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Abstract

Several studies have already addressed the question whether R&D subsidies lead to additionality effects or crowd out firms' private investment. This paper provides insights into the impact of R&D grants on private R&D expenditure, distinguishing between research and development activities. We employ parametric treatment effects models and IV regression methods. The hypothesis that firms respond differently to R&D subsidies depending on the nature of the R&D activity is confirmed. R&D subsidies are found to mainly contribute to an increase in development expenditure. By contrast, crowding out effects for the research part cannot be rejected.

Keywords: R&D subsidies, R&D expenditure, research, development, policy evaluation, treatment effects model, IV model

JEL-Classification: C21, H50, O38

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1 Introduction

Innovation and R&D activities have become crucial components in modern knowledge-based economic systems (Romer, 1990). However, R&D is a risky process exhibiting high levels of uncertainty (Dasgupta and Maskin, 1987). Moreover, once knowledge is created by one company, other companies can never be fully prevented from free-riding on the R&D efforts of the company that did commit to the initial R&D investment (Arrow, 1962). Risk and negative externalities give cause for the actual level of R&D spending to be lower than what would be socially desirable. Governments are well aware of this underinvestment problem and attempt to counter it by reducing the price of private R&D through granting public R&D funding to those projects which would normally not be undertaken. The aim of the government obviously is to increase the total R&D expenditure, which, in the ideal case, ultimately should result in more innovative output. However, it is possible that companies replace their own R&D budget with the money they received from the government. In that case, the total R&D expenditure would not increase and the instrument of public R&D funding would not be effective.

Several studies have already addressed the question whether R&D subsidies lead to additionality or crowd out firms' private investment on R&D (for reviews see e.g. David et al, 2000; Aerts et al, 2007; David and Hall, 2000). Traditionally these studies examine the efficiency of public support on the aggregate level of the total R&D activity; only few attempts have been made to treat R&D investment not as one single, homogenous activity, but rather investigate the effect of a subsidy on its two components, namely research and development.

Uncertainty is an important issue in R&D activities. It is commonly known that projects which are characterized by being "far from the market" exhibit an even higher level of uncertainty than the average R&D project. Also in terms of appropriability, "far from the market" research activities may suffer from stronger negative externalities, which decreases the likelihood of profitability and higher levels of underinvestment. Nevertheless, a healthy innovation system needs a good balance between research activities on the one hand and development activities on the other hand, to close potential gaps between knowledge creation and the diffusion of this knowledge to its implementation on the market or in the society. Therefore, governments may tend to allocate more funding to research activities. As a result, potential heterogeneity in additionality effects may arise, when public funding is allocated to different kinds of R&D activity.

This paper empirically analyzes the effect of public R&D subsidies on private R&D investments in Flanders, employing parametric treatment effects models and IV methods. We try to assess the problem of potential heterogeneity by investigating additionally effects on disaggregated R&D expenditures, namely research and development. In the next section, the relevant literature is discussed. Subsequently, we briefly explain the econometric methods underlying the empirical evidence. After a description of the data in the fourth section, the estimation results are presented and subsequently discussed in the two last sections.

2 Literature Review

There is a vast body of literature on the additionality effects of direct R&D grants. The typical issue in evaluation research is the selection bias: the so-called 'treatment' (here: receipt of public funding) usually does not apply randomly to the subjects. On the one hand, governments may cherry-pick projects with the highest expected (social) value. On the other hand, also the receiving parties may act in a mechanism of self-selection, as some may have an information advantage or be better acquainted with policy measures they qualify for. As a result, the treatment very likely is strongly correlated with the output indicator to be evaluated, which introduces endogeneity in the evaluation model. The fourth section explains further details about econometric correction methods to counter this endogeneity issue.

Only relatively recently, the issue of selectivity is explicitly taken into account in this domain. So far, Austria, Denmark, Finland, Flanders, France, Germany, Ireland, Israel, Norway, Spain, Sweden and the US have been subject to an evaluation exercise of their public R&D funding system. Most studies[1] tend to reject full crowding-out effects but the results remain ambiguous (David et al. 2000 and Klette et al. 2000). Key reasons for these diverging conclusions are the use of different estimators, as

[1] Aerts and Czarnitzki (2004 and 2006), Aerts and Schmidt (2008), Aerts (2008a and 2008b), Ali-Yrkkö (2004), Almus and Czarnitzki (2003), Clausen (2007), Czarnitzki (2001), Czarnitzki and Fier (2002), Czarnitzki and Hussinger (2004), Duguet (2004), Ebersberger (2005), Fier (2002), González and Pazó (2006), González et al. (2005), Görg and Strobl (2007), Hussinger (2008), Hyytinen and Toivanen (2005), Lööf and Heshmati (2005), Streicher et al. (2004) reject full crowding-out effects, while Busom (2000), Heijs and Herrera (2004), Kaiser (2004), Lach (2002), Suetens (2002), Toivanen and Niininen (2000) as well as Wallsten (2000) find indications that public R&D funding replaces private R&D investments to some extent.

well as the application for a broad range of countries, each with their own specific science and technology policy (David et al., 2000).

Some studies (e.g. Aerts and Czarnitzki (2004 and 2006a), Aerts and Schmidt (2008), Aerts (2008a and 2008b) and Suetens (2002)) have already investigated the impact of subsidies in Flanders. However, they do not distinguish between the different components of R&D expenditure (research vs. development). A recent study of Czarnitzki et al. (2008) analyses the productivity effects of R&D spending at a disaggregate level. They deal with the relationship between patents on the one hand and R&D expenditure and its components, i.e. research and development, on the other hand, in a knowledge production function framework; the implication of the decomposition of R&D activities remains unclear. Joglekar and Hamburg (1983 and 1996) build a theoretical model and conclude that governments should avoid providing companies with financial incentives to conduct basic research, as this reduces the companies' own investment. Link (1982) conducts OLS regressions on a sample of 275 US manufacturing firms and finds a negative impact of public funding on the expenditure on basic research; the impact on development expenditure is significantly positive. Robson (1993) and Diamond (1999) use aggregate time-series data on federal R&D expenditure in the US. They both find evidence of a positive relationship between federal R&D expenditure and private basic research. Higgins and Link (1982) employ data on 147 US manufacturing firms and find crowding out effects for research expenditure. However, neither Higgins and Link (1982) nor Link (1982) control for potential endogeneity between R&D expenditure and funding, which by now is common in the literature. Clausen (2007) applies an IV approach on a sample of Norwegian manufacturing and service firms. He finds that research subsidies have a significant additionality effect on research expenditure, but that development subsidies are subject to crowding-out effects.

In the next section we will briefly explain the particularities of the Flemish R&D funding system. Subsequently, we come to a description of the data and the variables which are employed in the empirical part.

3 Public R&D funding system in Flanders

The Institute for the Promotion of Innovation through Science and Technology in Flanders (IWT) was established in 1991 by the Flemish government as a regional public institution to provide R&D and innovation support in Flanders. It offers one single counter where companies can apply for a subsidy. This implies that subsidies, at the Flemish, Belgian and European level, are evaluated and granted through IWT. Accelerated depreciation for R&D capital assets and R&D tax allowances are available through the federal Belgian government. In contrast to most countries, the Belgian R&D tax allowances are fixed and not granted as a percentage: for each additional employee employed in scientific research, the company is granted a tax exemption for a fixed amount, in the year of recruitment. However, as Van Pottelsberghe et al. (2003) indicate, very few Belgian companies actually make use of these fiscal measures. Main reasons are a low level of acquaintance with the system, high administration costs and the fact that the measures are not significantly substantial: e.g. the tax exemption is a short term measure while R&D is typically a long term process. Direct R&D funding through IWT remains the largest source of public R&D grants in the private sector in Flanders[2]. IWT supports companies with financial aid to conduct industrial research and development projects. In this connection special attention is drawn to small and medium enterprises (SME) due to their specific characteristics and needs. Despite the fact that the lion's share of funding is still absorbed by the big enterprises, the number of projects submitted by small and medium enterprises is about three times higher than that of the large companies and keeps on growing during the last few years. Any SME submitting an R&D project or an SME innovation project to IWT is also eligible for a so-called "subordinated loan"[3]. The total funding (subordinated loan and subsidy) amounts to a minimum of 15% and a maximum of 80% of the total project costs. Furthermore, also EUREKA[4] projects are granted through IWT. Thus, approved projects are evaluated on the eligibility criteria for the EUREKA program, and additional funding may be added to the project budget. However, only a relatively small number of Flemish innovation projects are supported through EUREKA. In general, the total amount of subsidies granted by IWT is rising. In 1992, when IWT was founded, a total amount

[2] The interested reader is referred to Aerts and Czarnitzki (2006a) for a detailed overview of the public R&D funding system in Flanders. Important to mention here is that, after recent changes in the set-up of the measures, fiscal stimuli are becoming increasingly popular, especially tax reduction measures for R&D employees. For the current research, these fiscal measures were not yet relevant; they will become so, however, in the future.

[3] Since the launch of VINNOF, the Flemish Innovation Fund, in 2006, subordinated loans are longer provided by IWT. The system of subordinated loans has been totally revised. These loans are not taken into account in the empirical part of this paper; we only use the subsidy amounts actually received by companies.

[4] EUREKA is a pan-European network for market-oriented, industrial R&D which aims to enhance European competitiveness through its support to businesses, research centres and universities.

of 14 million EUR of subsidies was granted. In 2004, IWT already supported over 300 companies with a total funding budget of 78 million EUR (Aerts and Czarnitzki, 2006).

4 Selectivity issue

This section will explain more in detail the nature of the endogeneity problem which may distort estimation results of the relationship between public R&D funding and R&D activity. Next, we briefly explain the methodology which will be employed to eliminate the potential bias caused by this selectivity problem.

The outcome variable Y, in our case the expenditure on R&D activities, can be modelled as follows[5]:

$$Y = \begin{cases} X\beta + S\alpha + U & \text{if} \quad S = 1 \\ X\beta + U & \quad\quad S = 0 \end{cases}, \tag{1}$$

where X and β represent a set of exogenous variables and their respective parameters. S refers to the treatment status (S=1: treated; S=0: untreated; treatment is the receipt of a subsidy in this case) and α measures the impact of this treatment. U is the error term with zero mean and U is assumed to be uncorrelated with X. However, as indicated before, it is not unlikely that U is correlated with S: subsidized companies may well have been more R&D active than the non-subsidized companies even without the subsidy program. This would imply a selection bias in the estimation of the treatment effect. R&D intensive firms may be more likely to receive an R&D subsidy, as governments aim at maximizing the probability of success and therefore may well cherry-pick proposals of companies with considerable R&D expertise. Moreover, it is also quite possible that only particular companies apply for public R&D grants because they have an information advantage and are acquainted with policy measures they qualify for. In an experimental setting, without any selection bias and random subsidy allocation, U and S are not correlated. This is most likely not the case in current innovation policy practice, though. Therefore, standard econometric approaches, regressing Y on X and S by OLS, are not valid and other approaches, taking this potential endogeneity properly into account, should be employed. Econometric literature has developed a range of methods (see e.g. the surveys of Heckman et al., 1999; Blundell and Costa-Dias, 2000, 2002; Aerts et al.,

[5] We omit firm indices for the sake of readability.

2007). Examples of these methods are difference-in-differences estimations, matching, selection models and instrumental variable (IV) estimations (including simultaneous equation systems). We will apply the latter two methods in the empirical part. In the following paragraphs, they are very briefly explained.

The subsidy allocation can be modelled by the following selection equation:

$$S^* = Z\gamma + V\ , \tag{2}$$

where S* is an index, measuring the probability to receive public funding, depending on a set of company characteristics Z and parameters γ, as well as an error term V. When S* is positive, the company is granted a subsidy:

$$S = \begin{cases} 1 & if\ S^* > 0 \\ 0 & otherwise \end{cases}. \tag{3}$$

The two-step selection model estimates two equations. A discrete choice model predicts the probability of being treated (S*) (the selection equation) and the outcome variable is regressed linearly on the treatment variable, controlling for observable exogenous characteristics (the outcome equation). Theoretically, the outcome equation is defined through the nonlinearity of the hazard parameter (also labelled as the inverse Mills ratio). However, in practice, most observations are located within the quasi-linear range of the hazard parameter (Puhani, 2000). Hence, to identify the treatment effect, an exclusion restriction is imposed. This requires the existence of at least one variable, which is insignificant in the outcome equation, but at the same time significant in the selection equation. This regressor should not be correlated with the error term V of the selection equation. The selection model directly controls for the part of the error term U which is correlated with S. It is commonly assumed that U and V follow a joint normal distribution[6], resulting in the following conditional outcome equations:

$$\begin{aligned} E(Y|S=1) &= X\beta + \alpha + \rho\phi\left(\frac{Z\gamma}{\sigma_V}\right)\Phi\left(\frac{Z\gamma}{\sigma_V}\right)^{-1} \\ E(Y|S=0) &= X\beta - \rho\phi\left(\frac{Z\gamma}{\sigma_V}\right)\left[1-\Phi\left(\frac{Z\gamma}{\sigma_V}\right)\right]^{-1}, \end{aligned} \tag{4}$$

where the last term in each equation represents the error term conditional on S. An important advantage of this methodology over matching lies exactly here: by

[6] The assumption of joint normality of U and V can be relaxed, though. The interested reader is referred to Hussinger (2008).

separating the impact of S from the selection process, any correlation with unobserved variables is corrected for.

This model has often been criticized as it is quite demanding on assumptions about the structure of the model. Therefore, the evaluation of the funding status is introduced in an IV framework. Moreover, while the application of treatment effects models is limited to binary treatment only, IV regressions allow refining the impact of the measure in a continuous treatment set-up[7]. This will provide a further robustness check, as here not only the funding status, but now also the funding amount is taken into account.

An instrument Z* is defined and a transformation g is applied, satisfying the requirement that g(Z*) is uncorrelated with U conditional on X, and that Z* is not completely determined by X. Unlike the selection model, IV is a simpler estimator as it omits the selection equation estimation. However, its major drawback lies in the identification of the instrument Z*: it has to be valid as well as relevant. Only in that case, the estimates will be consistent. Overidentifying restrictions are tested by the Hansen-Sargan test. Its joint null hypothesis claims that the instruments Z* are valid, i.e. uncorrelated with the error term U, and that the excluded instruments are rightfully excluded from the estimated equation. The identification of the equation, i.e. whether the excluded instruments are relevant, is tested in the Anderson canonical correlations likelihood-ratio test. Its null hypothesis is that the equation is underidentified. Consequently, the potential endogeneity is adequately corrected for, if the Hansen-Sargan test holds and the Anderson canonical correlations likelihood-ratio test is rejected. Moreover, compliance with the Stable Unit Treatment Value Assumption (SUTVA) is required: the treatment of one firm should not affect the treatment effect on another firm (Rubin, 1990). Unfortunately this cannot be tested.

5 The data

The potential crowding-out effect of R&D subsidies in Flanders is addressed empirically with data from the biannual Flemish Research and Development Survey. This mainly quantitative survey covers most EU countries with a by and large harmonized questionnaire and the collected data are used to compose the European

[7] Most frequently, IV regressions are applied on discrete treatment variables. However, the same procedure is valid for continuous treatment variables (see e.g. Wooldridge, 2002).

Innovation Scoreboard. The set-up of the Flemish R&D survey is inventory-based: all potential R&D active companies are identified and surveyed. We pool two consecutive waves, i.e. the 2004 and 2006 R&D surveys[8]. The R&D data are supplemented with patent application data from the European Patent Office since 1978. Balance sheet data from the National Bank of Belgium (Belfirst) was merged to the dataset to provide financial indicators. Last, information on the subsidy size and history of each company was added: IWT keeps track of all subsidy applications and potential subsequent grants.

5.1 Variables

The receipt of subsidies is denoted by a dummy variable (FUN) indicating whether the firm received public R&D funding. The amount of subsidies received is measured by AMT (in million EUR). No distinction is made with respect to the source which provided the public funding; the impact is an average effect over the different funding schemes.

The outcome variables measure a company's R&D expenditure. First, we test the impact of an R&D subsidy on private R&D expenditure in general: RDX (in million EUR). R&D is defined in accordance with the Frascati Manual (OECD, 2002: 30) as: *"creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications"*. Second, we disentangle the company's total R&D expenditure into research expenditure (RDX_R) on the one hand and development expenditure (RDX_D) on the other hand.

Two variables enable correcting properly for the potential selectivity problem. In the treatment effects model they serve as excluded explanatory variables in the outcome regressions, which are significant in the selection equation, though. In the IV-set-up, they act as a vector of instruments. They are computed from the company's subsidy history. AMT/PROJ_past5yrs contains the total public R&D funding the company received (in million EUR) in the preceding 5 years, divided by the number of projects in this period. PROJ/EMP_past5yrs (in number / FTE) is a count variable, reflecting the total number of project proposals each company submitted in order to obtain an

[8] The data collected in the surveys refer to the period 2002-2004 (2004 survey) and 2004-2006 (2006 survey). The funding variables are measured in 2003 and 2005, respectively. To avoid endogeneity problems in the selection equation, the covariates are measured, whenever possible, at the beginning of the reference period. Only R&D active companies are kept for the analysis.

R&D subsidy in the preceding five years. These variables seem to be able to provide reliable instruments, since they are highly correlated with a company's current funding status but at the same time, the company's current R&D activity does not influence its subsidy history. To obtain the right fit in the estimate dimensions, also the logarithmic transformations of these variables (lnAMT/PROJ_past5yrs and lnPROJ/EMP_past5yrs) were used in the respective models.

We use several control variables which may affect both the subsidy receipt and R&D effort, respectively. Including the number of employees allows controlling for size effects, which are empirically often found to explain innovativeness (see e.g. Veugelers and Cassiman, 1999). Moreover, the Flemish S&T policy puts high value on R&D activities performed by small and medium sized companies. Therefore, the size variable is also expected to influence the subsidy receipt. The logarithmic transformation (lnEMP) is used to avoid potential estimation biases caused by skewness of the data.

Another important variable is the firms' patent stock (PAT). As we use data from two cross-sectional datasets, which do not include time-series information, the patent stock enables us to control for previous (successful) R&D activities. Obviously, not all innovation efforts lead to patents, which Griliches (1990: 1669) formulated nicely as *"not all inventions are patentable, not all inventions are patented"*. Likewise, not all patented innovations result from R&D activities; the R&D process is only part of a company's innovative activity[9]. Moreover, the propensity to patent may be heterogeneous among firms. However, as data on previous R&D expenditure are not available, the patent stock is the best approximation of past innovation activities. We use all patent information in the EPO database and generate the stock of patents for each firm as the depreciated sum of all patents filed at the EPO from 1978 until 2001 (1997):

$$PAT_t = (1-\delta)PAT_{t-1} + PATA_t \,, \qquad (5)$$

where PAT is the patent stock of a firm in period t and t-1, respectively, PATA is the number of patent applications filed at the EPO and δ is a constant depreciation rate of knowledge which is set to 0.15 as common in the literature (see e.g. Jaffe, 1986;

[9] Innovative activity is defined as "all those scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of technologically new or improved products or processes" (OECD/Eurostat, 1997: 10).

Griliches and Mairesse, 1984). On the one hand, firms that exhibit previous successful innovation projects indicated by patents, are more likely to receive public R&D funding, because the public authorities may follow the 'picking-the-winner' principle in order to minimize the expected failure rates of the innovation projects, and hence, to maximize the expected benefit for the society. On the other hand, the patent stock controls for the past average innovative engagement of the firms, because it is expected that firms that were highly innovative in the past will continue this strategy. The patents are counted only until 2001 (1997), to ensure that the stock definitely refers to past innovation activities, in order to avoid a simultaneous equation bias in the regression analysis. The patent stock enters into the regression as patent stock per employee (PAT/EMP) to reduce the potential multicollinearity with firm size.

The export quota (EXQU = exports / turnover) measures the degree of international competition a firm faces. Firms that engage in foreign markets may be more innovative than others and, hence, would be more likely to apply for subsidies.

Next, variables reflecting the technological and financial quality of the company may play a significant part in both the subsidy and R&D story. These characteristics are proxied by capital intensity (CAPint) as the value of fixed assets per employee and cash-flow (CASHF) (both in million EUR) respectively. Both variables are obtained from balance sheet records provided by the National Bank of Belgium (through the Belfirst database). CASHF is also divided by the number of employees (CASHF/EMP) to avoid multicollinearity with firm size.

A dummy variable indicating whether a firm belongs to a group (GROUP) controls for different governance structures. Firms belonging to a group may be more likely to receive subsidies because they presumably have better access to information about governmental actions due to their network linkages. In addition to group membership, FOREIGN indicates whether this group is domestic or foreign-owned.

As we use data from two pooled cross-sections and the average R&D expenditure was subject to a downward trend (see e.g. Debackere and Veugelers, 2007), a year dummy (YEAR=1 for the R&D 2006 wave) was included in each regression to control for differences over time. Moreover, the monetary variables[10] were deflated (EconStats, 2007). Extreme outliers with respect to the funding amount and R&D activity were

[10] AMT, RDX, RDX_R, RDX_D, AMT/PROJ_past5yrs, CAPINT and CASHF/EMP.

removed. The final sample consists of 521 observations. The summary statistics of the variables used to evaluate the input additionality of Flemish R&D subsidies are presented in Table 1.

Table 1: Summary statistics dataset (521 observations)

Variable	Mean	St. Dev.	Min.	Max.
TREATMENT VARIABLES				
FUN (dummy)	0.3724	0.4839	0.0000	1.0000
AMT (in mio EUR)	0.0708	0.1721	0.0000	1.3284
OUTCOME VARIABLES (in mio EUR)				
RDX	0.6593	0.9995	0.0018	5.6797
RDX_R	0.2905	0.5835	0.0000	4.6522
RDX_D	0.3688	0.7057	0.0000	5.3603
INSTRUMENTS				
AMT/PROJ_past5yrs (in mio EUR)	0.0064	0.0359	0.0000	0.5462
PROJ/EMP_past5yrs (in number / FTE)	0.0818	0.2704	0.0000	3.0000
CONTROL VARIABLES				
lnEMP (in FTE)	4.1011	1.4365	0.0000	8.1928
PAT/EMP (in number / FTE)	0.5038	2.9132	0.0000	44.7887
EXQU (in %)	57.8287	34.6946	0.0000	100.0000
CAPINT/EMP (in mio EUR /FTE)	97.2213	309.5593	0.3778	4856.3270
CASHF/EMP (in mio EUR /FTE)	16.7101	44.5740	-509.7109	400.9867
GROUP (dummy)	0.5969	0.4910	0.0000	1.0000
FOREIGN (dummy)	0.2265	0.4190	0.0000	1.0000
YEAR (dummy)	0.5259	0.4998	0.0000	1.0000

Note: the details of BR are not presented here. To compute the logarithmic transformation values of AMT, RDX, RDX_R, RDX_D, AMT/PROJ_past5yrs and PROJ/EMP_past5yrs, zero values before the transformation were replaced by the minimum observed logarithmic value after the transformation.

6 Estimates

This section presents empirical evidence on the impact of R&D subsidies on R&D expenditure in Flanders, distinguishing between research and development. We employ parametric treatment effects models as well as IV regression models. First, the impact of the mere funding status is evaluated in the treatment effects framework. Table 2 reports the estimates of the selection equation. The amount of funding (AMT/PROJ_past5yrs) and the number of projects (PROJ/EMP_past5yrs) received in the past are highly significant in the selection equation; they strongly influence the likelihood to receive public R&D funding in Flanders. This seems to indicate that there is a high level of continuity in the receipt of public funding. International orientation (EXQU) positively influences the likelihood to receive public funding for R&D projects. Industry affiliation matters as well.

The outcome equations are estimated, taking the estimated coefficients from the selection equation (Table 2) into account. In this way, the actual treatment effect is separated from the potential selection bias. In Table 3 the outcome estimates are presented.

Table 2: Treatment effects model: selection equation

	Probit estimates			**Marginal effects**		
AMT/PROJ_past5yrs	18.4998	(5.0669)	***	7.0528	(1.9697)	***
PROJ/EMP_past5yrs	0.6433	(0.2583)	**	0.2453	(0.0985)	**
lnEMP	0.0370	(0.0588)		0.0141	(0.0224)	
PAT/EMP	0.0522	(0.0407)		0.0199	(0.0156)	
EXQU	0.0037	(0.0019)	*	0.0014	(0.0007)	*
CAPINT/EMP	0.0005	(0.0003)		0.0002	(0.0001)	
CASHF/EMP	-0.0002	(0.0014)		-0.0001	(0.0006)	
GROUP	-0.1848	(0.1419)		-0.0707	(0.0545)	
FOREIGN	-0.2316	(0.1721)		-0.0863	(0.0624)	
YEAR	-0.0423	(0.1203)		-0.0161	(0.0459)	
CONSTANT	-1.2162	(0.3343)	***			
Industry Dummies	$X^2(11) = 39.59$					
Log-Likelihood	-304.29251					
Pseudo R^2	0.1153					
# obs.	521					

dy/dx is for discrete change of dummy variable from 0 to 1; *** (**,*) indicate a significance level of 1% (5, 10%); the standard errors (between brackets) are obtained by the delta method.

A first conclusion is that the receipt of a public R&D grant clearly has a positive impact on a company's R&D effort in general: funded companies show higher R&D expenditures than their non-funded counterparts; on average about 1.2 million EUR. This result confirms positive additionality effects of R&D subsidies on R&D expenditure in Flanders and is in line with previous analyses for Flanders (Aerts and Czarnitzki, 2004 and 2006a; Aerts and Schmidt, 2008 as well as Aerts 2008a and 2008b).

As already mentioned in the previous sections, different R&D activities may be affected in a different way by R&D subsidies. The estimates in Table 3 confirm this hypothesis. When we disentangle a company's total R&D expenditure into research and development, the picture looks a little different. Crowding-out effects cannot be rejected for the research part (RDX_R) in the total R&D expenditure. However, the expenditure devoted to development (RDX_D) is significantly larger in subsidized companies.

The parametric treatment effects models reveal that the Flemish R&D policy positively contributes to a company's total expenditure and more specifically mainly the expenditure on development activities. In the following, the evaluation of the funding status (FUN) is extended in an IV framework: we do not only consider whether a company is provided with public funding or not, but also take the exact amount of funding (AMT) a firm received from IWT into account. This enables a more profound insight in the nature of the additionality effects found in the treatment effects model, since these models only reject full crowding-out effects. However, it is still possible that funded companies to some extent replace private money with the public grant. To be more precise, if IWT grants 1 EUR of subsidies, but the firm additionally spends only less than 1 EUR on R&D expenditure, this would mean that the subsidy partially crowds out companies' private R&D effort.

Table 3: Treatment effects model: outcome equations

	RDX			RDX_R			RDX_D		
HAZARD	-0.6203	(0.1974)	***	-0.1689	(0.1225)		-0.4514	(0.1474)	***
FUN	1.2038	(0.3202)	***	0.3211	(0.1971)		0.8828	(0.2391)	***
lnEMP	0.2896	(0.0357)	***	0.1167	(0.0219)	***	0.1729	(0.0266)	***
PAT/EMP	0.0132	(0.0144)		-0.0084	(0.0088)		0.0216	(0.0107)	**
EXQU	0.0012	(0.0013)		0.0017	(0.0008)	**	-0.0005	(0.0010)	
CAPINT/EMP	0.0004	(0.0002)	**	0.0002	(0.0001)	**	0.0002	(0.0001)	
CASHF/EMP	0.0031	(0.0009)	***	0.0002	(0.0006)		0.0030	(0.0007)	***
GROUP	0.2062	(0.0951)	**	0.0784	(0.0582)		0.1277	(0.0710)	*
FOREIGN	0.1846	(0.1080)	*	0.0664	(0.0661)		0.1182	(0.0806)	
YEAR	0.0038	(0.0779)		-0.0081	(0.0477)		0.0119	(0.0581)	
CONSTANT	-1.2038	(0.3202)	***	-0.5870	(0.1226)	***	-0.9111	(0.1494)	***
Joint significance of Industry Dummies	$\chi^2(11) = 39.59$		***	$\chi^2(11) = 26.76$			$\chi^2(11) = 23.96$		**

Note: the industry dummy coefficients are not shown here; the test on their joint significance is reported, though. The standard errors (between brackets) are heteroskedastic consistent.
The selection equation includes: AMT/PROJ_past5yrs and PROJ/EMP_past5yrs.

As discussed before, both the amount of funding received and the number of projects submitted by the company in the preceding 5 years are expected to provide reliable instruments in an IV approach of the additionality issue. Table 4 shows the regression results for our different measures of a company's R&D activity. The coefficient of RDX is highly significant and positive. Moreover, the tests on the quality of the instrumental variables confirm that the model requirements hold. A subsidy of 1 million EUR increases the average R&D expenditure with 1.644 million EUR. In line with the results from the treatment effects model, we find that this increase in R&D expenditure mainly comes from the increased expenditure on development activities (the treatment effect amounts to 1.4072 million EUR).

Table 4 IV Regression

	RDX			RDX_R			RDX_D		
AMT	1.6438	(0.6223)	***	0.2366	(0.4364)		1.4072	(0.4943)	***
lnEMP	0.2690	(0.0365)	***	0.1143	(0.0291)	***	0.1547	(0.0273)	***
PAT/EMP	0.0238	(0.0084)	***	-0.0047	(0.0055)		0.0285	(0.0075)	***
EXQU	0.0019	(0.0012)		0.0021	(0.0009)	**	- 0.0002	(0.0009)	
CAPint	0.0006	(0.0001)	***	0.0002	(0.0000)	***	0.0003	(0.0001)	***
CASHF/EMP	0.0034	(0.0011)	***	0.0002	(0.0004)		0.0033	(0.0012)	***
GROUP	0.1072	(0.0604)	*	0.0542	(0.0385)		0.0529	(0.0465)	
FOREIGN	0.1340	(0.1038)		0.0536	(0.0857)		0.0805	(0.0749)	
YEAR	0.0397	(0.0631)		- 0.0054	(0.0493)		0.0451	(0.0481)	
CONSTANT	- 1.2274	(0.1700)	***	- 0.5284	(0.1289)	***	- 0.6990	(0.1208)	***
Joint significance of Industry Dummies	$\chi^2(11) = 51.58$		***	$\chi^2(11) = 31.57$		***	$\chi^2(11) = 29.72$		***
Instrument tests:									
Anderson	$\chi^2(2) = 118.769$		***	$\chi^2(2) = 118.769$		***	$\chi^2(2) = 118.769$		***
Hansen-Sargan	$\chi^2(1) = 1.200$			$\chi^2(1) = 2.375$			$\chi^2(1) = 0.062$		
Centered R^2	0.5069			0.2134			0.4283		

Note: the industry dummy coefficients are not shown here; the test on their joint significance is reported, though. The instruments used are AMT/PROJ_past5yrs and PROJ/EMP_past5yrs. The standard errors (between brackets) are heteroskedastic consistent. Number of obs.: 521

7 Conclusion

Government intervention in private R&D activity is common practice nowadays. However, its impact may not be unambiguously positive, as presupposed by many governments. The issue of an adequate evaluation of the public R&D funding forces itself and many researchers in many countries investigate whether R&D grants stimulate private R&D investments, as companies may simply replace private R&D budgets with the public money provided by the government. However, different components of the R&D activities may exhibit different behaviour with respect to R&D subsidies.

This paper provides insights into the impact of R&D grants, distinguishing between research and development activities and employing parametric treatment effects models and IV regression methods. The main data source is the Flemish R&D Survey, supplemented with information from companies' balance sheets (National Bank of Belgium), patenting activity (EPO) and subsidy history (IWT).

Size, previous innovative activity, international competition, group membership, foreign ownership and industry affiliation may induce a considerable selection bias, rendering the receipt of a subsidy endogenous. Controlling for this bias, using information on the company's subsidy history, we conclude that R&D subsidies in Flanders bring about positive additionality effects, measured in R&D expenditure. However, a decomposition of the different R&D activities reveals that firms respond differently to R&D subsidies, depending on the nature of the R&D activity. The treatment effects model and the IV regression on the amount of funding show that additionality effects from the receipt of public R&D funding only lead to an increase in development expenditure and have no impact on the private expenditure on research activities.

The restriction to R&D active companies implies that the additionality effect can only be derived in terms of additional R&D spending. However, subsidies can be a trigger, pushing companies without any R&D activity to become R&D active. If these switchers would be taken into account as well, the treatment effects are very likely to be higher.

Governments may opt for other ways to stimulate research activities in industry, though. Stimulating (with or without financial incentives) collaborative research projects might be one option. For example, Czarnitzki et al. (2007) find that German and Finnish collaborating firms and firms that both collaborate and receive subsidies spend more on R&D activities. Furthermore they show that firms engaging neither in collaboration nor public innovation programs would increase their R&D expenditure when they would start conducting cooperative research (either subsidized or not).

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