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An Empirical Analysis of Factors Explaining the Level of R&D Subsidies and their Productivity Effects

Evidence from Firm-Level Panel Data

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Abstract:

The Industrial Research Promotion Fund (*Forschungsförderungsfond,* FFF) is Austria's most important source of finance funding R&D projects carried out by business enterprises. However, the decision on the level of R&D subsidies will be affected by both the funding agency's objectives and firm characteristics. This paper analyzes the factor explaining the intensity of R&D subsidies as well as their productivity effects. The analysis is based on unique panel data for about 1,000 Austrian firms receiving R&D subsidies for the period 1996-2002. The results of the panel data analysis suggest that the ratio of R&D subsidies to total R&D expenditures is significantly negatively related to both firm size and the current R&D intensity, but not to the cash-flow ratio in the past. Furthermore, we find that newly founded enterprises as well as firms in the electrical machinery and software industry have a significantly higher ratio of R&D subsidies to total R&D. In contrast, fast output growth in the past is associated with a lower R&D subsidy ratio. Overall, the results are consistent with the fund's strategy. Using a Cobb-Douglas function to assess the productivity effects of both privately and publicly funded R&D, we find that the initial R&D subsidy-sales ratio has a significant but small effect on the change in output per worker in the following two years. Overall, two percent of the annual change in output per worker of about 5.8 percent during the period can be attributed to the initial R&D subsidy sales ratio.

JEL: O 32, O 38

Keywords: R&D Subsidies, Management of Technological Innovation and R&D, Government Policy, Productivity

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1 Introduction

Policymakers increasingly recognize the importance of research and development (R&D) as a driver of productivity growth. Governments use both indirect and direct measures to stimulate technological activity. In Austria, the Industrial Research Promotion Fund (FFF) happens to be the major distributor of R&D subsidies to firms with € 62 million distributed in 2002. Given total business enterprise expenditures on R&D of about € 2,800 million in 2002 (Statistics Austria), R&D subsidies only account for a small share of total business R&D expenditures.

In recent years, there has been growing interest in R&D subsidies and the measurement of their impact. Previous studies of the possible impact of publicly funded R&D activities can be divided into two main groups: input additionality analysis and output additionality analysis. Output additionality analysis assesses the impact of publicly funded R&D on both research output (i.e. patents) and overall productivity growth. Input additionality analysis investigates whether publicly funded R&D is complementary and thus "additional" to privately funded R&D spending (see Arvanitis 2003; David et al., 2000, for a review). There have been few studies investigating in detail the effects of privately vs. publicly funded R&D on productivity growth based on non-U.S. data. Griliches (1998) summarizes the results of extensive econometric studies of rates of return to privately and publicly funded R&D in the United States. These rates of return range between 18 – 20 percent. The author suggests that there is no differential effect of publicly financed versus private R&D on the levels and rates of growth of total factor productivity at the firm level, although the differences are evident at the industry level. Using U.S. data, Lichtenberg and Siegel (1991) and Nadiri (1993) find that the productivity effects of publicly funded R&D were lower than the estimated effects of privately funded business R&D. Using data for eleven finish manufacturing industries, Niininen (2000) finds that the productivity effect of publicly financed R&D is similar to that of privately financed R&D. Combined, total industrial R&D accounts for nine percent of total factor productivity growth. Using aggregate data for 16 OECD countries, Guellec and van Pottelsberghe (2001) show that increases in both private and public R&D have a positive and significant impact on the change in total factor productivity. Using industry panel data for German manufacturing, Bönte (2003) found positive and significant productivity effects of publicly financed R&D. More recently, both OECD (2001) and Bassanini and Scarpetta (2001) have reported cross-country regressions that suggest a negative return on public sector R&D. Guellec and Van Pottelsberghe (2001) suggest that considerable caution is needed in drawing policy conclusions from empirical analysis at the aggregate level. In this paper, we will investigate the impact of public support for R&D at the firm level.

The amount of subsidies is not exogenous but endogenously determined by the funding agency's selection rule. According to technology guidelines and budget constraints, the funding agency decides which projects to subsidize, as well as what amount and what kind of subsidy the projects will receive. Based on certain criteria, the agency ranks the applications and funds the best project. According to the fund's strategy, the size, age, industry affiliation and performance of the firm as well as the firms' R&D intensity may all influence the level of R&D subsidies.

This paper will present new results on the determinants of the level of R&D subsidies as well as the productivity effects of privately and publicly funded R&D at the firm level. In the first part of the paper, the determinants of R&D subsidies will be examined. Due to data limitations, we will investigate determinants of the level of R&D subsidies of supported firms rather than the determinants of the probability to receive subsidies.

In the second part of the paper, we investigate the relationship between privately and publicly funded R&D and labor productivity growth. The analysis is based on large sample of Austrian firms doing R&D provided by the FFF for the period 1995-2002. It would be preferable to compare the productivity effects between supported and non-supported firms. However, the small sample size of non-supported firms prevented a detailed analysis of the treatment effects.

The layout of the paper is as follows. In section 2, we present the empirical model and the hypotheses, while in section 3 we present some summary statistics. In section 4, the empirical results for the determinants of the R&D subsidy ratio and the productivity effects of R&D subsidies are presented. Finally, in section 5 we make some concluding remarks.

2 Empirical model and hypothesis

2.1 Hypotheses about the agency's allocation rule

The funding agency's strategy depends on a number of factors. In principle, the FFF's strategy is to open all industrial R&D projects. The FFF decides whether to give subsidies to a R&D project. If the decision is positive, the amount of the subsidies will be determined. The decision whether or not to subsidize an R&D project as well as the decision on the level of subsidies may depend on specific selection criteria. According to the public agency's guidelines, the fund encourages R&D in small firms and in start-up firms (see www.fff.co.at). Furthermore, a special grant program called "start-up" is established, favoring technology-oriented companies established during the past three years and consisting of less than 50 employees. The support of small firms can be justified by the presence of capital market imperfections and by the fact that R&D may involve fixed set-up costs, part of which may be sunk costs. Another grant program, "R&D dynamics", is designed to provide financing to firms with a lower-than-average R&D intensity but with high R&D growth in the past.

Another program initiative is the micro technology program. Therefore, we would expect industry variation as well. In particular because the potential for profitable R&D projects in micro technology is higher, we expect a higher R&D subsidy ratio in R&D-intensive industries using micro technologies such as the electronic industry and instruments, opposed to industries not using micro technologies. Other selection criteria taken into consideration include measures of firm performance such as sales growth rates and cash flow in the past. In order to test the impact of past firm performance, we include the cash flow to sales ratio (lagged two years) and the annual growth rate of total sales in the last two years as additional explanatory variables.

In the following, five hypotheses concerning the determinants of the R&D subsidy ratio are formulated that will be evaluated in the following empirical work:

H1: We expect that both small firms and young firms receive higher R&D subsidies to total R&D.

H2: The R&D subsidy ratio decreases with increasing firm size.

H3: The R&D subsidy ratio may be higher in the software (Nace 72) and the electronic industry (NACE 30-33) than in other industries.

H4: Fast-growing firms as well as firms with a high cash flow sales ratio in the past are expected to receive higher amounts of R&D subsidies.

H5: The R&D subsidy ratio is significantly negatively related to the current R&D intensity.

2.2 Factors explaining the R&D subsidy ratio

The general specification used in the following empirical implementation relates the log ratio of R&D subsidies to total R&D expenditures to log R&D intensity, average annual growth rate of total sales in the past two years, cash flow ratio in the past two years as well as a set of appropriate control variables. In addition, we control for time and fixed effects:

$$\log(RDSUB_{it} / RD_{it}) = \alpha_1 \log(RD_{it} / Y_{it}) + \alpha_2((\log(Y_{it}) - \log(Y_{it-2})) + \alpha_3 CFR_{it-2}$$
$$+ \sum_{k=1}^{K} \beta_k X_{kit} + \theta_i + \lambda_t + \varepsilon_{it},$$

where i and t are indexes of firm and year, respectively. θ_i and λ_t denote fixed and time effects. $\log(RDSUB_{it} / RD_{it})$ is the natural logarithm of the ratio of R&D subsidies to total R&D expenditures. CFR_{it-2} denotes the cash flow to sales ratio, $\log(RD_{it} / Y_{it})$ is the natural logarithm of R&D intensity, measured as the ratio of R&D to turnover. $(\log(Y_{it}) - \log(Y_{it-2}))$ is the growth rate of total sales in the last two years and X_{kit} are other explanatory variables that are considered relevant. Appropriate control variables, which may affect the level of R&D subsidies, include firm age, legal status, industry affiliation and size dummies. In particular, firm age represents a good control variable because one of FFF's strategies is to support newly founded firms. Age effects are captured by a dummy variable indicating whether firms were founded less than six years before the survey year. Furthermore, we include a dummy variable indicating whether the firm is a company with limited liability (GmbH). Year dummies control for common shifts over time. In order to account for the firms' industry affiliation, we use eleven industry dummies. Firm size is defined by the number of employees and firms are divided into six size classes: the reference group has less than 10 employees, the three medium-sized classes are defined as 10-24, 25-49, 50-249, while large firms are defined to have 250-499 and more than 500 employees. As normalization we exclude one of the industry dummies and size classes each in the estimation.

2.3 Production function

The empirical model is based on the R&D capital stock model developed on Griliches (1979). Many empirical studies of the productivity effects of R&D relate the change in total factor productivity to the R&D expenditure output ratio because it avoids the problems of measuring the R&D capital stock. The model can be written as:

$$\dot{TFP} = \eta + \rho(RD_{it} / Y_{it})$$

where $\dot{TFP}$ denotes average annual growth of total factor productivity. Since data on investment are not available, we work with labor productivity growth rather than total factor productivity growth. Furthermore, we use the logarithm of the R&D subsidy to sales ratio rather than the level of the R&D subsidy to sales ratio. It is important to keep in mind that the impact of R&D subsidies is lagging and would surface after a certain period *after* the utilization of the R&D subsidies. Following Guellec and van Pottelsberghe (2001), we assume a two-year time lag for the impact of both publicly and privately financed R&D. The resulting production function relates the average annual growth rate of labor productivity to lagged levels of both the adjusted R&D intensity and the R&D subsidy sales ratio:

$$\Delta \log(Y_{it} / L_{it}) = c_1 \log((RD_{it-2} - RDSUB_{it-2}) / Y_{it-2}) + c_2 \log(RDSUB_{it-2} / Y_{it-2})$$
$$+ c_3 CFR_{it-2} + \sum_{k=1}^{K} c_k Z_{kit} + \theta_i + \lambda_t + \varepsilon_{it}$$

where i and t are indexes of the firm and the year, respectively. $\Delta \log(Y_{it} / L_{it})$ denotes the average annual growth rate of labour productivity between t and t-2. θ_i and λ_t denote fixed and time effects. R&D subsidies are subtracted from total R&D expenditures in order to avoid double counting[1]. This gives the logarithm of the adjusted R&D intensity lagged two years: $\log((RD_{it-2} - RDSUB_{it-2}) / Y_{it-2})$. $\log(RDSUB_{it-2} / Y_{it-2})$ is the natural logarithm of R&D subsidies as percentage of total turnover lagged two years. CFR denotes the cash flow to sales ratio lagged two years and Z_k are other explanatory variables (i.e. firm age, legal status, industry affiliation

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[1] The average annual growth rate is calculated as:
y $\Delta \log(Y_{it} / L_{it}) = \exp[\log(Y_{it} / L_{it}) - \log(Y_{it-2} / L_{it-2})] / 2$

and firm size). Since output prices are difficult to get at the two-digit level, one can use the year dummies to proxy the unknown output deflator. The main hypothesis is that the productivity effects of both privately and publicly financed R&D are positive and significant, but we expect that these effects are lower for publicly funded R&D than those estimated for privately financed R&D.

To estimate the factors explaining R&D subsidies and their productivity effects, we use the IV techniques introduced by Hausman and Taylor (1981). Recall that the Hausman Taylor strategy is to divide the time-varying variables and time-invariant variables into exogenous (i.e. independent of individual effects) and endogenous, therefore possibly correlated with fixed effects. In the production function, the endogenous explanatory variables are R&D subsidies to sales ratio, the adjusted R&D intensity, firm age and legal status. In our specification of the R&D subsidy equation, the endogenous explanatory variables are the growth rate of total sales lagged two years, the cash flow ratio lagged two years, the current R&D intensity and the duration of the R&D project. Dummy variables for firm size, industry affiliation and year are all assumed to be exogenous.

3 Data and descriptive results

The data used in this study are based on a unique data set containing all firms involved in R&D applying for R&D subsidies from the FFF. The Austrian Industrial Research Promotion Fund (FFF) is Austria's most important source of finance for R&D projects carried out by business enterprises. The support of the FFF comprises non-repayable grants, loans and guarantees for bank loans. Loans and guarantees are measured in net present value terms. Note that grants account for 90 percent of total R&D subsidies. Projects are supported with up to 50% of their total R&D project costs.

The FFF project database allows us to identify exactly whether a R&D project is subsidized. This database also includes total project costs, duration in months, total amount of R&D subsidies, level of grants, loans and liabilities and the NACE code. For the period 1995-2003, the funding agency granted subsidies and loans to 7,599 projects of a total of 10,438 projects. This gives a rejection rate of 27.2 percent (see Table 1). Aggregating the projects over firms allows us to calculate the percentage of firms receiving R&D subsidies. Of the total sample containing 7,762 observations on firms, 5,820 firms received R&D subsidies, resulting in a rejection rate of 25 percent (see Table 1).

Table 2 shows the matrix of transition probabilities measuring the probabilities whether or not a firm is likely to receive R&D subsidies. For those firms receiving subsidies for R&D projects, we find that the probability to receive subsidies in the following year is about 0.85. Given the small sample size of firms without R&D subsidies, it is difficult to measure productivity effects between recipients and non-recipients of R&D subsidies. Therefore, we restrict our descriptive analysis to firms receiving R&D subsidies. Also, only little information on the characteristics of non-subsidized firms is available.

Table 3 gives summary statistics of the sample of firms receiving subsidies for at least one R&D project. The duration of the R&D projects is on average 14.5 months with a minimum duration of one month and a maximum duration of 60 months. The ratio of R&D subsidies to total costs of the R&D project is about 22 percent, with higher values for the period 2001-2003.

Table 1: Share of subsidized projects and firms (percentages)

	Share of subsidized projects	Share of subsidized firms
1995	76.0	78.8
1996	78.1	81.9
1997	79.9	82.1
1998	78.1	79.4
1999	77.8	79.9
2000	73.4	73.3
2001	72.4	74.5
2002	57.7	61.9
2003	70.8	72.5
total	72.8	75.0

Notes: The total number of projects is 10,438 and the corresponding number of firm observations is 7,762.
Source: FFF project database.

Table 2: Transition probabilities for the receipt of R&D project subsidies, frequencies

	No publicly funded R&D projects	One or more publicly funded R&D projects	Total
No publicly funded R&D projects	115	194	309
	37.2	54.7	100
One ore more publicly funded R&D projects	374	2,789	3,163
	15.4	84.6	100
Total	489	2,983	3,472
	15.2	84.9	100

Notes: Transition probabilities measure the probability that a firm receiving subsidies for one or more R&D projects in period t will receive R&D subsidies for one or more R&D projects in period t+1.
Source: FFF project database.

Table 3: Summary statistics: project-based information

	Duration in months	R&D subsidies to total costs of R&D project					# of obs.
	mean	mean weighted	mean	median	min	max	
1995	14.9	21.9	28.2	22.5	3.9	100.0	733
1996	14.9	22.1	27.0	22.8	7.4	100.0	732
1997	15.0	21.9	27.0	23.2	4.6	100.0	804
1998	15.1	20.6	25.9	23.0	1.7	100.0	825
1999	14.9	21.7	26.1	23.3	7.2	100.0	842
2000	14.8	21.5	26.2	22.8	7.5	100.0	955
2001	14.6	23.2	30.0	23.9	9.4	100.0	829
2002	14.2	24.0	33.5	24.7	5.8	120.0	918
2003	12.4	23.0	32.9	24.6	2.0	120.0	933
total	14.5	22.3	28.6	23.5	1.7	120.0	7,571

Notes: The sample includes subsidized projects.
Source: FFF project database.

The FFF project database has been linked with information on the FFF firm database. Firms applying for an R&D project were requested to give information on sales, number of total employees, total R&D expenditures, R&D personnel, foundation year, cash flow and total exports for the last three years before the application for an R&D project. The sample size is 12,333 observations on 3,585 firms. It can be considered approximately representative of all firms doing R&D in Austria. The database includes all firms with at least one employee. The linked project-firm database is constructed in various steps. Since the duration of R&D projects usually exceeds one year, the subsidies granted have to be distributed equally between the years. Next, we sum up the amount of R&D subsidies by firm and year. Finally, the project database is merged with the firm database leaving us with information on about 1,250 firms with 3,500 observations. Furthermore, we exclude firms with a ratio of R&D subsidies to total R&D expenditures above two. Similarly we exclude firms with R&D to sales ratio above one. This leads to a final sample of 1,125 firms with 3,179 observations.

Table 4 reports the evolution of the R&D subsidy ratio as well as R&D intensity among the supported firms for the period 1995-2002. The aggregate mean R&D subsidy ratio is quite stable about 4 percent[2]. The aggregate average R&D intensity of the supported firms is 5 percent and appears to be increasing in 2001 and 2002.

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[2] The aggregate mean ratio is calculated as the ratio of the sum of R&D subsidies to the sum of total R&D expenditures.

Table 4: R&D intensity and R&D subsidy ratio (supported firms), 1995-2002

	R&D/sales			R&D subsidies/total R&D			# of obs.
	mean (aggregate)	mean	median	mean (aggregate)	mean	median	
1995	5.0	12.6	5.6	2.6	13.6	7.4	294
1996	5.0	11.7	5.0	3.0	13.0	8.4	357
1997	4.6	12.6	5.1	3.7	14.1	9.0	407
1998	4.1	11.8	5.0	4.2	15.1	10.5	471
1999	4.7	12.8	5.2	4.1	16.4	10.5	477
2000	4.4	12.4	5.2	4.0	16.2	11.0	486
2001	6.1	14.4	5.8	4.4	14.8	10.5	456
2002	8.5	15.8	6.5	3.4	15.2	10.2	231
total	5.1	12.9	5.3	3.7	14.9	9.7	3,179

Notes: Firms receiving R&D subsidies are included. Number of firms is 1,125.
Source: Linked FFF project-firm database, own calculations.

Table 5: R&D intensity and subsidies ratio by firm size (supported firms)

	R&D/sales			R&D subsidies/total R&D			# of obs.
	mean (aggregate)	mean	median	mean (aggregate)	mean	median	
Firm size:							
0-9	20.9	32.7	27.2	18.0	24.9	18.0	487
10-24	13.6	20.3	13.2	14.9	19.6	14.5	459
25-49	11.2	14.8	8.1	12.8	18.8	14.1	302
50-99	6.1	7.8	4.2	12.1	18.9	13.0	353
100-249	4.8	5.5	3.3	7.5	12.1	8.7	573
250-499	3.9	4.9	2.9	7.6	9.4	6.7	475
>500	5.1	5.5	3.1	2.4	4.8	3.1	530
Total	5.1	12.9	5.3	3.7	14.9	9.7	3,179
Firm age:							
Last 5 years	4.5	23.0	12.3	5.8	19.9	13.8	
Six and more	5.1	9.8	4.7	3.5	13.4	8.7	

Notes: Number of firms: 1,125.
Source: Linked FFF project-firm database, own calculations.

Table 5 presents the breakdown of both R&D intensity and R&D subsidy ratio by firm size and firm age. Small and medium-sized firms posses the expected higher R&D subsidy ratio than large firms. The R&D subsidy ratio ranges between 18 percent (aggregate means) in the smallest size class (0-9 employees) and 2.4 percent in the largest size class. Furthermore, we find that firms that are five years old or less have an R&D subsidy ratio of about 5.8 percent as compared to that of firms that are more than six years old with an R&D subsidy ratio of about 3.5 percent. The variation of the R&D subsidy ratio across firm size and firm age is in line with the fund's objectives.

Table 6: Summary statistics (supported firms)

	Mean	Median	Std. Dev.	Min	Max
	estimation sample of the R&D subsidy equation (# of obs.: 2,483, # of firms: 909)				
Ratio of R&D subsidies to total R&D	14.5	9.6	18.5	0.1	198.1
R&D/sales	11.1	5.0	15.6	0.0	99.2
Growth rate of total sales, t, t-2	15.1	8.5	30.2	-71.0	236.7
Cash flow/total sales, t-2	8.0	7.9	13.8	-99.1	94.1
Duration of the project in months	14.4	13.8	3.0	3.0	28.0
	estimation sample of the production function (# of obs.: 1,527, # of firms: 581)				
Ratio of R&D subsidies to total sales, t-2	2.0	0.4	6.8	0.0	193.8
R&D (minus R&D subsidies) to sales, t-2	10.9	4.8	16.4	0.0	99.5
Change in output per worker, t, t-2	5.8	4.7	17.8	-65.2	137.8

Notes: Variables are expressed as a percentage of 100.
Source: Linked FFF project-firm database, own calculations.

Table 7: Summary statistics (dummy variables, percentage share of total)

Food, beverages, textiles and clothing (15-19)	6.4	year dummy 1996	11.9
Wood, paper, publishing (20-22)	5.3	year dummy 1997	14.1
Chemicals, rubber (23-25)	12.4	year dummy 1998	16.5
Non-metallic mineral products (26)	4.1	year dummy 1999	16.5
Metals, fabricated metal products (27-28)	9.5	year dummy 2000	17.0
Machinery (29)	21.0	year dummy 2001	15.8
Electrical machinery, instruments (30-33)	19.5	year dummy 2002	8.3
Transport equipment (34-35)	6.3	*other indicators*	
Other manufacturing (36)	1.4	company with limited liability (GmbH)	98.6
Computer services (72)	12.0	Enterprises founded in last five years	16.1
Firm size distribution in terms of employees, L		founded in last five yrs * year dummy 1996	1.9
L <10 employees	12.3	founded in last five yrs * year dummy 1997	2.5
10 ≤ L<25 employees	13.9	founded in last five yrs * year dummy 1998	2.6
25 ≤ L<50 employees	9.6	founded in last five yrs * year dummy 1999	2.6
50 ≤ L<100 employees	11.5	founded in last five yrs * year dummy 2000	2.4
100 ≤ L <250 employees	19.7	founded in last five yrs * year dummy 2001	2.7
250 ≤ L <500 employees	15.1	founded in last five yrs * year dummy 2002	1.5
L ≥ 500 employees	18.0		

Notes: Number of observations is 2,483, number of firms is 909. Variables are expressed as a percentage of 100.
Source: Linked FFF project-firm database, own calculations.

Table 6 reports averages and standard deviations of key variables used for the estimation. Note that for the period we examine, the growth of output per worker is quite high at 5.8 percent per year on average. The mean cash flow to total sales ratio is about 8 percent.

Table 7 contains information on the firms' industry affiliation, size classes, year dummy variables, a dummy variable indicating whether the firm is less than 6 years old and interaction effects between year dummies and the dummy variable for newly founded firms. About 12.5 percent of the 2,483 observed firms have less than 10 employees. About 15 and 18 percent, respectively, belonged to the large firm size class with 250-499 and more than 500 employees. With respect to the industry affiliation, the sample of firms doing R&D is broken down into eleven sub sectors. The share of firms is the highest in machinery (21 percent), followed by electrical machinery and instruments (19.5 percent), chemicals (12.4 percent) and the software industry (12 percent). Furthermore, 16 percent of the firms are five or less years old.

In order to get a first insight into the relationship between the change in labour productivity in the following years and the initial R&D subsidy sales ratio we provide a scatterplot with a regression line. We find a significantly positive relationship between the between lagged R&D subsidy ratio the growth rate of labour productivity in the following years (see Graph 3).

4 Empirical results

4.1 Factors explaining the R&D subsidy ratio

In order to quantify the main factors behind the amount of R&D subsidies, the logarithm of the R&D subsidy ratio is regressed against potential explanatory variables discussed above. As noted earlier, the sample includes only firms receiving R&D subsidies. Table 8 reports the results for the Hausman-Taylor instrumental variable estimator as well as the standard fixed effects model. We also report results of a different specification with interaction terms between year dummies and the indicator on newly founded firms.

The most important factors explaining the logarithm of R&D subsidy ratio are firm size, the log current R&D intensity, firm age and the growth rate of total turnover in the past two years. The ratio of R&D expenditures to total turnover is significantly negative suggesting that firms with a high R&D intensity have a lower R&D subsidy ratio. Note that this is consistent with the fund's objectives. Furthermore, we find that the R&D subsidy ratio continuously decreases with firm size, which probably reflects another one of the public agency’s goals. For instance, the R&D subsidy ratio is 37 percent lower for firms with 25-49 employees than for firms with 0-9 or 10-24 employees. The difference between small firms and medium-sized firms with 50-99 employees is 53 percent. The differences for the other size classes (100-249 employees, 250-499 employees and 500 and more employees) are 78, 82, and 91 percent, respectively[3]. Firms founded in the last five years have a significantly higher R&D subsidy ratio of about 31 percent on average compared to firms that are 6 or more years old[4]. This is also consistent with the funding agency's strategy. The interaction variables between year and the indicator on firm age show that the subsidy effect of newly founded enterprises is the highest in 2000 and appears to be declining in 2001 and 2002. The significantly negative coefficient on the change in turnover indicates that firms with a higher sales growth rate during the past two years have a lower current R&D subsidy ratio. This means that fast-growing firms get lower subsidies than slowly growing firms. Surprisingly, the lagged ratio of cash flow to turnover is not a major determinant of the R&D subsidy ratio. The legal form is not significant either. Firms in electrical machinery, instruments and software tend to have a significantly higher R&D subsidy ratio. In contrast, we find lower R&D subsidy ratios in chemicals.

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[3] The percentage effect is calculated as exp(coefficient)-1.

[4] The percentage effect is calculated as exp(0.27)-1.

Table 8: Determinants of the ratio of R&D subsidies to total R&D: Panel estimates

	Hausman-Taylor IV estimates				Fixed effects estimates			
	(1)		(2)		(3)		(4)	
	coeff.	t-value	coeff.	t-value	coeff.	t-value	coeff.	t-value
Log R&D to sales ratio, %	-0.48**	-10.31	-0.45**	-10.61	-0.49**	-10.70	-0.50**	-10.87
Change in sales, t, t-2, %	-0.37**	-4.11	-0.34**	-4.07	-0.38**	-4.33	-0.40**	-4.47
Cash flow to sales ratio, t-2, %	0.10	0.51	0.08	0.47	0.07	0.37	0.11	0.58
Founded in the last five years	0.27**	3.56			0.20*	1.89		
Log project duration in months	2.94**	3.04	1.89**	2.11				
Company with limited liability (GMBH)	0.86*	1.68	0.22	0.49				
Year dummy 1996 (ref. 2002)	-0.07	-0.79	-0.06	-0.77	-0.05	-0.55	-0.07	-0.81
Year dummy 1997	-0.02	-0.26	-0.06	-0.70	0.00	-0.05	-0.07	-0.85
Year dummy 1998	-0.02	-0.21	-0.03	-0.39	-0.02	-0.28	-0.07	-0.84
Year dummy 1999	0.05	0.60	0.04	0.52	0.05	0.59	0.01	0.15
Year dummy 2000	0.07	0.98	0.04	0.59	0.06	0.75	0.01	0.09
Year dummy 2001	0.07	0.97	0.04	0.55	0.05	0.62	0.02	0.20
Founded in the last five yrs * yr 96			0.33**	2.45			0.20	1.09
Founded in the last five yrs * yr 97			0.26*	1.90			-0.04	-0.17
Founded in the last five yrs * yr 98			0.17	0.88			-0.43	-1.54
Founded in the last five yrs * yr 99			0.12	0.88			0.10	0.61
Founded in the last five yrs * yr 00			0.39**	3.07			0.39**	2.60
Founded in the last five yrs * yr 01			0.24*	1.95			0.26*	1.66
Founded in the last five yrs * yr 02			0.23*	1.79			0.14	0.86
Industry, size dummies								
Food & bev., textiles and clothing	0.09	0.55	0.04	0.26				
Wood, paper, publishing	0.13	0.72	0.14	0.78				
Chemicals, rubber	-0.25*	-1.71	-0.25*	-1.77				
Non-metallic mineral products	0.27	1.16	0.11	0.48				
Metals, fabricated metal products	-0.11	-0.73	-0.14	-0.93				
Electrical machinery, instruments	0.33**	2.40	0.22*	1.70				
Transport equipment	0.26	1.32	0.16	0.82				
Other manufacturing	0.44	1.28	0.28	0.82				
Computer services	0.65**	3.33	0.44**	2.38				
Other industries	-0.16	-0.64	-0.14	-0.57				
10 -24 employees	-0.12	-0.80	-0.22	-1.58				
25-49 employees	-0.46**	-2.71	-0.58**	-3.58				
50-99 employees	-0.75**	-4.55	-0.83**	-5.11				
100-249 employees	-1.52**	-9.84	-1.53**	-10.11				
250-499 employees	-1.74**	-10.31	-1.76**	-10.63				
> 500 employees	-2.43**	-14.68	-2.47**	-15.17				
Constant	-11.63**	-4.27	-8.03**	-3.21	-3.96**	-27.24	-3.94**	-26.92

Notes: Dependent variable is log R&D subsidies to total firms R&D expenditures. Number of observations is 2,483. The references for industry and size dummies are machinery and 0 -9 employees, respectively. * denotes significance at the 10% level; ** denotes significance at the 5% level.

4.2 Productivity effects of the amount of R&D subsidies

As stated in section two, we investigate the productivity effects of public R&D in a production function framework. The change in labor productivity is a function of the logarithms of the ratio of privately and publicly financed R&D to sales, ten sector dummies, six size dummies, five year dummies, dummy variables for firms founded during the last five years and legal status.

Results for Hausman-Taylor IV estimator and the standard fixed effects model are reported in Table 9. Note that both R&D variables are allowed to be correlated with the individual effects. The results indicate that both privately financed R&D and publicly financed R&D make significant contributions to future labor productivity growth as indicated by the elasticities of 0.11 and 0.05. Moreover, we find that newly founded firms have higher labor productivity growth than firms with six or more years.

The magnitude of the productivity effect of R&D subsidies is quite large given the median R&D subsidy sales ratio of 0.4 %. To give an example of the magnitude, we consider a ten percent increase in the R&D subsidy ratio. This would lead to an increase in the growth rate of turnover of about 0.5 percentage points per year given the elasticity of 0.05. Given the elasticities of the production function, one can also calculate how much of the observed change in output per worker can be attributed to the effects of publicly and privately funded R&D. Combined, both funding sources of R&D account for 24 percent of the change in output per worker per year[5]. However, the contribution of privately funded R&D is less than 2 percent, while the contribution of privately funded R&D is 22 percent.

Furthermore, for a number of reasons the large productivity effects of privately funded R&D should be regarded with caution. As noted by Hall and Mairesse (1995), the use of flow rather than stock data tends to overestimate the productivity effects. Furthermore, the relative large productivity effects may partly be due to the omission of capital. Thus, the productivity effects seem to be the upper limit. Furthermore, the sample is reduced heavily due to the inclusion of two-year lags and may be no longer representative. Another concern arises out of the use of gross sales rather than value added as a proxy for output. However, in one of the few studies that used data on both gross sales and value added, Hall and Mairesse (1995) found only small differences in the estimated productivity effects based on value added rather than sales.

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[5] Elasticities are multiplied by the average sample means displayed in Table 6 and are then divided by the average change in output per worker.

Table 9: Change in labor productivity and R&D subsidy ratio: Panel estimates

	Hausman Taylor IV estimates		Fixed effects estimates	
	coeff.	t-value	coeff.	t-value
Log R&D subsidies to sales ratio, t-2, %	0.05**	6.24	0.05**	6.46
Log adj. R&D to sales rato, t-2, %	0.11**	7.85	0.11**	8.21
Founded in the last five years	0.13**	3.32	0.11**	2.74
Company with limited liability	1.90	1.60		
Year dummy 1998 (ref. 1997)	-0.02	-0.77	-0.01	-0.63
Year dummy 1999	-0.02	-1.06	-0.02	-0.92
Year dummy 2000	0.00	0.20	0.01	0.56
Year dummy 2001	-0.02	-0.85	-0.02	-1.13
Year dummy 2002	-0.09**	-3.68	-0.10**	-4.06
Food, beverages, textiles and clothing[1]	0.11	1.64		
Wood, paper, publishing	0.18*	1.65		
Chemicals, rubber	0.04	0.56		
Non-metallic mineral products	0.17	1.07		
Metals, fabricated metal products	0.08	1.39		
Electrical machinery, instruments	-0.10**	-2.18		
Transport equipment	0.00	0.02		
Other manufacturing	0.10	0.88		
Computer services	-0.20**	-3.24		
other industries	0.03	0.31		
10 -24 employees[2]	0.04	0.75		
25-49 employees	0.09	1.32		
50-99 employees	0.09	1.35		
100-249 employees	0.03	0.43		
250-499 employees	0.06	0.82		
> 500 employees	0.05	0.69		
Constant	-1.14	-0.97	0.77**	12.55

Notes: The dependent variable is average annual change in labor productivity between time t and t-2. Number of observations is 1,527 and the number of firms is 581. [1],[2] The references for industry and size dummies are machinery and 0-9 employees, respectively. * denotes significance at the 10% level; ** denotes significance at the 5% level.

5 Conclusions

This paper provides first systematic evidence on the determinants and productivity effects of the amount of R&D subsidies. The empirical evidence comes from a unique panel data provided by the *Forschungsförderungsfond*. In the first part of the paper, we investigated the determinants of R&D subsidies if firms had received subsidies. R&D subsidies are measured as grants plus the net present value of loans. The empirical research indicates that the R&D subsidy ratio is significantly negatively related to both firm size and the R&D intensity, but not to the cash flow ratio in the past. Furthermore, we find that newly founded enterprises as well as firms in electrical machinery and computer services have a significantly higher ratio of R&D subsidies to total R&D. In contrast, fast output growth in the past does lead to a higher R&D subsidy ratio. Overall, the results are consistent with the fund's strategy. The second part of the study measures the impact of R&D subsidies on the growth of output per worker from 1997 to 2002. Using a Cobb-Douglas function to assess the productivity of input factors, we find that the amount of R&D subsidies as well as privately financed R&D expenditures (both expressed as a percentage of sales) have a significant and positive effect on output growth in the following years. Furthermore, the impact of R&D subsidies is relatively large considering the amount of subsidies spent. A ten percent increase in the R&D subsidy sales ratio would lead to a rise in the growth rate of output per worker of about 0.5 percentage points in the next two years. Furthermore, we find that the productivity effects of publicly funded R&D were much lower than those estimated for privately funded R&D. In future work, we will investigate the determinants of the probability to receive R&D subsidies.

6 References

Arvanitis, S. (2003), Microeconometric Approaches to the Evaluation of RTD Policies: A Non-Technical Summary of the State of the Art, in: W. Polt and J. Rojo (eds.), Handbook on the Evaluation of Research and Technology Policy: Concepts,Tools and Indicators, Edward Elgar, Cheltenham (erscheint demnächst).

Bassanini, A. and S. Scarpetta (2001), The Driving Forces of Economic Growth: Panel Data Evidence for the OECD Countries, OECD Economic Studies 33, 9-56.

Bönte W. (2003), Does federally financed business R&D matter for US productivity growth?, Applied economics, 35 15, 1619-1625.

David, P. A., B. H. Hall, and A. A. Toole (2000), Is Public R&D a Complement or Substitute for Private R&D? A Review of Econometric Evidence, Research Policy 29, 497-529.

Griliches, Z. (1979), Issues in Assessing the Contribution of Research and Development to Productivity Growth, Bell Journal of Economics 10, 1.

Griliches Z. (1998), R&D and Productivity: The Econometric Evidence, Chicago, IL: The University of Chicago Press.

Guellec D. and B. VanPottelsberghe DeLaPotterie (2001), R&D and productivity growth: panel data analysis of 16 OECD countries, OECD Economic Studies 2, 103-126.

Hall, B. H. and J. Mairesse (1995), Exploring the Relationship between R&D and Productivity in French Manufacturing Firms, Journal of Econometrics 65, 263-293.

Hausman J.A. and W.E Taylor (1981), Panel data and unobservable individual effects, Econometrica, 49,1317-1398.

Lichtenberg, F, R. and D. Siegel (1991), The Impact of R&D Investment on Productivity – New Evidence Using Linked R&D-LRD Data, Economic Inquiry 29, 203-222.

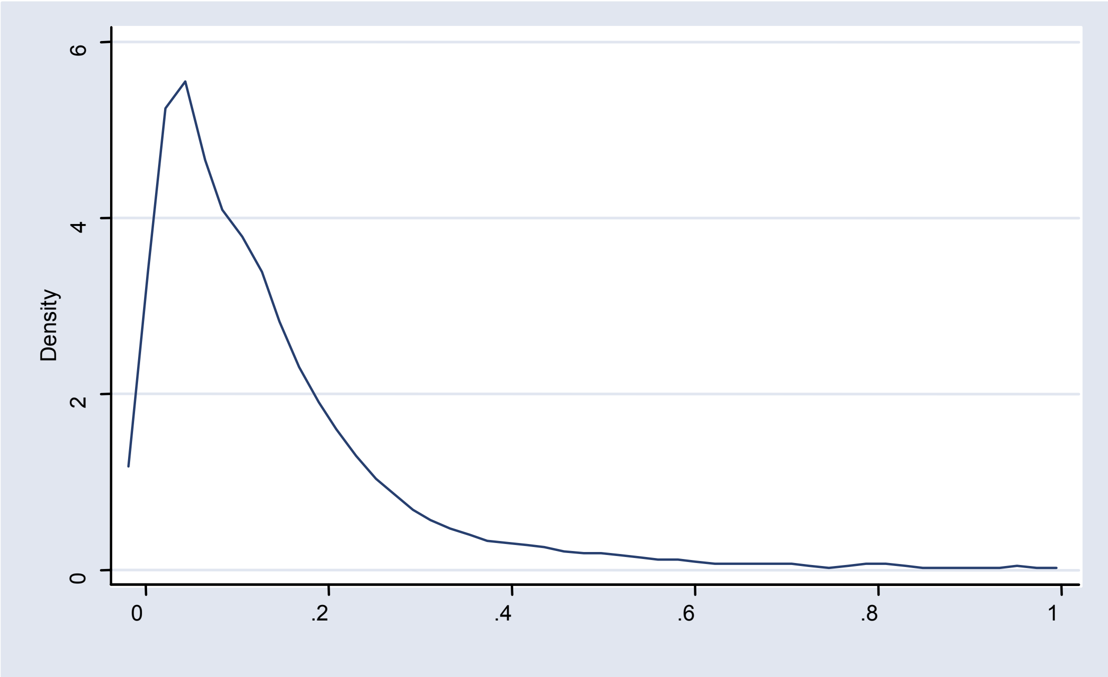
Nadiri, M. I. (1993), Innovations and Technological Spillovers, NBER Working Paper No. 4423.

Niininen, P. (2000), Effects of Publicly and Privately Financed R&D on Total Factor Productivity Growth. Finnish Economic Papers vol. 13/2000, no. 1, pp. 56-68.

OECD (2001), The Sources of Economic Growth in OECD Countries, Paris: OECD.

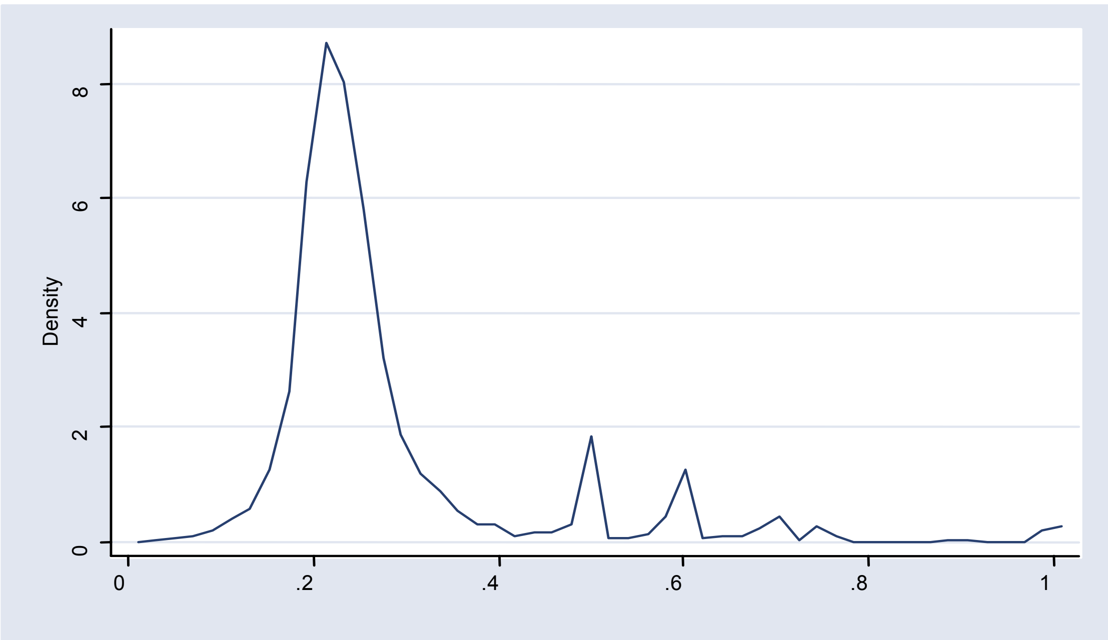
Appendix:

Graph 1: Ratio of R&D subsidies to total R&D



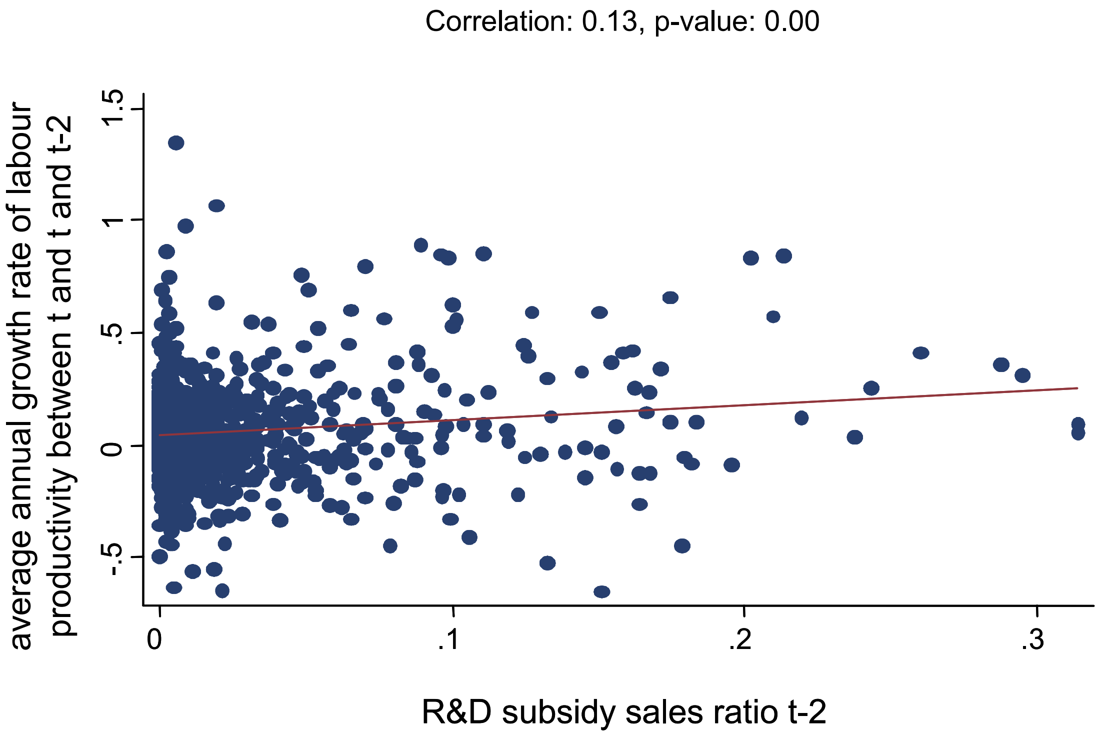
Notes: # of obs.: 2,461. Firms with an R&D subsidy ratio above 1 are excluded. Univariate Kernel density estimates.

Graph 2: Ratio of R&D subsidies to total R&D project costs



Notes: # of obs.: 7,524. Univariate Kernel density estimates.

Graph 3: Correlation between the growth rate of labour productivity in the following two years and the initial R&D subsidy-sales ratio



Notes: # of obs. 1521. Six firms with a R&D subsidy sales ratio above 0.4 are excluded.

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