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IMPACT OF PUBLIC R&D FINANCING ON PRIVATE R&D – DOES FINANCIAL CONSTRAINT MATTER?

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ABSTRACT: This study analyses how public R&D financing impacts companies. Our main goal is to study whether public and private R&D financing are substitutes or complements, and whether this impact differs between financially constrained and unconstrained companies. Our company-level panel data cover the period from 1996 to 2002. The statistical method employed in the research takes into account the possibility that receiving public support may be an endogenous factor. Our results suggest that public R&D financing does not crowd out privately financed R&D. Instead, receiving a positive decision to obtain public R&D funds increases privately financed R&D. Furthermore, our results suggest that this additionality effect is bigger in large firms than in small firms.

KEY WORDS: Public finance, R&D, research and development, substitute, financial constraint.

ALI-YRKKÖ, Jyrki. **JULKISEN T&K-RAHOITUKSEN VAIKUTUS YRITYSRAHOITTEISEEN T&K-TOIMINTAAN – ONKO RAHOITUSRAJOITTEELLA MERKITYSTÄ?** Helsinki, ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2004, 22 s. (Keskusteluaiheita, Discussion Papers; ISSN 0781-6847; no. 943).

TIIVISTELMÄ: Tässä tutkimuksessa tarkastellaan julkisen tutkimus- ja tuotekehitysrahoituksen vaikutuksia yrityksiin ja millainen merkitys rahoitusrajoitteella on näihin vaikutuksiin. Tutkimuksen tavoitteena on siis selvittää lisääkö vai vähentääkö julkinen t&k-rahoitus yrityksen omarahoitteista t&k-toimintaa. Lisäksi selvitetään, onko tämä vaikutus erilainen rahoitusrajoitteisilla ja ei-rahoitusrajoitteisilla yrityksillä. Aineistona käytetään yritystason paneliaineistoa vuosilta 1996-2002. Tutkimusmenetelmässä otetaan huomioon, että julkisen t&k-rahoituksen saaminen on endogeeninen tekijä. Tutkimuksen mukaan julkinen t&k-rahoitus ei syrjäytä yritysrahoitteista t&k:ta vaan pikemminkin täydentää sitä. Tutkimuksen keskeisin tulos on, että julkisen t&k-rahoituksen lisäysvaikutus on suurempi suurilla yrityksillä kuin pienillä yrityksillä. Sen sijaan lisäysvaikutus on samansuuruinen sekä hyvän että huonon koronmaksukyvyn omaavilla yrityksillä

AVAINSANAT: julkinen rahoitus, t&k, tutkimus ja tuotekehitys, korvaavuus, rahoitusrajoite

1 INTRODUCTION

The creation of new knowledge is often seen to play an important role as a source of economic growth (Romer 1990). Furthermore, due to the widely accepted view, the social return of R&D is greater than the private return, thus unsurprisingly the public sector in almost all industrial countries tries to foster technological change by using a variety of instruments, such as R&D loans and subsidies, national R&D laboratories and tax cuts. This study focuses on the issue of whether public R&D funding complements or substitutes private R&D and whether this impact differs between financially constrained and unconstrained companies.

Two most often mentioned rationales for government support are both based on the market imperfections leading to underinvestment in private R&D. First, the output of R&D is knowledge or know-how that usually cannot be kept secret. Due to the diffusion of the results of R&D uncontrolled by the investor, the social return to R&D exceeds its private return (e.g. Arrow 1962). Another rationale for government funding relies on capital market imperfections such as informational asymmetries. Due to these imperfections, it may be costly or difficult to use external financing for R&D investment. Hence, in some cases the capital market restrains or blocks the innovativeness of companies.

Even though public R&D funding has widely accepted theoretical roots, the question arises whether R&D policy really stimulates the total R&D activity of the private sector. Public R&D funding increases the total R&D expenditure only if the grants cause firms to undertake projects that would otherwise be unrealised or smaller. Otherwise, subsidised firms use public funding as a substitute source of financing. In sum, it is an open empirical question whether public R&D funding really complements private R&D and thus increases the total R&D expenditure. There exists an extensive empirical literature focusing on this issue (for survey, see David, Hall & Toole 2000). The majority of the studies have reported complementary effects but substitute effects have also been found. However, recent papers (see Klette, Moen & Griliches 2000 and Wallsten 2000) have questioned the results of previous studies. According to the criticism, the majority of the statistical analyses ignores the possibility that grants are endogenous. In other words, public and private R&D expenditure are correlated because companies with an increase in private spending receive subsidies not because subsidies cause private R&D to increase.

The focus of this study is to empirically examine the impact of public R&D funding on private R&D. We pay special attention to capital market imperfections by examining what kind of effect financial constraint has on the relationship between public and private funded R&D. Due to the intangible and uncertain nature of R&D investment, external finance opportunities for inventive activities are potentially restrictive. This argument suggests that firms use primarily internal finance to fund their R&D investment. It also implies that public R&D subsidies and loans might be attractive sources of finance. If a firm suffers financial constraint to fund its R&D projects, it is less probable that this firm uses public R&D funding only as a substitute source of financing.

Contrary to most previous studies, our unique panel data enables us to distinguish companies that have applied for and obtained public funding, applied for and obtained only part of what they applied for, applied for and been rejected, and firms that have not even applied for funding.

The rest of the paper proceeds as follows. Section 2 includes relevant theoretical and empirical literature concerning the relationship between public and private R&D funding. Section 3 describes the data. Section 4 gives an empirical analysis and results. Section 5 contains a summary and concluding remarks.

2 LITERATURE REVIEW

The main argument for public R&D funding is that the social return of R&D is higher than the private return, and thus from the perspective of the national economy firms underinvest in R&D. Underinvestment occurs because imperfect capital markets prevent companies from investing in all R&D projects with positive NPV (net present value), or because the results of R&D spill over to other organisations.

The public R&D funding may impact private R&D through various direct and indirect channels. According to Lach (2000), at least three impact channels can be identified. *First*, public R&D funding can be seen as lowering the private cost of R&D project and making an unprofitable project profitable. *Second,* if R&D infrastructure, equipment or other R&D facilities are bought with an R&D subsidy, then the fixed costs of other R&D projects are lowered. *Third,* in some cases know-how or knowledge developed in subsidised projects diffuse to other projects improving their probability of success. Therefore, public R&D funding potentially increases the current and future R&D activities of companies.

Even though public R&D funding has several potential positive impacts, its real effect depends heavily on whether public R&D funding actually augments the total R&D expenditure of firms. If public funding replaces private R&D, then the public R&D policy is inappropriate. A number of empirical studies applying various degrees of data aggregation have addressed this issue. While some studies have used macro-level data (e.g. Levy 1990, Guellec & van Pottelsberghe 2000), others have utilised plant-level (e.g. Lichtenberg 1984) or firm-level datasets. Due to the limited possibilities of macroeconometric models to take into account heterogeneities between firms, we focus on empirical studies where micro-level data has been utilised.

Irwin & Klenow (1995) evaluate the Sematech programme by the US government, which was a research consortium consisting of large US semiconductor companies. Findings of the study suggest that public funding decreases companies’ R&D expenditure that might be the result of eliminating overlapping R&D efforts. Contrary to the Sematech programme, the Small Business Innovation Research (SBIR) programme was directed to small companies in order to stimulate their technological innovations. The results by Lerner (1999) indicate that the subsidised firms in the areas with a high degree of venture-capital activity increase employment and sales more rapidly than other firms do. The study by Branstetter & Sakakibara (1998) focuses on the performance of heavily subsidised Japanese research consortia. The results suggest that frequent participation in R&D consortia has a positive impact on firms' R&D expenditure and research productivity. The evidence from Norway (Klette & Moen 1998) suggests that public R&D funding does not replace private R&D efforts, and that subsidies do not increase their privately financed R&D either. Moreover, Klette & Moen find that subsidies stimulate R&D expenditure particularly by small and large firms as opposed to medium size firms. The recent literature (see e.g. Wallsten 2000, Klette, Moen & Griliches 2000) has questioned the results by numerous previous studies with an argument that only a few studies have explicitly taken into account the potential endogeneity of public funding.

Wallsten (2000) examines the same SBIR programme as Lerner (1999) but points out the importance of controlling for the endogeneity of grants. Using the instrumental variable approach Wallsten reports an (almost) complete crowding out effect. Busom (1999) analyses 154 Spanish firms of which roughly 50 per cent had received public subsidies. Due to the data limitations, Busom is unable to make an exact estimate of crowding out or complementary. However, her endogeneity controlled analyses suggest that 41 companies spend more on R&D than they would have without the subsidy and 29 firms would have spent at least as much as in the case of no subsidy. Czarnitzki and Fier (2002) examine 210 German firms operating in the service sector. Applying a non-parametric matching approach, they find evidence that public funding has fostered the private innovation efforts of firms. By analysing more than 1,600 French firms Duguet (2003) concludes that no significant substitution effect appears. Similar results have also been reported by Almus & Czarnitzki (2002), Hussinger (2003) and Gonzalez, Jaumandreu & Pazo (2004). The evidence from Israel (Lach 2000) suggests that subsidies do not completely crowd out private R&D. Lehto (2000) analyses the effect of public funding on the total R&D spending of Finnish plants. By taking into account the potential endogeneity of public funding, he concludes that publicly funded R&D does not crowd out private R&D. Niininen & Toivanen (2000) apply a simultaneous equations approach and find evidence that Finnish firms with moderate cash flow add their own R&D expenditure as a response to a subsidy but when the cash flow is big enough, this relationship disappears.

This short survey demonstrates that existing empirical studies do not allow for a definitive conclusion regarding the sign of the relationships between publicly and privately funded R&D. Hence, it is still an open empirical question whether public R&D funding increases or decreases privately funded R&D. In order to answer this question, more research with more comprehensive datasets is needed.

To our knowledge, no existing study in this field has focused on the role or impact of financial constraint (see however Niininen & Toivanen 2000). Our purpose is to extend the public R&D funding literature by following the fixed investment and financial constraint literature (see e.g. Fazzari, Hubbard & Petersen 1988) and by studying the relationship between financial constraint and the impact of public R&D funding.

3 DESCRIPTION OF THE DATA

Our data is a unique company-level dataset consisting of Finnish companies operating in the Technology industry. The companies within the Technology industry operate mainly in the electronics and electro-technical, mechanical engineering and metals industries.

Three separate data sources have been merged making it possible to take into account a large set of explanatory variables. The R&D dataset is based on an investment survey conducted by The Confederation of Finnish Industry and Employers. Into this data, we have added the information of companies' financial statements provided by Balance Consulting and *Talouselämä* magazine. Finally, the data concerning the public R&D funding from the Finnish Technology Agency (Tekes) has been merged together with the two datasets mentioned.

In contrast to many previous studies, we are able to distinguish firms that 1) have applied for and obtained public funding, b) applied for and obtained only part of the amount they applied for, c) applied for and been rejected, d) and firms that have not even applied for public funding. Thus our dataset allows us to distinguish between firms that applied for funding but were denied and those that did not even apply.

With respect to the public funding variable, the choice between the subsidy *granted* and *actually paid* had to be made. While both alternatives include advantages and disadvantages, we follow the study by Meeusen & Janssens (2001) and use subsidies *granted*[1].

Our unbalanced database consists of 441 companies with various time series (Table 3.1)[2].

Table 3.1. The structure of the panel data by observations per company

Number of annual observations	3	4	5	6	7
Number of companies	119	109	65	73	75
Share of the companies, %	27.0 %	24.7 %	14.7 %	16.6 %	17.0 %

[1] In order to keep it simple, in the rest of the paper we have used public funding and public funding granted as synonyms.

[2] To control the potential bias caused by outliers, in terms of employment 5% of the biggest firms are excluded from the sample.

Companies with single or two observations available are excluded from the sample, thus our data includes only those companies with three or more annual observations (Table 3.1). As can be seen from the table, we have at least four observations for more than 90% of the companies. The next table (3.2) describes the data.

Table 3.2. Descriptive statistics (EUR. mill.)

	Count	Mean	Median	Standard Deviation	Minimum	Maximum
Total R&D	1640	1.00	0.35	1.63	0.001	15.59
Private R&D	1640	0.92	0.30	1.56	0	15.59
Public funding (paid)	1640	0.086	0.015	0.195	0	2.04
Net Sales, EUR mill.	1640	42.79	10.78	112.96	0.15	1272.6
Operating profit	1640	4.25	0.93	13.34	-67.67	261.35
Long term debt	1640	4.62	0.94	13.82	0	331.75
(Long term debt)^2	1640	212.27	0.88	2832.21	0	110057.3
R&D intensity	1640	0.07	0.028	0.17	0.00006	2.66
Operating profit,%	1640	0.086	0.101	0.23	-5.5	2.03

Our data consists of a pooled sample of companies over the seven-year period from 1996 to 2002. In Table 3.3 we report the annual breakdown of our sample concerning the number and the share of companies that have received public funding.

Table 3.3. R&D and public funding

	Number of firms	% of firms receiving subsidy	Mean (Subsidy/Total R&D) ratio for firms with subsidy>0
1996	198	16.7	0.16
1997	311	36.7	0.23
1998	363	51.2	0.28
1999	361	54.5	0.33
2000	357	55.5	0.29
2001	278	53.6	0.30
2002	213	52.6	0.31
All years	441	45.8	0.27

On average, nearly half of the companies in our data have received public funding. This share has remained rather stable during the period 1998-2002. Among the supported companies, the average share of public funding of the total R&D expenditure is 27%.

Even though the most recent three years indicate a slightly increasing share of public funding, it is uncertain whether this change is permanent. Thus, while this share has varied during the period 1996-2002, no clear trend can be observed.

The existing literature suggests that R&D investments suffer from imperfections in the capital market (see e.g. Hall 1992, Hao & Jaffe 1993, Himmelberg and Petersen 1994, Hyytinen & Toivanen 2002). Due to these imperfections, some firms face financial constraint implying that in these firms the role of public R&D funding is potentially different than in some other firms. We closely follow the fixed investment literature and categorise the firms employing different criteria to identify firms that are likely to face either higher costs of external finance or difficulty in getting external finance. Firm size and indebtedness are used as *a priori* criteria to classify firms that potentially suffer financial constraints and those who do not. Out of our three classifications two are based on firm size and one is based on indebtedness. Due to capital market imperfections, such as informational asymmetries (see e.g. Greenwald, Stiglitz & Weiss 1984), small firms are more likely to face financial constraints. Firms with a high level of debt, in turn, create a greater probability of bankruptcy that can raise the cost of borrowing or negatively affect the availability of credit. To classify firms, we use the following criteria. In classification 1, 10% of the sample has been classified as small firms (in terms of employment) and in classification 2, 25% are small. In classification 3, a firm is considered an indebted firm (in year *t*) if its interest rate expenditure exceeds its operating profit. Descriptive statistics by classifications are shown in Table 3.4.

Table 3.4 reveals some interesting differences between the groups. According to classifications 1 and 2, small firms seem to invest more on R&D (relative to net sales) than larger firms. Similarly, indebted firms invest more on R&D than the reference group. These differences are statistically significant at the better than 1% level. The table also indicates that small firms obtain more public R&D funding (relative to the total R&D) than large firms. Correspondingly, there seems to be a similar difference between indebted and non-indebted firms. However without more rigorous analysis, it is not easy to reach any conclusions about the relationship between R&D, public R&D funding and financial constraint.

Table 3.4. Descriptive statistics (means and two-tailed *t*-tests for means) by firm size and indebtedness

	Classification 1 10% of firms are classified as small firms		**Classification 2** 25% of firms are classified as small firms		**Classification 3** Indebtedness[3]	
	Small	Large	Small	Large	Indebted	Non-indebted
Total R&D, EUR mill.	0.18	1.06***	0.24	1.2***	1.13	1.00
Private R&D, EUR mill.	0.146	0.974***	0.20	1.10***	0.92	0.98
Public funding (granted), EUR mill.	0.06	0.13**	0.07	0.13***	0.22	0.11***
Public funding (paid), EUR mill.	0.04	0.09***	0.05	0.10***	0.15	0.08***
Net Sales, EUR mill.	1.76	45.83***	2.37	53.25***	27.79	44.32
Profit, EUR mill.	0.162	4.55***	0.24	5.28***	-2.29	4.75***
Long term debt, EUR mill.	2.59	4.77	1.22	5.50***	6.16	4.58
(Long term debt)^2, EUR mill.	130.28	218.34	44.22	255.73	229.17	214.46
Total R&D/Net sales	0.24	0.06***	0.18	0.04***	0.27	0.06***
Public funding (paid) /Total R&D	0.26	0.15***	0.28	0.13***	0.28	0.15***
Profit, %	-0.06	0.1***	0.03	0.10***	-0.29	0.11***

*** = significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

[3] We define a firm as indebted if its interest rate expenditure exceeds its operating profit.

4 EMPIRICAL ANALYSIS

Our main interest is to examine whether the public R&D funding crowds out or stimulates privately financed R&D. To analyse the impact we use privately financed R&D as a dependent variable. We follow the existing literature and add several control variables to our regressions. To capture the size effects, net sales is added to the model (see e.g. Klette & Moen 1998). Net sales might also serve as a proxy for expected market demand (see Swenson 1992). As described in the literature review, both theoretical and previous empirical studies suggest that financial factors affect R&D investment. To control the effect of financial variables, profit or cash flow (Toivanen & Niininen 2000, Klette & Moen 1998), debt (Toivanen & Niininen 2000) and its squared term (see Hall 1991) have been included in the regression equation.

Our baseline specification for the estimation is:

$$\begin{aligned} RD\_PRIV_{it} &= \alpha + \beta_1 PUBLIC_{it} + \beta_2 Y_{i,t-1} + \\ &\quad \beta_3 \Pi_{i,t-1} + \beta_4 B_{i,t-1} + \beta_5 B^2_{i,t-1} + v_{it}\,, \end{aligned} \tag{1}$$

where subscripts *i* and *t* are the firm and time indexes, respectively, RD_PRIV_{it} is the firm's private funded R&D, $PUBLIC_{it}$ is the amount of public R&D funding, $Y_{i,t-1}$ is sales, $\Pi_{i,t-1}$ is profit, $B_{i,t-1}$ is long-term debt, $B^2_{i,t-1}$ is squared long-term debt, and v_{it} is an error term.

Our estimation strategy proceeds as follows. First, we estimate the model (1) by using the ordinary least-squares (OLS) method. This method, however, ignores the possibility that public funding is an endogenous variable. To control the potential endogeneity, the instrument variable (IV) method is used. An appropriate instrument correlates with the endogenous public funding variable but is not correlated with unobserved factors that have an impact on the dependent variable. According to Lichtenberg (1988) and Wallsten (2000) one ideal instrument is the value of funds that are potentially awardable to firm *i* in year *t*.

Following Wallsten (2000), for firms that have applied for public funding, we define the instrument, $BUDGET_{it}$, as follows:

$$BUDGET_{it} = AWARD_{at} \times \left(TEKESBUDGET_{at}\right), \tag{2}$$

where subscripts *i*, *a*, and *t* refers firm, industry and year, respectively[4]. The dummy variable $AWARD_{at}$ gets a value 1 if the company *i* operating in industry *a* obtains public funding in the year. The variable $TEKESBUDGET_{at}$ is Tekes's budget for industry *a* in year *t*. Similarly, for a firm that applied in year *t* but was rejected, $BUDGET_{it}$ is defined as Tekes's budget for industry *a* in year *t*.

For firms that have never applied for Tekes funding, the calculation of $BUDGET_{it}$ is more complicated. In this case, we have first calculated the probability of receiving funding if the firm had applied for it. The probability has been calculated by dividing the number of firms in industry *a* that received public funding by the total number of firms that applied for it in industry *a*. Then this probability, $p(AWARD_{at})$, has been multiplied by Tekes's budget ($TEKESBUDGET_{at}$) for industry *a* in year *t* (equation 3).

$$BUDGET_{it} = p(AWARD_{at}) \times (TEKESBUDGET_{at}) \tag{3}$$

In addition to the $BUDGET_{it}$ instrument, we also use another instrument. Presumably, the amount that a company has applied for ($APPLIED_{it}$) in year *t* correlates with the amount granted to the company in the same year. However, it is hard to see why $APPLIED_{it}$ should correlate with the unobserved determinants of private R&D, conditional on the actual R&D funding received[5].

Table 4.1 reports the results of OLS and instrument variable (IV) regressions of equation (1).

4 Approximately one-third of our sample companies operate in the electronics industry and two-thirds operate in the metal and engineering industry.

5 We also estimated our models by using only *Budget* as an instrument (see Robustness tests).

Table 4.1. Effects of public funding on private R&D

	(a) Pooled OLS	(b) IV	(c) Pooled OLS	(d) IV
(Public funding)$_t$	.6169116*** (.1522762)	.8645195*** (.2493533)		
(Public funding)$_{t-1}$			1.021892*** (.1753828)	1.255741*** (.2348298)
Sales$_{t-1}$	.0034151** (.0015203)	.0032901 (.0022243)	.0032093** (.0013955)	.003091 (.0020313)
Profit$_{t-1}$	.0265798* (.0157024)	.0264262 (.0183004)	.0278918* (.0146042)	.0281044* (.0171702)
Long-term debt$_{t-1}$	.0707117*** (.0121451)	.0689176*** (.019879)	.0715736*** (.0118566)	.070748*** (.0189163)
(Long-term debt)$^2_{t-1}$	-.0007477*** (.0001695)	-.0007266*** (.0002501)	-.0007865*** (.0001704)	-.0007833*** (.0002512)
Constant	.3436345*** (.0764625)	.3190393*** (.0829895)	.3339273*** (.0751646)	.3176829*** (.0815247)
+ Year dummies				
Number of observations	1640	1640	1640	1640
F-test (joint)	19.10	11.14	22.88	15.99
P-value	<0.001	<0.001	<0.001	<0.001
R^2	0.39	0.39	0.41	0.41

NOTES: Heteroscedasticity-corrected standard errors in parentheses.
Instruments (column b): Year dummies, BUDGET(t), APPLIED(t), Sales(t-1), Profit(t-1), Long-term debt(t-1), Long-term debt^2(t-1)
Instruments (column d): Year dummies, BUDGET(t-1), APPLIED(t-1) , Sales(t-1), Profit(t-1), Long-term debt(t-1), Long-term debt^2(t-1)
F-test = tests the hypothesis that all coefficients excluding constant are zero.
*** = significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

According to the OLS estimation (columns *a* and *c* in Table 4.1), the coefficient for the public funding both in time *t* and *t-1* are positive and statistically significant at the 1% level suggesting additionality between public and privately funded R&D. Moreover, the coefficients of sales, profit and debt are also positive and statistically significant.

These estimates, however, might be biased because of the presence of endogeneity of public funding variables. To control the potential endogeneity of public funding, IV estimation was carried out (columns *b* and *d*)[6]. Again, the public funding has a positive and statistically significant impact on private R&D. Interestingly, the coefficients of public funding in IV estimations are even higher than in OLS estimations. Hence in contrast to Wallsten's study (2000), controlling endogeneity does not change the positive impact of public funding. The results of IV models (columns *b* and *d*) also suggest that debt has a statistically significant (non-linear) positive effect on private R&D. Furthermore, the results (weakly) indicate that profit increases private R&D.

In sum, all regressions in Table 4.1 indicate that public R&D funding does not crowd out privately financed R&D. Instead, they suggest that receiving a positive decision to obtain public R&D finance increases private R&D efforts.

4.1 Does liquidity constraint matter?

Next, we ask whether there are differences in the impact of public funding between financially constrained and unconstrained firms. To do this we follow the fixed investment literature and use *a priori* criteria to classify our firms into constrained and unconstrained firms as introduced in Section 3.

We employ three distinct methods to categorise our firms and include a dummy variable (=1 for financially constrained firms) denoted by *D* and its interaction with the regressors into the model

In the following regressions, the instrument variable method has been used.

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6 Our first-stage estimations (see Appendix) suggest that *Budget* and *Applied* are positively and statistically significantly correlated with *public funding*.

Table 4.2. The impact of public funding and financial constraint

	(Model 1) **Classification 1** (10% are small)		(Model 2) **Classification 2** (25% are small)		(Model 3) **Classification 3** (Indebtedness)	
	(a)	(b)	(c)	(d)	(e)	(f)
Public funding$_t$	.877897*** (.253481)		.87774*** (.260566)		.903688*** (.282489)	
Public funding$_{t-1}$		1.23882*** (.2360302)		1.25001*** (.2432595)		1.2339*** (.259894)
Sales $_{t-1}$	.0030721 (.0021823)	.002931 (.0020016)	.0030188 (.0021537)	.0028732 (.0019714)	.0029302 (.0029204)	.067783 (.373972)
Profit $_{t-1}$	.0262963 (.0180183)	.0279744* (.0169659)	.0260813 (.0177126)	.027795* (.0166681)	.0271564 (.0253968)	.0273299 (.023248)
Debt $_{t-1}$	.072421*** (.0200561)	.073321*** (.0193588)	.067719*** (.0204284)	.068864*** (.0197719)	.075242*** (.0210142)	.0757*** (.020313)
$(\text{Debt})^2_{t-1}$	-.000741*** (.0002446)	-.000793*** (.0002485)	-.000691*** (.0002466)	-.000745*** (.0002514)	-.000759*** (.0002485)	-.00081*** (.000253)
Constant	0.33908*** (.08795)	0.3423*** (.08632)	0.41896*** (.09904)	0.41273*** (0.09718)	0.50582*** (.11247)	0.4822*** (.1069)
D (Dummy)	-.179583*** (.0606504)	-.196499*** (.0545213)	-.205937*** (.0677567)	-.211552*** (.0623196)	.3235486* (.1767483)	.193458 (.14305)
D*Public funding$_t$	-.865261*** (.2750605)		-.503564*** (.3057745)		-.4652494 (.3462708)	
D*Public funding$_{t-1}$		-.5497394* (.334249)		-.7757654 (.3151758)		
D*Sales $_{t-1}$	-.0221961 (.0233341)	-.0105359 (.0167402)	-.0085331 (.0145095)	.0048367 (.0134761)	.0066264 (.0073164)	.007678 (.006625)
D*Profit $_{t-1}$	-.0323552 (.0968891)	-.0557169 (.0672118)	-.167965*** (.0560099)	-.173178*** (.0476063)	.0779936 (.0911393)	.1064701 (.08474)
D*Debt $_{t-1}$	-.132649*** (.0210677)	-.133122*** (.0204472)	-.124455*** (.0324514)	-.109479*** (.0313567)	-.0095546 (.0483977)	-.0008141 (.047535)
$D^*(\text{Debt})^2_{t-1}$	.001819*** (.0002711)	.001872*** (.000273)	.001676*** (.0004818)	.0015*** (.0004721)	-.0003322 (.0006905)	-.0003741 (.000686)
+ year dummies						
Number of obser-vations	1640	1640	1640	1640	1610	1610
F-test (joint)	44.63	56.97	24.25	33.78	10.35	12.3
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

NOTES: Heteroscedasticity-corrected standard errors in parentheses.

Instruments: Columns a, c and e: BUDGET(t), APPLIED (t), Sales(t-1), Profit(t-1), Long-term debt(t-1), Long-term debt^2(t-1), dummy*BUDGET(t), dummy*APPLIED (t), dummy*Sales(t-1), dummy* Profit(t-1), dummy* Long-term debt(t-1), dummy* Long-term debt^2 (t-1)

Columns b, d and f: BUDGET(t-1), APPLIED (t-1), Sales(t-1), Profit(t-1), Long-term debt(t-1), Long-term debt^2(t-1), dummy*BUDGET(t-1), dummy*APPLIED (t-1), dummy*Sales(t-1), dummy* Profit(t-1), dummy* Long-term debt(t-1), dummy* Long-term debt^2 (t-1)

F-test = tests the hypothesis that all coefficients excluding constant are zero.
*** = significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

The first seven coefficients relate to the sub-sample with no financial constraint, while the remaining seven coefficients estimate the difference of the coefficients on each variable across the two sub-samples.

The results of the first two columns (*a* and *b*) indicate that the additionality effect of public funding on privately funded R&D is clearly smaller in small firms (10% of firms are small) than larger firms. The statistic of the F test (not reported in the table) also suggests that the coefficient of public funding is different in small firms and large firms. However, even though the impact of $public\ funding_t$ (.877897-.865261) on private R&D is close to zero in small firms (column *a*), the result does not alter the conclusion that the impact of public funding on the total R&D of small firms is positive. When 25% of the firms are classified as small firms, the estimation echoes the result that the additionality effect of public R&D funding is bigger in large firms than in small firms (column *c*). Another interesting result is that while debt seems to increase the private R&D of large firms, it decreases the private R&D of small firms. In columns (*e*) and (*f*), firms with poor interest coverage have been defined as financially constrained. Again, the results indicate that public funding increases private R&D efforts. However, all interaction terms are statistically insignificant indicating that the coefficients are the same across the two sub-groups.

It is notable that we have used three distinct methods to find firms that potentially suffer financial constraints, and none of the estimations suggest that public R&D finance crowds out the privately funded R&D of non-financially constrained firms. Instead, the additionality effect seems to be even larger in large firms that *a priori* were classified as non-financially constrained firms. One potential explanation is that small firms are partially financially constrained. Thus, they can not afford to increase privately funded R&D as much as larger firms.

The important implication of our results is that our evidence does not support the view that the public sector should just finance those firms that suffer financial constraints.

4.2 Robustness tests

Next, we perform a number of robustness tests. To save space we do not report these tests in detail.

Robustness test 1: To test to what extent our results depend on the choice to estimate the model by using both *Budget* and *Applied* as instruments, we re-run the regressions (Tables 4.1. and 4.2) by using only *Budget* as an instrument. According to the results of these new regressions, our major result that public R&D funding increases privately funded R&D holds.

Robustness test 2:

Do our results change if we use public funding *paid* instead of public funding *granted?* To address this concern, we run a model by using public funding *paid* as a regressor. Our estimations based on the alternative public funding variable show that the coefficient of the public funding variable remains positive and statistically significant. We also re-ran the regressions in Table 4.2. Again, our result that the impact of public funding on private R&D is smaller in the case of small firms (10% are small) holds. However in contrast to the results in column *c* (Table 4.2), when 25% of the smallest firms are classified as financially constrained, we do not find a statistically significant difference between the coefficient of large firms (75%) and small ones (25%).

Robustness test 3:

To what extent are our results specific to the period on which we focus? To address this question, we ran our models separately for the period 1997-1999 and 2000-2002. The results of these new regressions show that our basic qualitative results hold: *First*, the coefficient of public R&D funding remains positive and statistically significant. *Second*, this additionality effect is stronger in larger firms than in smaller ones.

Robustness test 4:

Does the exclusion of 5% of the largest firms as outliers bias our results concerning the difference between small and large firms? To test this concern, we re-ran models by excluding only 3% of the biggest firms. Again, our result that the impact of public funding on private R&D is smaller in the case of small firms holds.

5 DISCUSSION AND CONCLUSIONS

This study analysed the impact of public R&D funding on privately financed R&D using data on Finnish firms during 1996-2002. Moreover, we studied the impact of financial constraint on the relationship between public and privately funded R&D.

The findings of this paper did not support the view that public R&D funding crowds out privately financed R&D. Instead, our analysis suggests that receiving a positive decision to obtain public R&D funds increases privately financed R&D. Our results hold after we took into account the potential endogeneity of public funding. Moreover, our regressions suggest that a firm’s debt has a statistically significant negative but nonlinear effect on privately financed R&D. The results (weakly) indicate also that profit increases private R&D.

This paper also contributes to the existing literature by analysing whether the impact of public R&D financing on private R&D is different in potentially financial constrained and unconstrained firms. To classify firms as financially constrained and unconstrained, we followed the fixed investment literature and used a firm size and the firms’ indebtedness as classification criteria. Our econometric results suggest that the additionality effect of public funding on private R&D is bigger in large firms than in small ones. However, according to our results there are no differences in the size of coefficient of public funding between indebted and non-indebted companies.

The important policy implication of our results is that public R&D funding increases firm’s total R&D expenditure also in the case of non-financially constrained firms. Thus, our evidence does not support the view that the public sector should finance only financial constrained firms. It is, however, unclear how generalisable our results are to other industries because our data consisted of companies operating only in one industry. Hence, a more extensive dataset is needed to get a more comprehensive conclusion about the impacts of public R&D funding.

6 APPENDIX

Data appendix

The data related to financial reports came from Balance Consulting Ltd. and from *Talouselämä* magazine's top 500 database. All variables are deflated using the GDP price index (1995=100).

Total R&D expenditure

> Total R&D expenditure (irrespective of financing) of the firm as reported in the investment survey by the Confederation of Finnish Industry and Employers.

Public R&D funding

> This data came from the National Technology Agency (Tekes). Public funding includes R&D loans and subsidies.

Privately financed R&D

> Privately financed R&D has been calculated by subtracting public R&D funding from the total R&D expenditure.

Sales

> Net sales came directly from the income statements of firms.

Profit

> Operating profit came directly from the income statements of firms.

Debt

> Long-term debt came directly from the balance sheets of firms.

Table A.2. Correlation matrix

	Private R&D$_t$	Public funding$_t$	Public funding$_{t-1}$	Net sales$_{t-1}$	Profit$_{t-1}$	Debt$_{t-1}$	(Debt$_{t-1}$)^2	Budget$_t$	Budget$_{t-1}$
Private R&D$_t$	1.0000								
Public funding$_t$	0.3664	1.0000							
Public funding$_{t-1}$	0.4366	0.3416	1.0000						
Net sales$_{t-1}$	0.4389	0.1387	0.2137	1.0000					
Profit$_{t-1}$	0.4765	0.1820	0.2730	0.7985	1.0000				
Debt$_{t-1}$	0.3186	0.0902	0.1534	0.5906	0.6085	1.0000			
(Debt$_{t-1}$)^2	0.2107	0.0252	0.0728	0.4046	0.4507	0.8975	1.0000		
Budget$_t$	0.1678	0.3108	0.1182	0.0346	0.0673	-0.0371	-0.0710	1.0000	
Budget$_{t-1}$	0.1455	0.0448	0.2252	0.0559	0.0770	-0.0011	-0.0129	0.0079	1.0000

Table A.3. First-stage regressions (IV regressions in Table 4.1)

	Column *b* in Table 4.1	Column *c* in Table 4.1
Dependent variable	Public funding$_t$	Public funding$_{t-1}$
(Budget)$_t$	.000688*** (.0002375)	
(Budget)$_{t-1}$		.0005255** (.0002326)
(Applied)$_t$	.3783243*** (.0032729)	
(Applied)$_{t-1}$		.3940916*** (.0032312)
Sales$_{t-1}$	-.0001083** (.0000433)	-.0000627 (.0000401)
Profit$_{t-1}$	-.0001118 .0003354	-8.83e-06 (.0003104)
Long-term debt$_{t-1}$	.00134** (.0005969)	.0005019 (.0005511)
(Long-term debt)$^2_{t-1}$	-.0000152 ** (7.64e-06)	-.0000147** (7.05e-06)
Constant	-.0203588 (.0131461)	-.004774 (.0103988)
+ Year dummies		
Number of observations	1640	1640
F-test (joint)	1366.25	1503.27
P-value	< 0.001	< 0.001
R^2	0.902	0.91

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