0.098	/		
ln*HHI*	/			0.05	*	0.028
ln*CR*	/			0.29	***	0.105
Constants	-2.26	***	0.834	-4.10	***	0.693
	incl. industry and year dummies					
Log-likelihood	-863.98			-1,533.92		
McFadden Pseudo R^2	0.337			0.165		
Number of observations	1,967			4,495		

**** (**, *) denotes significance at the of 1% (5%, 10%) level*

Members of a Western German (in the case of Eastern German companies) or foreign company group receive public support less frequently. This may be due to parent companies' centralised R&D. In this case, subsidiaries do not submit applications for public innovation assistance. On the other hand, effects of entry requirements for promotion designed to be limited for subsidiaries are reflected in these variables.

Credit rating (measured by the rating CR) and market structure (ln*HHI*) also play a role in the Western German states. When one considers patent stocks in the West, R&D departments offer no additional explanatory power to the estimation of participation likelihood.

As one can deduce from Tables A1 and A2 in the appendix, a clear divergence is shown between both the Western and Eastern German states on the one hand and supported and non-supported firms on the other. Supported firms are larger on average, have a R&D department, are more likely to have applied for a patent in the past and are exporters. Particularly striking in the West are the differences in firm size: supported companies employ an average of 652 individuals, decidedly more than non-supported firms' average of 260. As expected, the measures of innovation, R&D and innovative projects, are higher in supported firms. It does bear mentioning that the significant differences in the determinants of probability for public funding between the two groups indicate a definite selection bias. The estimated (unbounded) propensity score in particular differs sharply, amounting to 0.42 for supported firms and -0.93 for those not supported in the East. Similar deviations of -0.72 and -1.38, respectively, are also evident in Western Germany.

Impact of public R&D funds – Comparing promoted firms with the control group

In order to avoid a bias due to self-selection, nearest-neighbour matching is applied in the following as described in Section 3. For the 735 (638) beneficiaries from Eastern Germany (Western Germany) the most similar firm is selected from the control group, followed by a comparison of the criteria's mean values. If no significant difference is found in the determinants of support -- particularly in propensity score -- the remaining differences in the target variable (R&D- and innovation expenditures) can be traced back to public support. The mean comparison of the exogenous variables serves here as a "quality check" of the matching procedure. If the differences disappear after the matching, the process is considered successful. However, if significant mean differences remain, the groups are not yet comparable; an additional criterion may need to be added to the matching function or further restrictions applied.

Table 2: Mean Comparison after Matching; Entire Sample

	Eastern Germany				Western Germany			
	Supported Firms		Selected Control Group		Supported Firms		Selected Control Group	
Number of observations	731		731		628		628	
Variable	Mean value	Std. error	Mean value	Std. error	Mean value	Std. error	Mean value	Std. error
EMP	157.64	11.570	144.19	6.628	634.45	33.590	584.69	29.992
1n*Pat*	/		/		-6.27	0.150	-6.40	0.147
NoPat	0.64	0.018	0.67	0.017	0.29	0.018	0.29	0.018
RDDEPT.	0.68	0.017	0.64	0.018	/		/	
AGE	7.02	0.134	6.78	0.175	/		/	
DEXP	0.78	0.015	0.79	0.015	0.97	0.007	0.97	0.007
WGROUP	0.19	0.014	0.21	0.015	/		/	
FOREIGN	0.05	0.008	0.05	0.008	0.11	0.013	0.11	0.013
1n*HHI*	/		/		3.30	0.049	3.31	0.053
1n*CR*	/		/		5.27	0.011	5.28	0.011
Propensity score	0.41	0.033	0.37	0.031	-0.72	0.021	-0.73	0.021
R&D	0.76	0.116	0.31 ***	0.037	4.21	0.707	1.95 ***	0.196
ln*R&D*	-1.84	0.066	-5.20 ***	0.163	-0.35	0.077	-3.23 ***	0.200
*R&D/SALES*100*	6.40	0.386	2.25 ***	0.191	4.38	0.244	2.22 ***	0.131
D(R&D>0)	1.00	0.000	0.67 ***	0.017	1.00	0.000	0.73 ***	0.018
ln*IE*	-1.10	0.061	-4.05 ***	0.169	0.25	0.072	-2.11 ***	0.193
*IE / SALES * 100*	10.82	0.500	5.50 ***	0.424	6.39	0.283	3.89 ***	0.197

***** (**, *) denotes a significant mean difference in a two-sided t-test at the levely of 1% (5%, 10%). The distribution of observations across industries is identical after the matching.*

In the matching, the non-supported firm with the closest propensity score is selected for each supported enterprise. In doing so, however, certain conditions must be met: the chosen twin must belong to the same industry as the promoted firm and its observation must originate from the same or immediately previous year. The possibility that twins can stem from the period *t-1* allows a firm to serve as its own control observation if its support status changes from "no" to "yes". This is a preferable case; both observations are most likely equal in non-observed criteria such as management quality.

As Table 2 demonstrates, the differences between the selected pairs disappear after the matching. But, the differences in the target variables remain significantly different from zero. Supported Eastern German (Western German) firms thus exhibit an R&D intensity of 6.4% (4.4%) on average compared to an average of 2.25% (2.2%) in the absence of promotion. Additionally, one must consider that all of the supported firms are engaged in R&D, compared to just 67% of the control observations. According to this calculation, one-third of the beneficiary companies would not have been involved in R&D if they had not received support.

Case II: Supported Firms vs. Firms Permanently Performing R&D

If one restricts the control group to firms engaged in R&D, similar results appear in the estimation of participation likelihood. Still, in the case of Eastern Germany the export dummy continues to be insignificant. The same effects seen in the comparison of supported firms and firms in general are apparent in the remaining determinants. Overall, however, the explanatory power of the regressions with respect to participation in support programs is noticeably diminished when comparing supported firms to firm permanently performing R&D.

Significant differences also appear before the matching (cp. Appendix Tables A3 and A4). Interestingly, average firm size in the two groups is no longer dissimilar in Eastern Germany when firms active in R&D are observed.

Table 3: Probit Regression for Program Participation; R&D-performing firms only

Dependent Variable: *PF*	**Eastern Germany**			**Western Germany**		
Exogenous variable	Coeff.		Std. error	Coeff.		Std. error
ln*EMP*	0.67	***	0.232	-0.6		0.124
$(\ln EMP)^2$	-0.07	***	0.026	0.03	***	0.012
RDDEPT	0.36	***	0.105	/		
ln*PAT*	/			0.08	***	0.024
NoPat	-0.43	***	0.113	-0.52	***	0.195
Ln*AGE*	-0.31	***	0.107	/		
DEXP	0.14		0.108	0.28	**	0.135
FOREIGN	-0.73	***	0.188	-0.20	**	0.087
WGROUP	-0.34	***	0.123	/		
ln*HHI*	/			0.05	*	0.031
ln*CR*	/			0.30	**	0.117
Constants	-0.24		1.124	-3.00	***	0.791
incl.industry and year dummies						
Log-likelihood	-505.69			-1294.14		
Pseudo R²	0.1291			0.07		
Number of observations	1,008			2,401		

***** (**, *) denotes an error probability of 1% (5%, 10%).*

However, only 265 control observations (non-supported firms) are available for the 726 supported, permanent R&D performers in Eastern Germany. From one perspective this presents a problem for the analysis; the pool of potential control observations is relatively small. This problem can be solved by making repeated allocations of individual control observations to support cases. On the other hand, this still indicates that R&D status in Eastern Germany is also susceptible to public R&D support. A considerable number of the firms that do not receive support also choose not to engage in R&D. In other words, the vast majority of R&D-active companies in Eastern Germany receive some form of public promotion (cf. Figure 3). The marginal amount of control observations available in the Eastern German states is also responsible for the lack of an appropriate matching partner for approximately every eighth supported firm. The effect of the “loss” of observations may yet remain limited; R&D intensity of the non-observed firms differentiates only slightly from the one for firms included in the estimation. This result in – if at all – a slight underestimation of the effect of support. Sufficient control observations are available in Western Germany so that these problems do not arise.

Table 4: Comparison of Mean Values after Matching; R&D-performing firms only

	Eastern Germany				**Western Germany**			
	Supported Firms		Selected Control Group		Supported Firms		Selected Control Group	
Number of observations	637		637		627		627	
Variable	Mean	Std. error	Mean	Std. error	Mean	Std. error	Mean	Std. error
EMP	135.32	7.558	149.60	7.661	629.34	32.830	592.64	30.316
1n*Pat*	/		/		-6.24	0.150	-6.40	0.145
NoPat	0.69	0.018	0.67	0.019	9.29	0.018	0.29	0.018
RDDEPT.	0.66	0.019	0.66	0.019	/		/	
AGE	6.99	0.120	7.21	0.297	/		/	
DEXP	0.77	0.017	0.77	0.167	0.97	0.007	0.97	0.007
WGROUP	0.21	0.016	0.20	0.016	/		/	
FOREIGN	0.01	0.004	0.01	0.004	0.11	0.013	0.11	0.013
ln*HHI*	/		/		3.30	0.049	3.29	0.052
ln*CR*	/		/		5.27	0.011	5.28	0.011
Propensity score	0.84	0.020	0.81	0.020	-0.49	0.015	-0.50	0.015
R&D	0.65	0.113	0.47	0.053	4.20	0.708	1.91 ***	0.186
ln*R&D*	-1.95	0.070	-2.56 ***	0.077	-0.35	0.077	-0.35 ***	0.735
*R&D/SALES * 100*	6.24	0.416	3.13 ***	0.163	4.37	0.245	2.75 ***	0.138
ln*IE*	-1.21	0.065	-1.62 ***	0.070	0.26	0.072	-0.06 ***	0.067
*IE / SALES * 100*	10.64	0.538	6.60 ***	0.375	6.37	0.282	4.83 ***	0.221

**** (**, *) denotes a significant mean value difference in a two-sided t-test with an error probability of 1% (5%, 10%). The distribution of observations across branches is identical after the matching.*

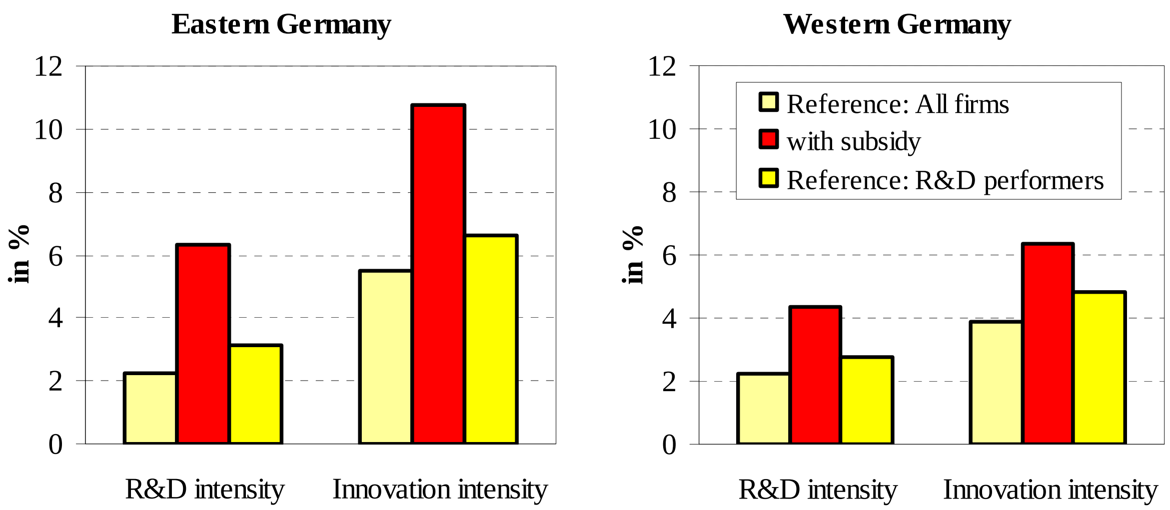
The matching results for the sample of R&D-performing firms are presented in Table 4. Promoted firms exhibit a mean value of €650,000 (€4.2 million in Western Germany). If the same firms had not received government support, they would have expended an average of just €470,000 (€1.9 million in the West). The mean of R&D expenditures is actually no longer significantly different from zero, but this can be attributed to asymmetry in the distribution of these expenditures. If this variable is transformed into logarithms or an intensity value, a t-test also produces significant differences. Alternatively, one can perform a test on median differences which is robust against skewness. This also results in a significant difference of medians: At the median the supported firms spend €153,000 on

R&D, compared to the control group's €77,000. In the absence of government support, R&D intensity would have amounted to an average of 4.7% (2.8% in Western Germany) instead of 6.5% (4.4%); similarly, innovation intensity would have shifted from 10.6% (6.4%) to 6.6% (4.8%, cp. Table 4).

Summary of Input Addionality Effects

The results with regard to input additionality are summarized in Figure 4. Differences between the two sets of comparison groups are interpretable in that R&D promotion not only affects firms' levels of R&D expenditures; it should be recognized that such support can even stimulate the decision to initially incorporate R&D operations. The disparities indicated by Chart 4 are all statistically significant. Both R&D intensity and innovation intensity are markedly higher for supported firms compared to those not receiving funding. Additionally, one can ascertain that these differences are much more pronounced in the Eastern German states than in the West. This could be traced back to both higher support levels and stronger impacts of R&D promotion in Eastern Germany. This question cannot be pursued further, however, as no information on levels of promotion is currently available in the data set.

Figure 1: Effects of public R&D subsidies on R&D- and Innovation Intensity



Source: Mannheim Innovation Panel; own calculactions (based on Table 2 and 4).

When restricted to R&D-performing firms, the supported Eastern German firms' mean R&D intensity weighs in at 6.5%, compared to 3.3% in the comparison group. Innovation intensity reveals similar differences, 10.6% for supported and 6.6% for non-supported firms. Of course, the fact that only 265 control observations are available for the 726 supported, R&D-active firms should be recalled. This clearly allows us to conclude that R&D status in Eastern Germany relies heavily on government funding. The bulk of the companies not receiving public R&D support are not engaged in R&D. When the comparison between firms with R&D support and those (still innovating) firms without support is applied, the discrepancies are brought into starker relief; indeed, in this case the stimulating effect of promotion on initial implementations of R&D is also added into the model. The comparison group's R&D intensity then only amounts to approximately 2.3%. According to this estimation, only 33% of the supported firms would have been involved in research and development had they not received funding.

6. Effects of R&D Subsidies on Innovation Output

The input analyses show that R&D subsidies affect R&D spending positively in both Eastern and Western Germany. Recipient firms invest significantly more in R&D compared to the counterfactual situation where no subsidies were in place. However, it is questionable whether this additional innovation input induced by public policy does also improve innovation outcome. It may be possible that subsidized projects are more risky undertakings than the purely privately financed ones, because it is more difficult to find private investors willing to support such research plans. The subsidies could also be spend inefficiently and therefore not lead to an increased output. The increase of wages of R&D personnel without a corresponding productivity gain is an example. Finally, the subsidies could reroute the firm's R&D portfolio towards technologies where the firm is less productive in generating innovation output.

Patent indicators are a suitable measure for an output analysis. Patent applications are closer in time to the conducted R&D projects than sales with newly developed products or cost reductions due to the implementation of new processes in production, for instance. One disadvantage is that the actual economic value of patents may be very heterogenous. In this paper, we implicitly have to assume that the filed patents from non-subsidized firms are not more valuable than those filed by subsidized firms, and vice versa. In other words, it is assumed that there is no significant correlation between the average value of a patent and the subsidy.

Table 5 shows the regression results of a probit model on the propensity to patent and of a negative binomial model on patent counts for both Eastern and Western Germany.[8] In order to test for a possible lower efficiency of publicly financed R&D expenditure, we employ the concept of knowledge production functions (cf. Griliches 1990). R&D is assumed to be the most important input for the production of patents (cf. Licht and Zoz, 1998, for estimations of knowledge production functions for Germany). Industry dummies and time dummies control for different technological opportunities and appropriability conditions. As shown in chapter 3 we disentangle R&D expenditure in two components Y_i^0 and $\alpha_i = Y_i^1 - Y_i^0$, R&D expenditures which would have been spent if no subsidy was in place (Y_i^0), and in those expenditures that are induced by public funding α_i. The values of Y_i^0 and α_i are derived from the foregoing matching estimations.

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8 The data from the year 2000 cannot be used in these estimations, because our patent database does not include information beyond the year 1999 unfortunately.

Table 5: Regressions on the patenting activity of publicly funded firms

	Eastern Germany		Western Germany	
Number of observations:	497		491	
	Probit regression; dependent variable: patent application dummy			
	Coef.	Std. err.	Coef.	Std. err.
R&D induced by public funding (α_i)	0.32 ***	0.09	0.15 ***	0.03
non-subsidized R&D (Y_i^0)	0.45 ***	0.12	0.18 ***	0,03
Export intensity	0.14	0.32	0.60 **	0.26
Intercept	-1.12 ***	0.34	-1,81 ***	0.53
Industry dummies; test on joint significance	$\chi^2(10) = 18.57$ **		$\chi^2(10) = 14.79$	
Time dummies; test on joint significance	$\chi^2(2) = 5.45$ *		$\chi^2(2) = 3.73$	
Log-Likelihood	-212.03		-288.13	
Pseudo R^2	0.10		0.14	
	Negative-binomial regression, dependent variable: number of patent applications			
R&D induced by public funding (α_i)	0.78 ***	0.20	0.30 ***	0.04
non-subsidized R&D (Y_i^0)	0.91 ***	0.22	0.40 ***	0.04
Export intensity	-0.04	0.65	0.93 **	0.39
Intercept	-1.78 ***	0.67	-2.13 ***	0.71
Industry dummies; test on joint significance	$\chi^2(10) = 17.87$ *		$\chi^2(10) = 27.03$***	
Time dummies; test on joint significance	$\chi^2(2) = 4.38$		$\chi^2(2) = 16.42$ **	
Log-Likelihood	-356.63		-853.90	
Pseudo R^2	0.07		0.09	

**** (**, *) indicate a significance level of 1% (5%, 10%).*

The probit regressions on the probability to apply at least for one patent show that the coefficient of the non-subsidized R&D expenditures is about 0.45 in Eastern Germany and about 0.18 in Western Germany. The coefficient of publicly induced R&D is only 0.32 in Eastern Germany, and 0.15 in Western Germany. Thus, the publicly funded R&D achieves a productivity of about 71% (=0.32/0.45) of the non-subsidized R&D in Eastern Germany and about 83% (= 0.15/0.18) in Western Germany. Although smaller then purely privately financed R&D, the effects of subsidies are significantly positive on the output side of the innovation process. Under the assumption that firms conduct projects with highest expected returns even without subsidies in place, and start those with less expected return due to the subsidy receipt, this result is in accordance with the paradigm of decreasing marginal returns of R&D activities.

If the number of filed patent applications is considered rather than the propensity to patent, we find a similar result: The productivity of publicly funded R&D with respect to patents reaches 86% of the productivity of privately financed R&D in Eastern Germany (75% in Western Germany). The coefficient of publicly induced R&D is significantly different from zero in this case, too.

However, it should be pointed out that the difference in patent productivity between both kinds of R&D is only statistically significant in the count data model for Western Germany (at the 5% significance level). For the other cases, the hypothesis that both kinds of R&D are equally productive is not rejected.

In order to compare the patent productivity, on average, one can calculate marginal effects based on the coefficient estimates. For instance, based on the count data model on the number of patent applications, one would address the question "how does the average number of patents change, if R&D activity changes?" The marginal effects of publicly induced R&D are 0.22 (0.49) in Eastern (Western) Germany. Those of privately financed R&D are 0.26 (0.64) in Eastern (Western) Germany. All values are calculated at the sample means of the corresponding R&D variable. Thus, R&D in Eastern Germany is not as productive as in Western German firms (yet). Eastern German firms achieve roughly about 41% of the Western German R&D productivity level with respect to patents in the case of non-subsidized activity (45% in case of the subsidized R&D). However, this difference does not stem from the high levels of subsidies in Eastern Germany, because we find the lower productivity for both subsidized and non-subsidized R&D.

Export intensity is entered into the patent production function for two reasons. Exporters often have a higher productivity which may also be present in the invention process. In addition, exporter may have a higher propensity to seek patent protection in order to increase their competitive position in more contest foreign markets. Somewhat surprising we find that export activity is an important driver for Western German firm to apply for patent protection but has no influence on patent behaviour in Eastern Germany yet. One reason for this maybe that Eastern German firm view even the Western German market as a “foreign” market so that the export ratio is unable to capture the both mention “export” market hypothesis. However, a more stringent explanation needs a more complete analysis of differences in patenting behaviour in Eastern and Western Germany (cf. Legler et al. 2004) and is left for further research.

7. Synopsis and Interpretation of Results

The preceding sections first investigate whether governmental support of innovations, particularly R&D, stimulates innovation input – measured by R&D expenditures of Eastern German firms – or if these funds merely take the place of private resources. Secondly, tests are conducted to determine whether additional, government-induced R&D expenditures have a positive effect on innovation output, which is measured by firms’ patent activity. Analyses of innovation support of Western and Eastern German firms are then compared accordingly.

The econometric analyses demonstrate the presence of selection biases in receiving public R&D funds. Supported firms differ considerably from those not receiving aid: the former are larger on average, are more likely to feature an R&D department, are more likely to have already applied for at least one patent, and are also more likely to be internationally active. Thus, econometric methods that account for this sort of selection bias must be applied.

The look at the probability to participate in R&D-support programs shows significant discrepancies between the East and West. In Western Germany, support participation indicates a strong selection in favour of firms that already have a history of above-average amounts of innovation activity. The patent stocks of firms as a measure of past innovative success are an important determinant of receiving financial aid. A clear signal of a firm's access to R&D capacities or engagement in R&D (i.e., an R&D department) is actually secondary to proven success in innovation. In Eastern Germany, however, only a small amount of firms are able to show a past success record in the form of patents. Government promotion is spread out across a wider basis in the East; evidence of the ability to carry out R&D is enough to be eligible for public R&D support. This finding may reflects the different policy instruments being in place in both parts of Germany. While technology-specific project grants are the predominant mean of R&D policy, Eastern German can access also less technology-specific R&D support and specific support for R&D labour costs.

The implementation of the econometric processes reveals positive treatment effects; that is, public funds do not substitute for firms' own resources – they stimulate innovation input. At the same time, the estimated treatment effects are more pronounced in Eastern Germany than in the West. This allows one to conclude that, compared to their Western fellows, Eastern German firms are not as capable of acquiring capital from other financial channels. The estimations also indicate that a significant share of Eastern German firms would not be engaged in R&D without public support. This may hint towards the limited access to alternative sources of funding in East Germany.

The aforementioned differences in the input analysis are statistically highly significant. Both R&D- and innovation intensity are considerably higher in firms receiving public R&D grants. These contrasts are also much more distinct in the Eastern states. This may be due both to the East's greater share of supported firms and a stronger stimulation effect of R&D promotion.

An analysis of firms' patent activities shows that they are affected positively by support-induced R&D in both German regions. Likelihood of applying for at least one patent and number of patent applications are also analysed. With regard to both dimensions we only find little evidence that government induced R&D is less productive than R&D solely financed from firm's own pockets. Only in the case of Western Germany we a find significant lower productivity for public financed R&D. The difference in marginal productivity is less noticeable in Eastern Germany. Since Western German firms still engage in a substantial amount of R&D without government funding – allowing their average volume of R&D to be accordingly greater in comparison to Eastern German firms – the effects of promotion in Western Germany are less marked. In the East, however, publicly financed private R&D constitutes an essential component of total R&D and is thereby essential for innovation output.

In the light of the current discourse about future innovation policy in Eastern Germany our findings shed a far more positive light on the role of R&D in the transition process than the dismal tones by some contemporaries. R&D promotion has made a crucial contribution to R&D intensification in the Eastern German manufacturing industry. In the absence of public innovation promotion fewer firms would have been able to implement new products and processes in national and international markets. In this respect, there are considerable arguments for continuing such support.

On the other hand, the results also show that the findings on R&D input in the East leave something to be desired. Western German firms are able to realize a higher level of productivity with their R&D resources. Even though the differences between firms' publicly financed R&D expenditures and those privately funded are clearly greater in the West, patent productivity of supported R&D in Western Germany is still higher than firm-financed R&D in the East. However, this also implies that promotion of R&D activities in Western Germany yield higher returns in the form of patents than it does in the Eastern states. Assuming that additional R&D activity also improves international competitiveness and thus creates more export opportunities, one could consider reallocating public R&D funds from the East to the West to possibly realise a higher rate of growth instead of using these resources to stimulate the adjustment process in Eastern Germany. Similarly, the warnings concerning the West-East transfer's growth-impairing effect cannot fully be dismissed outright. However, the overall picture more likely indicates additional public R&D instead of increasing R&D support in Western German at expenses of the Eastern German innovation system which is still in transition.

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Appendix

Table A1: Mean Value Comparison before Matching – Eastern Germany, Entire Sample

	Supported Firms		Potential Control Group		
Number of observations	735		1224		
Variable	Mean	Std. error	Mean		Std. error
EMP	157,62	11,510	94,97	***	5,714
NoPat	0,64	0,018	0,86	***	0,010
RDDEPT	0,68	0,017	0,15	***	0,010
AGE	7,02	0,134	10,05	***	0,421
DEXP	0,79	0,015	0,46	***	0,014
WGROUP	0,19	0,014	0,17		0,011
FOREIGN	0,05	0,008	0,04		0,006
Propensity score	0,42	0,033	-0,93	***	0,022
R&D	0,76	0,116	0,08	***	0,017
ln*R&D*	-1,83	0,066	-9,31	***	0,100
*R&D / SALES * 100*	6,42	0,385	0,56	***	0,696
D(R&D>0)	1,00	0,000	0,22	***	0,012
ln*IE*	-1,10	0,613	-8,26	***	0,128
*IE / SALES * 100*	10,85	0,500	2,53	***	0,246

***** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.*

Tabelle A2: Mean Value Comparison before Matching – Western Germany, Entire Sample

	Supported Firms		Potential Control Group		
Number of observations	638		3.856		
Variable	Mean	Std. error	Mean		Std. error
EMP	652.11	34.067	259.95	***	7.671
ln*PAT*	-6.26	0.148	-8.97	***	0.060
NoPat	0.29	0.018	0.62	***	0.008
DEXP	0.97	0.007	0.79	***	0.007
FOREIGN	0.12	0.013	0.10	*	0.005
ln*HHI*	3.31	0.049	3.00	***	0.019
ln*CR*	5.28	0.011	5.31	***	0.004
Propensity score	-0.72	0.021	-1.38	***	0.010
R&D	4.29	0.701	0.54	***	0.040
ln*R&D*	-0.33	0.076	-6.68	***	0.080
*R&D / SALES * 100*	4.35	0.241	1.11	***	0.042
D(R&D>0)	1.00	0.000	0.46	***	0.008
ln*IE*	0.28	0.072	-5.41	***	0.086
*IE / SALES * 100*	6.38	0.280	2.60	***	0.083

***** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.*

Table A3: Mean Value Comparison before Matching – Eastern Germany (R&D-performers)

	Supported Firms		Potential Control Group	
Number of observations	726		265	
Variable	Mean	Std. error	Mean	Std. error
EMP	143.61	7.741	146.61	14.175
NoPat	0.64	0.018	0.81 ***	0.024
RDDEPT	0.68	0.017	0.50 ***	0.031
AGE	7.04	0.135	9.74 **	0.886
DEXP	0.78	0.015	0.68 **	0.029
WGROUP	0.19	0.015	0.22	0.026
FOREIGN	0.05	0.008	0.09 **	0.018
Propensity score	0.85	0.019	0.37 ***	0.033
R&D	0.65	0.100	0.37 **	0.076
Ln*R&D*	-1.87	0.065	-2.87 ***	0.122
*R&D / SALES * 100*	6.35	0.388	2.60 ***	0.289
ln*IE*	-1.13	0.060	-1.75 ***	0.120
*IE / SALES * 100*	10.76	0.504	6.42 ***	0.582

***** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.**

Table A4: Mean Value Comparison before Matching – Western Germany (R&D-performers)

	Supported Firms		Potential Control Group	
Number of observations	637		1,762	
Variable	Mean	Std. error	Mean	Std. error
EMP	645.44	33.460	376.83 ***	13.459
ln*PAT*	-6.26	0.148	-7.44 ***	0.093
NoPAT	0.29	0.018	0.42 ***	0.012
DEXP	0.97	0.007	0.91 ***	0.007
FOREIGN	0.12	0.013	0.13	0.008
ln*HHI*	3.31	0.049	3.08 ***	0.030
ln*CR*	5.28	0.011	5.27 ***	0.006
Propensity score	-0.49	0.016	-0.74 ***	0.009
R&D	4.28	0.702	1.18 ***	0.085
ln*R&D*	-0.33	0.076	-1.45 ***	0.045
*R&D / SALES * 100*	4.35	0.241	2.44 ***	0.081
ln*IE*	0.27	0.072	-0.62 ***	0.042
*IE / SALES * 100*	6.39	0.280	4.61 ***	0.143

**** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.*