R&D subsidies and foreign ownership:

Carrying Flemish coals to Newcastle?

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Abstract

The large presence of foreign-owned companies in Flanders, especially in R&D intensive industries, combined with a limited number of foreign affiliates receiving the lion share of Flemish R&D subsidies, raises questions about the impact of foreign ownership on the effectiveness of public R&D funding. Semi-parametric matching confirms positive input additionality effects, irrespective of the ownership structure. Next, the counterfactual, privately financed R&D expenditure was disentangled from the publicly induced, additional R&D expenditure. The results show that in general, both R&D expenditure components are translated into more R&D output, but foreign-owned companies realize more innovative output and capture economic value as well.

Keywords: R&D subsidies, R&D expenditure, innovative performance, economic value creation, foreign ownership, multinational, policy evaluation, semi-parametric matching

JEL-Classification: C14, C21, F23, 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 (see Arrow, 1962). In addition to this imminent externality problem, also capital market constraints may hamper private R&D effort (Himmelberg and Petersen, 1994). As a result, the actual level of R&D spending will 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.

As Hyytinen and Toivanen (2005) prove, especially companies depending on external finance are burdened by asymmetric information and moral hazard motives and may experience serious obstacles in raising adequate R&D budgets (see also Hall, 2005). Hence, multinational enterprises (MNEs) may be less subject to these threats, as *"The primary advantage of the multinational firm […] lies in the flexibility to transfer resources across borders through a globally maximizing network"* (Kogut, 1993: 242). Markusen (1998) collects evidence that MNEs expand their foreign activities especially in R&D intensive industries, as knowledge-based assets can easily be transferred and serve many production facilities. Serapio and Dalton (1999) confirm the increasing involvement of MNEs in R&D efforts through foreign affiliates. Foreign-owned firms may also benefit from a better organizational structure leading to a larger control over knowledge flows. Therefore, uncertainty and externality risks may be kept to a minimum (see e.g. Veugelers and Cassiman, 2004). Hence, the ownership structure of companies may result in heterogeneous effects of R&D subsidies and as a result, MNEs may be less likely to apply for a subsidy and on their turn, governments may be less inclined towards public R&D funding of MNEs. On the other hand, many scholars (see Bellak, 2004 for a survey) have shown that a significant performance gap exists between foreign-owned and domestic firms, to the benefit of the former. As a consequence, foreign-owned companies, exhibiting larger technical efficiency, may be just as well more effective in their R&D activities (De Backer and Sleuwaegen, 2005). The government's desire to maximize the expected rate of return of public R&D funding may therefore conversely justify why governments would also provide public R&D funding to MNEs.

Being a small, open economy, Belgium hosts a large share of foreign-owned MNE activity. For example, in 2000, foreign affiliates employed more than 40% of the total work force and created more than 50% of the total added value in the manufacturing industry (De Backer and Sleuwaegen, 2005). Research on Flemish data (the largest region in Belgium) learns that these foreign-owned companies are less likely to receive a subsidy (see e.g. Aerts et al., 2007). But then again, they harvest the larger R&D grant projects and, aggregated, the lion share of the total subsidy amount in Flanders. Obviously, it is imperative for policy makers to know how this skewed state of affairs is translated in R&D efforts and innovative output of domestic and foreign-owned companies. This is exactly the research question that will be tackled in this paper: do R&D subsidies have a different impact on the R&D expenditure and the innovative output of domestic versus foreign-owned firms in Flanders? After this introduction, the relevant literature is presented. Next, the main methodological difficulties and adequate solution mechanisms are described. The fourth section elaborates on the data. The results are presented in the fifth section. The last section concludes with some final remarks and paths for further research.

2. Literature Review

Two different literature streams are relevant for this research. First, the literature on the evaluation of the public R&D funding is reviewed. Second, we dive into the literature on the internationalization of R&D activities and more specifically, the different role played by domestic and foreign-owned companies in host countries.

2.1. Additionality of R&D subsidies

The predominant inquiry in the evaluation of public R&D funding addresses the impact of subsidies on the private R&D investments: does public money replace (or crowd out) private expenditure on R&D? After an extensive review of the literature, David et al. (2000) conclude that the results on potential crowding-out effects are ambiguous and they criticize that most existing studies neglect the problem of sample selection bias. R&D intensive firms may well be more likely to apply for a subsidy. Just as well, governments may be more inclined to grant them a subsidy. This makes R&D funding an endogenous variable, and should be tackled in an adequate way. Consequently, in more recent research the potential sample selection bias is taken into account through selection models, instrumental variable (IV) estimations (including simultaneous equation systems), difference-in-differences estimations and matching techniques. Although recent studies correct for a potential selection bias and tend to reject full crowding-out effects, the results remain ambiguous: many researchers reject full crowding-out effects, while others find indications that public R&D funding replaces private R&D investments to some extent (see Aerts et al. (2007) for a survey of methodologies and applications). Key reasons for these diverging conclusions are the use of different estimators, as well as their application on a broad range of countries, each with their own specific S&T policy. So far, Austria, Denmark, Finland, Flanders, France, Germany, Ireland, Israel, Norway, Spain, Sweden and the US have been subject to an R&D input evaluation analysis of their public R&D funding system[1].

Aerts and Czarnitzki (2004) address the additionality issue on a cross-section of Flemish manufacturing and selected service companies with the nearest neighbour matching approach. Next, they extend their research with in IV framework, adding information on the amount of subsidies companies receive (Aerts and Czarnitzki, 2006). Both full and partial crowding-out effects are rejected. Aerts and Schmidt (2008)

[1] Aerts and Czarnitzki (2004 and 2006), Aerts and Schmidt (2008), 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. (2006), Görg and Strobl (2007), Hussinger (2008), Hyytinen and Toivanen (2005), Lööf and Heshmati (2005) and 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.

employ the conditional difference-in-differences method with repeated cross-sections and find similar results. These studies jointly constitute substantial evidence supporting the positive effect of Flemish subsidies on private R&D spending. Conversely, Suetens (2002) applies an IV framework on a panel of Flemish firms, but her results are by and large not significant and full crowding-out cannot be rejected. A first explanation for these divergent results can be found in the use of a different methodology on a different dataset. Second, her variable of interest is, unlike in the research mentioned above (R&D expenditure), the number of R&D personnel. David and Hall (2002) emphasize the importance of differentiating between the impact of subsidies on expenditure and personnel, as companies may increase their R&D spending, but therefore not necessarily also their R&D staffing. Goolsbee (1998) for example, concluded that R&D subsidies are primarily translated into researcher wage increases. Using a matching approach, Aerts (2008) gives audience to the appeal of David and Hall (2002) to include labour market dynamics in additionality research and finds, in addition to positively significant R&D expenditure increases, a smaller, but still positive impact on the number of R&D employees, together with an increase of R&D wages.

The work of Görg and Strobl (2007) is of particular relevance here. They employ the conditional difference-in-differences technique on a rich panel data set of Irish manufacturing plants. They allow for a certain degree of heterogeneous treatment effects, distinguishing between small, medium and large grants and add the dimension of foreign ownership, given the importance of foreign multinational companies in Ireland. In contrast to the Flemish innovation policy though, the pubic R&D funding allocated to domestic Irish firms is almost five times larger than the support foreign-owned affiliates receive. They reject crowding-out of small and medium grants and find additionality effects of small grants. However, no effect can be confirmed in the sample of foreign-owned companies. They add that this result does not imply that public R&D grants to MNE affiliates are wasted, though, as they evaluate the effect on privately financed R&D and not on the total R&D investments. The R&D grants are really deployed in Ireland, for R&D activities which may otherwise have been conducted in other locations. Moreover, knowledge spillovers to the benefit of the domestic economy may well occur.

While investigating potential crowding-out effects of public R&D funding on private R&D expenditure is indisputably highly relevant for innovation policy evaluation, a rejection of such effects does not necessarily imply that increased R&D spending really induces technological progress and subsequently economic value creation. As hinted before, subsidies may just increase R&D wages instead of the real R&D effort. Moreover, an actual reinforcement of private R&D activities may be directed towards more risky and consequently less successful projects (Setter and Tishler, 2005). Hence, extending additionality research on R&D inputs to an analysis of the induced innovative and economic output is imperative to get a full understanding of the impact of R&D subsidies. Klette et al. (2000) survey the literature on evaluation studies, also measuring firm growth, firm value, patents,… Especially the work of Czarnitzki and Hussinger (2004) as well as Czarnitzki and Licht (2006) is of interest for this paper. The authors extend the traditional crowding-out question and link privately financed and publicly induced R&D to a company's patenting activity. Czarnitzki and Hussinger (2004) employ a two equation model. First, they conduct nearest neighbour matching and reject full crowding-out effects of R&D subsidies in German manufacturing firms. In a second equation, they estimate a Griliches-type knowledge production function, relating R&D spending to patenting activity. Especially interesting is the fact that they disentangle total R&D spending into the R&D expenditure a company would have invested in the absence of subsidies and R&D expenditure, induced by the receipt of subsidies, which comprises the amount of the subsidy itself, and the additionally induced privately financed R&D. These two components add up to the total observed R&D expenditure, but the decomposition allows analyzing the productivity of privately financed versus publicly induced R&D investment. The neo-classical paradigm of decreasing returns predicts that R&D projects, which would have been conducted anyway, exhibit higher returns; the marginal return of any additional R&D spending is smaller (Griliches, 1998). Czarnitzki and Hussinger (2004) indeed find that both components exert a significantly positive impact on the number of patents a company applies for, although the productivity of the public part is slightly lower. Patent counts do not give any indication of the social value of the publicly induced R&D, though. The return to these R&D budgets may well be higher than private benefits. Czarnitzki and Licht (2006) follow the same approach, distinguishing between

East and West Germany to investigate whether and how the massive supply of public innovation funding fosters the transformation of East Germany from a planned to a market economy after the re-unification of Germany. For both regions, subsidies are shown to positively affect the average R&D spending as well as the number of patent applications. However, the R&D productivity in West Germany is significantly higher than in East Germany, which casts doubt on the efficiency of the German subsidy allocation.

2.2. The internationalization of R&D activities

Standard literature on MNEs and their affiliate R&D activity focuses on the motives for international R&D activities. Initially, MNE affiliates conducted R&D abroad to adapt the MNE's products to local markets: the knowledge of the MNE is exploited to serve foreign markets: the so-called asset-exploiting (Dunning and Narula, 1995) or home-base-exploiting (Kuemmerle, 1997) motive. Over time however, R&D activities became more and more internationalized and foreign MNE affiliates became a potential source of valuable knowledge to the MNE head quarters. External knowledge is picked up and internalized in the MNE: the so-called asset-seeking (Dunning and Narula, 1995) or home-base-augmenting (Kuemmerle, 1997) motive. The increasing importance of the home-base-augmenting motive in the internationalization activities of MNEs excited a growing fear of national governments that foreign affiliate R&D activity may become a knowledge drain and hollow out the host country's innovative capability (Meyer-Krahmer and Reger, 1999 as well as Guellec and Zuniga, 2006). Conversely, domestic companies may also just as well benefit from the knowledge which is encased in these foreign-owned companies. An often mentioned prerequisite to realize positive spillover effects is a substantial level of absorptive capacity (Cohen and Levin, 1989 and Haskel et al., 2007). Veugelers and Cassiman (2004) investigate how foreign subsidiaries can channel international technology diffusion in Belgium. They find that unwanted spillovers are minimized by limiting the personnel turnover and cannot confirm the presence of positive spillovers to domestic companies. However, they also show that the host country gains significantly increase when foreign-owned technology sourcing affiliates closely cooperate with domestic firms. Ivarsson (2002) draws a similar conclusion from his research on Swedish companies and suggests efforts should be made to strengthen technological linkages. Nevertheless, even when the MNE knowledge does not spill over to domestic firms, foreign-owned affiliates may still create economic value for the host country's society. Bellak (2004) gives an extensive overview on research unravelling performance gaps between foreign-owned versus domestic firms, showing up in wages, skills, labour, productivity, growth, profitability and technology (see also Pfaffermayr and Bellak, 2000). He concludes that MNE affiliates outperform domestic companies, most often because of their ownership status and not because of the fact that they are foreign-owned; the gaps between domestic and foreign MNEs are significantly smaller than the gaps between uni-national and multinational firms. However, foreign ownership may still be a reason to explain a performance gap as foreign-owned firms face the liability of foreignness (Hymer, 1976 and Zaheer, 1995). Because foreign-owned firms are not familiar with the host country's context, they are disadvantaged relative to domestic firms. Firm-specific advantages enable multinationals to overcome this original discriminatory position (Caves, 1971). As a result, multinationals may excel after they have learned to adapt to the host country and consequently outperform the domestic companies.

Especially the potential difference in innovative effort and R&D efficiency between domestic and foreign-owned firms is interesting in the evaluation of additionality effects, as governments may cherry-pick exactly these high performing foreign-owned companies in their subsidy allocation decision to maximize the expected rate of return. Many researchers confirm the presence of a gap in innovative capabilities between foreign-owned and domestic companies. Country studies in favour of the higher innovative capabilities of foreign-owned firms cover Belgium (De Backer and Sleuwaegen, 2005), Finland (Ebersberger, Lööf and Oksanen, 2005), Norway (Ebersberger and Lööf, 2005), Sweden (Ebersberger and Lööf, 2004), and the UK (Frenz and Ietto-Gillies, 2007). Falk and Falk (2006) conduct propensity score matching to relate innovation intensity, computed as expenditures on innovation divided by sales, to foreign ownership in Austria and conclude that foreign affiliates spend relatively less on innovative activities. They do not evaluate potential differences at the output side of the innovative process, though. Ebersberger, Dachs and Lööf (2007) analyze the impact of foreign ownership on innovativeness in Austria, Denmark, Finland, Norway and Sweden. They found no differences in input, but higher levels of output in foreign-owned firms, again suggesting that foreign-owned firms conduct their R&D activities in a more efficient way. Explanations for the better performance of foreign-owned companies can be found in firm-specific assets of the MNE. Also, MNEs can capitalize scale advantages, possess a larger knowledge base, which is easily accessible for affiliates, and reduce duplicate research, because R&D activities can be shared and coordinated internally. Moreover, different ownership structures may be related to differences in innovative strategies, potentially resulting in higher efficiency. De Bondt et al. (1988) found that Belgian domestic firms focus on specific market segments, whereas MNE affiliates rather conduct more R&D efforts for larger markets. When foreign-owned companies can realize a higher efficiency in their innovative productivity and the innovative and economic value can subsequently be captured by the host country, the social value of public R&D funding of MNE affiliates may be very high. Positive impacts may arise on the host country's innovativeness (measured in patents, sales of new products,…) and create economic value (measured in net added value growth, employment,…). This would then justify why governments may allocate more public R&D funding to foreign-owned companies.

3. Methodology

An extensive range of econometric methods is available to correct for the selection bias in additionality research (see Aerts et al. (2007) for a comprehensive overview). In the following this endogeneity problem and the correction method employed here, i.e. the matching estimator, are explained. In a last subsection I briefly summarize how the counterfactual, privately financed, and the publicly induced R&D expenditure are disentangled in order to measure their respective impact on the technological progress and economic value in the host country.

3.1. Selection bias

I empirically evaluate the impact of public R&D funding. The average impact of a subsidy can be computed as follows:

$$\alpha_{TT} = E(Y_i^T \mid S_i = 1) - E(Y_i^C \mid S_i = 1), \qquad (1)$$

where Y is the outcome variable (e.g. R&D expenditure) of firm i, in the so-called treated (T) and counterfactual (C) situation, S is the treatment status (S=1: treated; S=0: untreated – treatment is the receipt of a subsidy here). So α_{TT} , the average impact of the treatment on the treated firms, results from comparing the actual outcome of subsidized firms with their potential outcome in case of not receiving a grant. The approach of measuring potential outcomes goes back to Roy (1951). The actual outcome $E(Y_i^T | S_i = 1)$ can be estimated by the sample mean of the outcome in the group of subsidized firms.

The counterfactual situation $E(Y_i^C | S_i = 1)$ can however never be observed and has to be estimated. In a hastily analysis a researcher could compare the average R&D spending of subsidized and non-subsidized companies to compute the treatment effect on the treated, assuming that:

$$E(Y_i^C | S_i = 1) = E(Y_i^C | S_i = 0) \quad (2)$$

However, subsidized companies may well have been more R&D active than the non-subsidized companies even without the subsidy program, which would imply a selection bias in the estimation of the treatment effect. Ex ante innovative and R&D intensive firms may be more likely to receive an R&D subsidy, as governments want to maximize the expected rate of return of their public money and therefore may well cherry-pick proposals of companies with considerable R&D expertise. Moreover, it is quite possible that those R&D intensive firms have an information advantage and are better acquainted with policy measures they qualify for. As a result they would be more likely to apply for a subsidy. Expression (2) only holds in an experimental setting where there would be no selection bias and subsidies are granted randomly to firms. This is most likely not to be the case in current innovation policy practice.

As the highest expected success is correlated with current R&D spending, the subsidy receipt (treatment) becomes an endogenous variable. To estimate treatment effects while taking this potential endogeneity problem into account, econometric literature has developed a range of methods (see e.g. the surveys of Heckman et al., 1999; Blundell and Costa-Dias, 2000, 2002 as well as Aerts et al., 2007, for a survey of methods applied in additionality research). Examples of these methods are selection models, instrumental variable (IV) estimations (including simultaneous equation systems), difference-in-differences estimations and matching. The latter method will be employed here.

3.2. Matching estimator

The matching estimator is a non-parametric method and its main advantage is that no particular functional form of equations has to be specified. The disadvantages are strong assumptions and heavy data requirements. The main purpose of the matching estimator is to re-establish the conditions of an experiment. The matching estimator attempts to construct an accurate counterpart sample for the treated firms' outcomes if they would not have been treated, by pairing each treated firm i with members h of a comparison group. Under the matching assumption, the only remaining difference between the two groups is the actual subsidy receipt. The difference in outcome variables can then be attributed to the subsidy.

Rubin (1977) proved that the receipt of subsidies and potential outcome are independent for firms with the same set of exogenous characteristics X=x:

$$Y_i^T, Y_i^C \perp S_i \big| X_i = x \quad . \tag{3}$$

This crucial conditional independence assumption (CIA) helps to overcome the problem that the counterfactual outcome $E(Y_i^C \big| S_i = 1)$ is unobservable. If the CIA holds, the expected outcome $E(Y_i^C \big| S_i = 0, X_i = x)$ can be used as a measure of the potential outcome of the subsidy recipients. However, the CIA is only fulfilled if all variables X influencing the outcome Y and selection status S are known and available in the dataset. This imposes heavy requirements on the richness of the dataset. If the relevant variables are known and available and the CIA holds, the equation

$$E\left(Y_i^C \big| S_i = 1, X_i = x\right) = E\left(Y_h^C \big| S_h = 0, X_h = x\right) \tag{4}$$

is valid and the average outcome of subsidized firms in the absence of a subsidy can be calculated from a sample of comparable -matched- firms.

Another feature the matching procedure relies on, is the compliance with the Stable Unit Treatment Value Assumption (SUTVA), which requires that the potential outcome for each treated firm is stable: it should take one single value (and not follow a distribution) and the treatment of one firm should not affect the treatment effect on another firm (Rubin, 1990). Unfortunately this cannot be tested.

In the matching process for all treated firms i a valid counterpart h should be found in the non-treated population and every firm should represent a potential subsidy recipient. Therefore, I impose a so-called common support restriction. If the samples of treated and non-treated firms would have no or only little overlap in the exogenous characteristics X, matching is not applicable to obtain consistent estimates. If the assumptions hold, the average treatment effect on the treated would consequently amount to

$$\alpha_{TT}^{M} = E\left(Y_i^T \middle| S_i = 1, X_i = x\right) - E\left(Y_h^C \middle| S_h = 0, X_h = x\right) \tag{5}$$

which can be estimated using the sample means of both groups.

In the ideal case, the matching procedure includes as many matching arguments X as possible to find a perfect twin in the control group of non-treated firms for each treated firm. However, the more dimensions that are included, the more difficult it becomes to find a good match: the so-called curse of dimensionality enters. Rosenbaum and Rubin (1983) showed that it is valid to reduce the number of matching dimensions X to a single index: the propensity score $\hat{P}(X)$, which is the probability to receive a subsidy. Lechner (1998) suggested a hybrid matching, where the propensity score $\hat{P}(X)$ and a subset of X condition the matching procedure. This increases the accurateness of the matching procedures, since the equivalence of these extra variables is explicitly imposed, in addition to their value in the propensity score. Each treated firm is then matched to its nearest neighbour by minimizing the Mahalanobis distance between the respective propensity scores and some additional matching arguments. To obtain the best possible match a large pool of controls is required. Therefore, I match with replacement and allow different treated firms to be matched to the same non-treated firm. This will cause a bias in the ordinary t-statistic on mean differences, which has to be corrected (Lechner, 2001).

3.3. R&D output evaluation

Once the additionality effect is estimated, it is disentangled in two components: the privately financed, counterfactual, R&D expenditure (RDC) on the one hand and the additional, publicly induced, R&D expenditure (RDdif) on the other hand, following Czarnitzki and Hussinger (2004) as well as Czarnitzki and Licht (2006). Obviously, the additional amount of R&D expenditure of companies which did not receive any funding is zero, and their counterfactual R&D spending equals their actual R&D expenditure. In summary, companies' R&D expenditure is disentangled as displayed in Table 1.

Table 1: Decomposition of R&D expenditure

---RDC---		---RDdif---	
Funded	**Non-funded**	**Funded**	**Non-funded**
$\left(Y^T \middle\| S=1\right)-\alpha_{TT}^M$	$\left(Y^C \middle\| S=0\right)$	α_{TT}^M	0

Next, different kinds of 'productivity functions' are estimated to relate R&D input to output within the additionality framework. The decomposition allows disentangling heterogeneous effects on the productivity of the counterfactual versus leveraged R&D spending. Innovative activity is measured in terms of the share of new products in the total sales as well as the engagement in a patent application. In addition to the productivity of companies' innovative efforts, also economic value creation more in general is measured, in terms of the growth of the net added value. Censored-normal as well as ordinary regression models are employed for the share of new products in the total sales and the growth of the net added value. A probit model is used to estimate potential productivity differences in the patenting activity.

4. The data

In Flanders, IWT, the Institute for the Promotion of Innovation through Science and Technology in Flanders, is the 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].

De Backer and Sleuwaegen (2005) confirm Belgium's weak FDI outward position relative to its FDI inward position: there is a strong foreign presence in Belgium. Vanweddingen (2006) describes the main characteristics of foreign-owned companies in Flanders. They are particularly present in R&D intensive sectors, especially in the chemical industry. The most important head quarter countries are the Netherlands (36%), the US (14%), France (11%) and Germany (9%). On average, Dutch affiliates are more knowledge intensive, while US affiliates are more technology intensive. German and US affiliates typically operate at a larger scale, employing more people.

The potential crowding-out effect of R&D subsidies in Flanders is addressed empirically with data from the Community Innovation Survey. The CIS is conducted biannually and covers most EU countries. The questionnaire is by and large harmonized. Eurostat (2004) presents detailed descriptive survey results for all countries, as well as aggregate statistics. To evaluate the impact of subsidies at the input side, here the CIS III (1998-2000) and IV (2002-2004) waves are pooled. To measure the impact of the subsidies at the output side, CIS IV (2002-2004) and V (2004-2006) data are used. The innovation data are supplemented with patent application data from the European Patent Office since 1978. Balance sheet data from the National Bank of Belgium (Belfirst) were merged into the dataset to provide additional ownership information and financial indicators. Last, information on the subsidy history of each company was added: IWT keeps track of all subsidy applications and potential subsequent grants.

[2] The interested reader is referred to Aerts and Czarnitzki (2006) for a detailed overview of the public R&D funding system in Flanders.

The receipt of subsidies is denoted by a dummy variable (FUN) indicating whether the firm, observed in the CIS IV (III)[3], received public R&D funding in the period 2002 to 2004 (1998 to 2000). On average 22% of the Flemish companies received public funding in the observation period. The Flemish government provided 68% of these firms with R&D funds; the national and European governments were less, but nevertheless important sources of public R&D funding of Flemish companies (40% and 19% respectively). The funding impact is measured as an average effect over the different funding schemes.

The independent variable of interest is a dummy variable indicating foreign ownership (FOREIGN). First, the CIS information on foreign ownership was extracted. Next, I compared this information with ownership information from the balance sheet data of the National Bank of Belgium. This allowed me to fill up some missing data. As common in the literature, foreign ownership was defined as being owned for at least 10% by a foreign mother company[4]. In my sample, 26% of the companies is owned by a foreign mother company. The most important countries where head offices of Belgian subsidiaries are located, are the Netherlands, the US, Germany, France and Great Britain.

The outcome variables are twofold. First, R&D expenditure[5] (in million EUR) at the firm level in 2004(2000), RD, is evaluated. However, as the distribution of this indicator is highly skewed in the economy, the R&D intensity, RDint (R&D expenditure / turnover * 100), is evaluated as well. Also due to the skewness of RD and RDint, some extreme values might affect the mean of the distribution significantly, so that a few observations may determine the estimation results. A logarithmic transformation scales down the large values and reduces the problem with these skewed distributions. Therefore, the logs[6] of RD and RDint are additionally evaluated as outcome variables. All outcome variables refer to the year 2004(2000).

Several control variables are introduced which may affect both the probability to receive R&D subsidies and R&D effort, respectively. As the subsidy dummy covers a

[3] In the description of the variables, I always refer to two years, i.e. the observation window of the CIS-waves.
[4] The low cut-off value of 10% is more rigid to some extent, though. More detailed information on the degree of ownership is included in the CIS IV and CIS V waves. The descriptive statistics show that 95% of the Flemish subsidiaries observed in the CIS are being owned by 50% or more by their parent company. Therefore, the control power of the parent companies is substantial in our sample.
[5] In the CIS survey, R&D expenditure is defined in accordance with the Frascati Manual (OECD, 2002).
[6] Zero values of *RD* and *RDint* were replaced by the minimum observed value.

three year period, I use, whenever possible, values of the covariates measured at the beginning of the reference period, 2002(1998) in order to avoid endogeneity problems in the selection equation. 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. Again, the logarithmic transformation (lnEMP) is used to avoid any potential estimation bias caused by skewness of the data.

PROJ is a count variable, reflecting the total number of project proposals each company submitted in order to obtain an R&D subsidy in the proceeding five years. It is obtained by merging the firm level CIS/patent information with the project level ICAROS database, in which IWT keeps track of all subsidy applications by Flemish companies. PROJ is an important control variable since it is very likely highly correlated with both the probability to receive a subsidy and the R&D activities. Companies which submitted many projects in the past may on the one hand be more innovative and therefore more likely to apply for a subsidy to support their extensive R&D activities. On the other hand, they are more experienced in applying for a subsidy and hence possibly more 'eligible' for a grant.

Another important variable is the firms' patent stock. As I 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[7]. 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. I use all patent information in the EPO database and generate the stock of patents for each

[7] Innovative activity is defined as "all those scientific, technological, organizational, 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).

firm i as the depreciated sum of all patents filed at the EPO from 1978 until 2001(1997):

$$PAT_{i,t} = (1-\delta)PAT_{i,t-1} + PATA_{i,t} \quad (6)$$

where PAT is the patent stock of firm i in period t and t-1, respectively, PATA are 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; 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 rate 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 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) and divided by the number of employees (CAPINT/EMP and CASHF/EMP) to avoid multicollinearity with firm size.

The variable SCOM acts as a measure of absorptive capacity, signalling to which extent information from competitors in the same industry is absorbed by the company. To avoid potential endogeneity with the outcome variables, this variable was rescaled on the three digit industry level. A dummy variable indicating whether a firm belongs to a group (GROUP) controls for different governance structures[8]. 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.

Finally, twelve industry dummies (BR) are included to allow for differences between sectors in the economy. The relationship between size and R&D activities is often found to depend on industry characteristics. Acs and Audretsch (1987), amongst others, conclude that large firms are more innovative when they operate in capital-intensive and highly concentrated sectors, while smaller firms expose a higher degree of innovative activity in industries which are highly innovative and dependent on skilled labour. Moreover, some funding schemes are directly targeted at specific industries or groups of industries, like Biotech programs. Therefore, interaction terms between the industry dummies and lnEMP (BR_lnEMP) are included as well. As I use data from two pooled cross-sections and the average R&D expenditure was subjected to a downward trend (see e.g. Debackere and Veugelers, 2007), a year dummy (YEAR=1 for the CIS IV wave) was included in the regressions to control for differences over time. Moreover, the monetary variables (RD, lnRD, CAPINT and CASHF) were deflated (EconStats, 2007). The total sample consists of 1441 observations, of which 313 companies received public R&D funding and of which 373 companies are owned by a foreign mother company. The summary statistics of the variables are presented in Appendix 1.

In the second step the counterfactual and additionally leveraged R&D spending are disentangled, to evaluate the impact of Flemish R&D subsidies at the output side of the innovative process and, more general, the economic impact. Obviously, developing successful innovative output is time-consuming. Therefore, lead variables are extracted from two other data sources. The subsequent CIS wave, i.e. the CIS V, conducted in 2006, provides information on the share in the total 2005 turnover, realized by products which are new to the market (TURNMAR = share * turnover). As a robustness check, also the impact on TURNMAR per employee (TURNMAR/EMP) is tested. Second, the CIS V asks whether the company applied for a patent in the period 2004-2006. This

[8] Obviously, this control variable only matters for domestic firms: foreign-owned firms by definition belong to a group.

information was translated into the dummy variable PATdum[9]. The variables TURNMAR, TURNMAR/EMP and PATdum however are only available as a lead variable for companies which are also observed in the CIS IV survey. Unfortunately, this results in a limited number of observations, as we loose the CIS III observations. To estimate a more general economic impact of R&D subsidies the net added value (the value of the output produced minus the costs of the intermediate goods) was computed from the Belfirst-database. The variable NAV_growth measures the growth of the deflated net added value of a company between 2005 and 2004 (2001 and 2000, respectively) and is linked to the firms observed in the CIS IV and III, respectively. An extra control variable, the one-year-lagged deflated net added value (NAV_{t-1}) was introduced to control for previous productivity. To avoid multicollinearity with size, this variable was normalized by the number of employees (NAV/EMP_{t-1}). The summary statistics of these variables can be found in Table 2.

Table 2: Summary statistics – output additionality

Variable	# obs.	Mean	Standard Deviation	Minimum	Maximum
TURNMAR	151	0.341	1.004	0	7.315
TURNMAR/EMP	151	2.277	3.917	0	23.878
PATdum	360	0.153	0.360	0	1
NAV_growth	1455	0.061	3.523	-32.927	61.845
NAV/EMP_{t-1}	1455	0.063	0.049	-0.848	0.702

5. Estimates

In this section, the estimation results are presented. First, I focus on the input side of the R&D process and measure potential additionality effects in terms of R&D expenditure and R&D intensity. In a second step, the impact on R&D spending due to public funding is first related to the output side of the R&D process, in terms of the share of new products in the turnover and the patenting propensity and second, to a more general economic indicator, i.e. the growth of the net added value realized by a company.

9 By using patent information from the CIS survey, I avoid the truncation problem which would occur if the EPO patent information would have been used.

As indicated in the methodological section, hybrid nearest neighbour matching with replacement is employed. To elucidate the role of foreign ownership in the additionality issue, the same matching procedure is conducted for three samples. First, the full dataset is used. Second, the full sample is split up according to ownership and potential additionality effects are evaluated for foreign-owned versus domestic firms. The propensity score $P(X)$ [10], lnEMP and YEAR[11] are used to select matched pairs with:

P(X) = f(FOREIGN, lnEMP, PROJ, PAT/EMP, EXQU, CAPINT/EMP, CASHF/EMP, SCOM, GROUP, YEAR, BR, BR_lnEMP). (7)

Full sample

The summary statistics in Appendix 1 show that funded and non-funded companies seem to exhibit different characteristics in both the outcome variables and the control variables. This is confirmed by two-sided t-tests[12]. Hence, the difference in outcome variables cannot be assigned as such to the receipt of a subsidy: a selection bias may be present here. Matching can solve this problem. First, the propensity to receive funding is estimated (see Table 3). As already indicated before, foreign-owned companies are significantly disadvantaged to receive a subsidy. This bias may be due to the applying (company) as well as the granting (government) side of the subsidy system. On the other hand, these foreign-owned firms receive a disproportionate amount of subsidies, potentially resulting in heterogeneous additionality effects, as hypothetically stated in this paper. Furthermore, size, experience in project applications, previous innovative activity and international competition are important determinants increasing the likelihood of being granted an R&D subsidy. Industry affiliation matters as well. As the interaction terms BR_lnEMP are jointly significant ($\chi^2(11) = 17{,}51^*$), I include them in the final propensity score estimates.

[10] Obviously FOREIGN is only included in the full sample; GROUP is only included when domestic firms are in the sample.
[11] YEAR is included to guarantee that companies are matched only to other companies observed in the same CIS wave. This overcomes the potential bias due to changes over time of the covariates and/or the outcome variables.
[12] Not reported, but available on request.

Table 3: Propensity to receive funding – full sample

	Probit estimates			Marginal effects		
	Coef.		Std.Err.	dy/dx		Std.Err.
FOREIGN°	-0.4530	***	0.1156	-0.1123	***	0.0254
lnEMP	0.0994	***	0.0372	0.0273	***	0.0102
PROJ	0.5459	***	0.0634	0.1497	***	0.0188
PAT/EMP	0.1018	***	0.0268	0.0279	***	0.0074
EXQU	0.7320	***	0.1348	0.2007	***	0.0364
CAPINT/EMP	0.0670		0.3383	0.0184		0.0928
CASHF/EMP	0.7975		0.5694	0.2187		0.1565
SCOM	0.1515		0.0934	0.0415		0.0256
GROUP°	0.1208		0.1024	0.0330		0.0278
YEAR°	-0.1977	**	0.0857	-0.0542	**	0.0234
constant	-1.6875	***	0.2109			
BR	$\chi^2(11) = 20.97$, $p = 0.0337$					
Log-Likelihood	-607					
Pseudo R²	0.1951					
# obs.	1441					

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

The predicted propensity to receive a subsidy (the so-called propensity score), is combined with lnEMP and YEAR to select pairs of subsidized and very similar non-subsidized companies. T-tests (see Table 4) on the matched samples do no longer exhibit significant differences in the control variables foreign ownership, size, past project applications, patent stock, export ratio, capital intensity, cash flow, absorptive capacity, group membership, industry affiliation and the probability to receive funding. However, the differences in the outcome variables remain significant: the funded companies are more R&D active; they spend more on R&D both in absolute terms (0.636 million EUR, or 58%) and in proportion to the turnover (2.73%, or 52%). The crowding-out hypothesis is rejected: the average R&D expenditure and the average R&D intensity have increased due to the public funding of R&D.

Table 4: Descriptive statistics after matching – full sample

	Subsidized companies		Selected control group		------------ α ° -------------		
	Mean	Std.Err.	Mean	Std.Err.			
RD	1.0962	0.1695	0.4598	0.0711	0.6364	***	58%
RDint	5.2155	0.5427	2.4869	0.3158	2.7286	***	52%
lnRD	-2.4131	0.1932	-4.5537	0.2405	2.1406	***	
lnRDint	-0.4997	0.1874	-2.5835	0.2325	2.0838	***	
# obs.	297		297				

Note: the control variables (FOREIGN, lnEMP, PROJ, PAT/EMP, EXQU, CAPINT/EMP, CASHF/EMP, GROUP, SCOM, YEAR, BR and BR_lnEMP) as well as the propensity scores are not significantly different after the matching and therefore not reported here. 16 funded companies were deleted due to common support restrictions.
° *** (**,*) indicate a significance level of 1% (5, 10%) of the t-tests on mean equality between the sample of funded firms and the selected control group. α is the average treatment effect of a subsidy on the funded firms. The relative difference is calculated as $\alpha_{TT}^{M} / E(Y_i^T | S_i = 1, X_i = x)$ .These statistics are based on Lechner's (2001) asymptotic approximation of the standard errors that accounts for sampling with replacement in the selected control group.

The next step now is to split the full sample according to ownership in foreign-owned and domestic companies and repeat the analysis.

Foreign sample

Again, a probit model is estimated to obtain a score for the propensity to receive public R&D funding. In the subsample of foreign-owned firms, size, past project applications and the export ratio positively influence the likelihood to receive a subsidy (see Table 5).

Table 6 presents the differences in the outcome variables after the matching. Also for the subsample of foreign-owned firms, the hypothesis of full crowding-out can be rejected.

Table 5: Propensity to receive funding – foreign sample

	Probit estimates			**Marginal effects**		
	Coef.		**Std.Err.**	**dy/dx**		**Std.Err.**
lnEMP	0.1706	**	0.0715	0.0497	**	0.0207
PROJ	0.8180	***	0.1527	0.2382	***	0.0519
PAT/EMP	0.0107		0.0605	0.0031		0.0176
EXQU	0.7054	**	0.2996	0.2054	**	0.0856
CAPINT/EMP	0.7180		1.1021	0.2091		0.3213
CASHF/EMP	-0.4756		2.1239	-0.1385		0.6180
SCOM	-0.0405		0.1858	-0.0118		0.0541
YEAR°	-0.3911	**	0.1899	-0.1117	**	0.0522
constant	-2.1909	***	0.5617			
BR	$\chi^2(10) = 8.79$, $p = 0.5517$					
Log-Likelihood	-140.6634					
Pseudo R²	0.2984					
# obs.	361					

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

Table 6: Difference in R&D effort after the matching – foreign sample

	Subsidized companies		Selected control group		------------------- α ° --------------------		
	Mean	Std.Err.	Mean	Std.Err.			
RD	1.7345	0.3250	0.6316	0.1410	1.1029	***	64%
RDint	3.3398	0.6632	1.5548	0.4845	1.7850	*	53%
lnRD	-1.1122	0.3475	-2.9090	0.4103	1.7968	**	
lnRDint	-0.3621	0.3011	-1.8293	0.3553	1.4672	**	
# obs.	75		75				

Note: Although BR_lnEMP were not jointly significant (χ^2 (10) = 5.51 p = 0.8548), they were included in the final propensity score for the sake of comparison with the other matching analyses. The control variables (lnEMP, PROJ, PAT/EMP, EXQU, CAPINT/EMP, CASHF/EMP, SCOM, YEAR, BR and BR_lnEMP) as well as the propensity scores are not significantly different after the matching and therefore not reported here. 13 funded companies were deleted due to common support restrictions.

° *** (**,*) indicate a significance level of 1% (5, 10%) of the t-tests on mean equality between the sample of funded firms and the selected control group. α is the average treatment effect of a subsidy on the funded firms. The relative difference is calculated as $\alpha_{TT}^{M} \big/ E\left(Y_i^T \middle| S_i = 1, X_i = x\right)$. These statistics are based on Lechner's (2001) asymptotic approximation of the standard errors that accounts for sampling with replacement in the selected control group.

Domestic sample

In the last step, the additionality analysis focuses on the subsample of domestic firms. The probit model (see Domestic sample in Table 7) signals the impact of past project applications, patent stock, and export ratio. After the matching the differences in outcome variables remain significant (see Domestic sample in Table 8): on average, a subsidy stimulates private R&D spending with 0.580 million EUR and the R&D intensity with 3.7%.

Now I proceed and compare the additionality effects of foreign-owned and domestic firms by evaluating the differences in outcome variables between the funded and non-funded companies for each group. However, one could criticize this approach, as foreign-owned and domestic companies may well be very different. For example, foreign-owned firms are typically larger than domestic firms. This may be correlated to the R&D activity and bias our comparison of additionality effects between foreign-owned and domestic firms. Therefore, the analysis of domestic firms was refined, by selecting a subsample of domestic firms which is similar to the sample of foreign-owned firms with respect to size, regional location and industry affiliation[13]. The estimates for the propensity score (see "Domestic subsample" in Table 7) are slightly different, but the additionality effects remain strongly positive (see "Domestic subsample" in Table 8): on average, funded companies spend 1.237 million EUR more on R&D and their R&D intensity exceeds that of non-funded companies with 2.9%.

[13] The subsample of domestic firms was selected in a hybrid matching model without replacement, selecting on similarities in the variables FUN, lnEMP, 11 industry dummies and 4 regional dummies. The number of observations reduces to 347.

Table 7: Propensity to receive funding – domestic sample

	Probit model Coef.	Marginal effects dy/dx	Probit model Coef.	Marginal effects dy/dx
	Domestic sample		Domestic subsample	
lnEMP	-0.0077	-0.0018	-0,0074	-0,0022
	(0.0406)	(0.0093)	(0.0871)	(0.0265)
PROJ	0.5748 ***	0.1317 ***	0.5095 ***	0.1549 ***
	(0.0687)	(0.0166)	(0.1365)	(0.0434)
PAT/EMP	0.1111 ***	0.0255 ***	0.1767 **	0.0537 **
	(0.0274)	(0.0064)	(0.0828)	(0.0259)
EXQU	0.4937 ***	0.1131 ***	0.9017 ***	0.2742 **
	(0.1415)	(0.0322)	(0.2630)	(0.0791)
CAPINT/EMP	-0.0165	-0.0038	2.2620	0.6879
	(0.3869)	(0.0887)	(2.2130)	(0.6731)
CASHF/EMP	0.8376	0.192	0.0972	0.02956
	(0.7379)	(0.1696)	(5.9211)	(1.8007)
SCOM	0.181 *	0.0415 *	0.1800	0.0547
	(0.1008)	(0.0231)	(0.1733)	(0.0525)
GROUP*	-0.148	-0.034	0.3207 *	0.0959 *
	(0.1006)	(0.0231)	(0.1858)	(0.0543)
YEAR*	-0.1425	-0.0327	-0.1368	-0.0413
	(0.0911)	(0.0209)	(0.1799)	(0.0538)
constant	-1.2122 ***		-1.5188 ***	
	(0.2196)		(0.4752)	
BR	χ^2 (11) = 15.64 p = 0.1551		χ^2 (11) = 8.68 p = 0.6518	
Log-Likelihood	-522.24896		-158.5842	
Pseudo R²	0.1422		0.2057	
# obs.	1353		347	

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

Table 8: Difference in R&D effort after the matching – domestic sample

	Subsidized companies Mean	Subsidized companies Std.Err.	Selected control group Mean	Selected control group Std.Err.	------------ α ° -------------		
Domestic sample							
RD	0.9007	0.2067	0.3204	0.0734	0.5803	**	64%
RDint	5.6354	0.6765	1.9062	0.2898	3.7292	***	66%
lnRD	-2.8590	0.2239	-5.4189	0.2749	2.5599	***	
lnRDint	-0.5586	0.2298	-3.3214	0.2723	2.7628	***	
# obs.	218		218				
Domestic subsample							
RD	1.5326	0.4591	0.2952	0.0532	1.2374	***	81%
RDint	4.2369	0.9879	1.3863	0.2449	2.8506	***	67%
lnRD	-2.1221	0.3444	-4.5588	0.4396	2.4367	***	
lnRDint	-0.5748	0.3214	-2.8101	0.4103	2.2353	***	
# obs.	85		85				

Note: BR_lnEMP ($\chi^2(11) = 21.65$ - $p = 0.0272$ for the full domestic sample and $\chi^2(11) = 4.76$ - $p = 0.9420$ for the domestic subsample) were included as well in the final propensity score. The control variables (lnEMP, PROJ, PAT/EMP, EXQU, CAPINT/EMP, CASHF/EMP, GROUP, SCOM, YEAR, BR and BR_lnEMP) as well as the propensity scores are not significantly different after the matching and therefore not reported here. 7 and 6 funded companies were deleted due to common support restrictions from the full and subsample, respectively.
° *** (**,*) indicate a significance level of 1% (5, 10%) of the t-tests on mean equality between the sample of funded firms and the selected control group. α is the average treatment effect of a subsidy on the funded firms. The relative difference is calculated as $\alpha_{TT}^{M} / E\left(Y_i^T \middle| S_i = 1, X_i = x\right)$. These statistics are based on Lechner's (2001) asymptotic approximation of the standard errors that accounts for sampling with replacement in the selected control group.

The crowding-out hypothesis is rejected for both foreign-owned and domestic firms. However, there seem to be differences in the size of the treatment effect. In general, the R&D intensity of subsidized firms is 2.7% higher than the R&D intensity of non-subsidized firms. However, the additionality effect on R&D intensity for foreign-owned firms is only 1.8%, while the effect for domestic firms is 3.7%. Even if I correct for the potential selection bias and only consider a selected sample of domestic companies[14], the impact of a subsidy on the R&D intensity is still larger (2.9%). Econometric tests however did not provide robust proof to support the significance of the difference in input additionality for foreign-owned and domestic firms. Nevertheless, as only a very limited number of foreign-owned companies receives a large part of the total subsidy amount available in Flanders, it is remarkable that there is no evidence indicating that the impact of subsidies is larger for foreign-owned companies.

Next, I concentrate on the output side of the innovation system and evaluate the effect of R&D subsidies on innovative output as well as economic value. As outlined in the methodological section, the estimates from the input additionality analysis allow disentangling private and publicly induced R&D expenditure. Subsequently, I can also unravel their respective impact on our new set of outcome variables. RDC represents the counterfactual R&D expenditure, i.e. the investment a company would have made in the absence of the subsidy system. RDdif measures the R&D expenditure which was induced by the subsidy. Obviously, the value for RDC of non-funded firms just equals their R&D spending as they reported it and their RDdif value is zero. The new set of outcome variables is fourfold: TURNMAR (share of new to the market products in the turnover * turnover in 2005), TURNMAR/EMP (TURNMAR divided by the number of employees), PATdum (a dummy variable reflecting patent applications between 2004 and 2006) and NAV_growth (the growth of the net added value, between t+1 and t). For TURNMAR and TURNMAR/EMP a censored regression (cnreg) was conducted, as well as ordinary regression (reg) (as a robustness check). PATdum was included in a probit model, and NAV_growth was plugged in into an ordinary regression. Additional covariates in the models are size (EMP) and industry affiliation (BR). In the model

[14] Different shares of non-innovators in the potential control group may provide an additional explanation as to why the treatment effects are lower when only a selected subsample of domestic firms is taken into account. The share of innovators in the total sample (1441 observations) amounts to 65%. The matching procedure enforces a high level of similarity between the funded (and per definition innovative) companies and non-funded (both innovative and potentially non-innovative) companies, including variables reflecting the innovative and technological strength of companies. As a result, the selected control group contains a large share of innovative companies and in the matched samples, the share of non-innovators is rather limited: 13% in the full matched sample (297 pairs); 14% in the domestic matched sample (218 pairs), 9% in the domestic matched subsample (85 pairs) and 5% in the foreign matched sample (75 pairs). T-tests reveal that the share of innovators is indeed significantly larger (p-value = 0.0001), when comparing the full domestic (436 companies) with the foreign (150 companies) matched samples. When we only take the subsample of domestic firms into account, the share of non-innovators is only slightly significantly higher (p-value = 0.0951) in the domestic matched sample (170 companies) compared to the foreign sample (150 companies). As a further robustness check, we conducted the analysis presented in the paper, but filtered out all non-innovators from the potential control group. The number of observations obviously drops significantly in the propensity score estimations, but apart from that, the results remain very similar.

estimating the impact on NAV_growth, the lagged value of the net added value per employee was included, to control for previous productivity, as well as the year of observation (YEAR =1 for CIS IV observations, as again pooled data from the CIS III and IV surveys is used). In a first series of regressions, a dummy variable indicating whether the company is a domestic firm (DOMESTIC = 1) is introduced, in addition to RDC and RDdif. The results are displayed in Table 9. Both RDC and RDdif have a significantly positive impact on the share of new products in the turnover and the patenting propensity: larger R&D efforts are efficiently translated into more R&D output. Remarkably, also the publicly induced private R&D spending delivers a significantly positive innovative output. Tests show that the coefficient of RDdif even is significantly larger than the coefficient of RDC in the probit model: the additionally leveraged R&D expenditure apparently is being used in a more efficient way, resulting in more innovative output. This is a positive result, as one could argue that publicly induced R&D investments are allocated to more risky projects and therefore not result in more innovative output (Setter and Tishler, 2005 and Aerts et al., 2007). RDC positively influences the growth of the net added value, but the publicly induced R&D expenditure does not seem to foster company growth. Overall, the conclusion is very optimistic, because the results confirm that R&D subsidies not only stimulate R&D input, but also positively influence R&D output. A positive impact on the economic value can not be supported empirically, though.

Surprisingly, the coefficient of DOMESTIC is significant and negative in some specifications. This may reflect heterogeneous effects for domestic versus foreign-owned firms. That is why a second bundle of very similar, but more flexible models is estimated. I now allow the coefficient estimates of RDC and RDdif to be different, depending on the ownership status, i.e. RDC and RDdif are interacted with DOMESTIC and FOREIGN (= 1-DOMESTIC), resulting in the variables RDCDOM, RDCFOR, RDdifDOM and RDdifFOR. The advantage of this set-up is that the regression coefficients and the probit marginal effects are directly comparable for the domestic and foreign-owned firms. The results (see Table 10) now demonstrate a more detailed picture and provide insight on the heterogeneous output effects of R&D subsidies. As expected, the counterfactual R&D expenditure has a positive impact on the share of new to the market products in the turnover, the patenting probability and the growth of the net added value, which is in line with the previous results. I also find proof to state that R&D subsidies and the subsequently induced R&D expenditure raise the share of new to the market products in the turnover and the patenting propensity. An astonishing result however, is that the censored regression model for TURNMAR and the probit model for PATdum provide evidence to conclude that the additionality effect is larger for foreign-owned firms. If we focus our attention to NAV_growth, it can be noticed that there is no significant effect stemming from the additional R&D expenditure of domestic firms, but in contrast a significantly positive impact on foreign-owned firms.

The current models investigate potential heterogeneity in domestic and foreign-owned firms. However, to some extent, this heterogeneity may be alleviated by the fact that the group of domestic firms includes independent companies as well as companies belonging to a Belgian group. Therefore, as a robustness check, an interaction term (DOMESTIC*GROUP) was included in the model presented in Table 10. The new variable only had a slightly significant positive impact in the probit model estimating the propensity to patent, but did not introduce any change in the remaining results.

Table 9: Additionality effects at the R&D output side I

Variable	TURNMAR (in mio €)		TURNMAR/EMP (in thsd €)		PATdum (dummy)		NAV_growth (in mio €)
	cnreg	reg	cnreg	reg	probit coefficients	marginal effects dy/dx	reg
NAV/EMP $_{t-1}$							-20.3390 **
							(9.0592)
DOMESTIC°	-0.3106 **	-0.1811	-1.6484 *	-0.8423	-0.3773 *	-0.0852 *	-0.0849
	(0.1322)	(0.1447)	(0.8648)	(0.6215)	(0.1958)	(0.0475)	(0.3277)
RDC	0.3278 ***	0.3170 ***	0.7411 ***	0.683 ***	0.2023 *	0.0411 *	0.4753 ***
	(0.0322)	(0.0473)	(0.2231)	(0.1669)	(0.1038)	(0.022)	(0.1680)
RDdif	0.3580 ***	0.3411 ***	1.0207 ***	0.8986 **	0.7322 **	0.1486 **	0.2479
	(0.0324)	(0.0724)	(0.2271)	(0.4244)	(0.3199)	(0.0727)	(0.2693)
EMP			-0.0053 ***	-0.0045 ***	0.0012 **	0.0002 ***	-0.0012
			(0.0019)	(0.0012)	(0.0004)	(0.0001)	(0.0010)
YEAR							0.2735
							(0.2102)
constant	0.4708 ***	0.5010	2.7486 **	2.8777 ***	-1.571 ***		1.1955
	(0.1764)	(0.3262)	(1.2596)	(0.7961)	(0.3733)		(0.8139)
BR	F(11. 137) = 1.73	F(11. 136) = 1.43	F(11. 136) = 0.74	F(11. 135) = 1.46	$\chi^2(11) = 18.84$		F(11.1437) = 2.88
	p = 0.0735	p = 0.1676	p = 0.6942	p = 0.1548	p = 0.0640		p = 0.0010
Tests				**RDC - RDdif = 0**			
	F(1.137) = 0.48	F(1.136) = 0.09	F(1.136) = 0.95	F(1.135)= 0.29	$\chi^2(1) = 2.76$		F(11.1437)= 0.98
	p = 0.4918	p = 0.7672	p = 0.3313	p = 0.5942	p = 0.0964		p = 0.3329
Number of obs.:	151	151	151	151	360		1455
(Pseudo) R^2	0.3453	0.7033	0.0473	0.2405	0.2435		0.1194

Standard errors (between brackets) are heteroscedasticly consistent
*** (**, *): significant at 1% (5%, 10%)
° dy/dx is for discrete change of dummy variable from 0 to 1

Table 10: Additionality effects at the R&D output side II

Variable	TURNMAR (in mio €)		TURNMAR/EMP (in thsd €)		PATdum (dummy)		NAV_growth (in mio €)
	cnreg	**reg**	**cnreg**	**reg**	**coefficients**	**marginal effects dy/dx**	**reg**
NAV/EMP $_{t-1}$							-19.7953 **
							(8.8982)
DOMESTIC°	-0.2700 *	-0.1623 **	-0.7252	-0.0977	-0.2078	-0.0514	0.0714
	(0.1450)	(0.0804)	(0.9456)	(0.6222)	(0.2287)	(0.059)	(0.2945)
RDCDOM	0.3421 ***	0.3368 ***	0.5719 **	0.5431 ***	0.4369 *	0.1024 *	0.4564 ***
	(0.0348)	(0.0490)	(0.2453)	(0.0921)	(0.2422)	(0.0591)	(0.1647)
RDCFOR	0.2959 ***	0.2620 ***	1.6535 ***	1.4371 *	0.2705 *	0.0634 *	0.6086 *
	(0.0747)	(0.0387)	(0.4910)	(0.2130)	(0.1443)	(0.0344)	(0.3245)
RDdifDOM	0.3279 ***	0.3109 ***	0.9445 ***	0.8305 ***	0.3551 *	0.0833 *	-0.0393
	(0.0345)	(0.0550)	(0.2340)	(0.4381)	(0.1992)	(0.0496)	(0.1533)
RDdifFOR	0.5110 ***	0.4999 *	1.4757 ***	1.3004 **	4.5903 ***	1.0765 ***	0.8596 *
	(0.0785)	(0.2572)	(0.5618)	(0.5381)	(1.4261)	(0.4111)	(0.5043)
EMP			-0.0055 ***	-0.0047 ***	0.0012 ***	0.0003 ***	-0.0014
			(0.0019)	(0.001)	(0.0005)	(0.0001)	(0.0010)
YEAR							0.2973
							(0.2049)
constant	0.3939 **	0.4348 **	2.0598	2.2806 **	-1.9307 ***		0.9995
	(0.1827)	(0.1917)	(1.2779)	(0.7040)	(0.4687)		(0.7459)
BR	F(11.135) = 1.51 p = 0.1347	F(11.134) = 1.45 p = 0.1593	F(11.134) = 0.84 p = 0.5968	F(11.133) = 1.54 p = 0.1252	χ²(11) = 20.54 p = 0.0384		F(11. 1435) = 2.91 p = 0.0008
Tests				**RDCdom - RDdifdom = 0**			
	F(1.135)= 0.09 p = 0.7678	F(1.134)= 0.12 p = 0.7289	F(1.134)= 1.37 p = 0.2439	F(1.133)= 0.44 p = 0.5076	χ²(1) = 0.08 p = 0.7809		F(1.1435) = 8.32 p = 0.0040
				RDCfor - RDdiffor = 0			
	F(1.135)= 4.30 p = 0.0399	F(1.134)= 1.00 p = 0.3200	F(1.134)= 0.06 p = 0.7995	F(1.133)= 0.06 p = 0.8036	χ²(1) = 9.56 p = 0.0020		F(1.1435) = 0.33 p = 0.5639
				RDCdom - RDCfor = 0			
	F(1.135)= 0.32 p = 0.5755	F(1.134)= 1.59 p = 0.2102	F(1.134)= 4.03 p = 0.0466	F(1.133)= 14.50 p = 0.0002	χ²(1) = 0.33 p = 0.5631		F(1.1435) = 0.20 p = 0.6517
				RDdifdom - RDdiffor = 0			
	F(1.135)= 4.55 p = 0.0347	F(1.134)= 0.53 p = 0.4699	F(1.134)= 0.82 p = 0.3664	F(1.133)= 0.52 p = 0.4723	χ²(1) = 8.60 p = 0.0034		F(1.1435) = 2.95 p = 0.0860
Number of obs.:	151	151	151	151	360		1455
(Pseudo) R²	0.3570	0.7192	0.0538	0.2665	0.3012		0.1342

Standard errors (between brackets) are heteroscedasticly consistent
*** (**, *): significant at 1% (5%, 10%)
° dy/dx is for discrete change of dummy variable from 0 to 1

6. Conclusion

The large presence of foreign-owned companies in Flanders, especially in R&D intensive industries, combined with a limited number of foreign affiliates receiving the lion share of Flemish R&D subsidies, raises questions about the impact of foreign ownership on the effectiveness of public R&D funding. In a first step, the additionality effect on R&D expenditure was investigated into detail, employing a semi-parametric matching approach. It was found that R&D subsidies are effective, in the sense that they induce R&D investments, both in domestic and foreign firms. The difference in additionally invested R&D budgets however, is not significantly different between the two samples. This is remarkable, given that foreign affiliates typically receive larger grants. In a next step, I elaborated on the results from the matching procedure and disentangled the counterfactual, privately financed from the publicly induced, additional R&D expenditure. These R&D investment components were subsequently used as input factors for some productivity functions, in order to investigate potential differences in efficiency. The results show that in general, both R&D expenditure components are translated into more R&D output: they both have a significantly positive impact on the share of new products in the turnover, as well as on the patenting activity. Only the counterfactual R&D expenditure adds to the economic value, though. Lastly, I analyzed whether efficiency differences exist in foreign-owned versus domestic firms. The tests show that both groups experience positive additionality effects, but also that foreign-owned firms use publicly induced R&D expenditures in a more efficient way: compared to the domestic firms, the share of new products in the sales, as well as the patenting activity, realized by the publicly induced R&D expenditure, is higher. Moreover, separating the foreign-owned firms shows that, in contrast to the domestic firms, they also capitalize growth of the net added value with the publicly induced R&D investments. Görg and Strobl (2007) do not find any support for additionality effects in their sample of Irish foreign-owned firms, but emphasize that this does not imply that the public R&D funding was wasted, as these firms now exhibit positive R&D investments, which may otherwise have been undertaken abroad. In contrast to the Irish situation, Flemish foreign-owned affiliates receive a substantial amount of public R&D money and this paper shows that the effects for Flanders are positive.

My results are in line with the existing literature on superior innovative capabilities of foreign-owned firms. Although there are no significant differences in input additionality effects on domestic versus foreign-owned firms, the Flemish government's policy of allocating large R&D grants to a limited number of foreign-owned firms, seems to be guided by their outperforming status in innovative activity. This excellence in innovative efficiency may be driven by firm-specific assets encased in the MNE and easily accessible by its affiliates. The significantly positive impact of R&D subsidies on the net added value growth may emanate from better performance. However, a less optimistic and more down-to-earth, but not implausible explanation for foreign-owned firms' higher output effects could additionally be found in purely economic arguments. R&D subsidies are the main instrument which gives some power to the Flemish government to attract or keep foreign multinational activity in Flanders. Large MNEs may bluntly conduct their accounting evaluation exercises and consider R&D subsidies as a net inflow of money in their calculation of the net profit which can be realized in their subsidiaries. In this case, concluding that the growth of the net added value is a direct result of higher performance due to an R&D subsidy would rather be a deception.

Two caveats are called for with respect to the measurement of public R&D funding in this paper. First, only information on a company's funding status was used. This implies that the hypothesis is limited to testing for the presence of full crowding-out effects: the results show that funded firms spend more on R&D activities However, it is possible that companies do not add the whole subsidized amount to their privately budgeted R&D expenditure, which would translate into partial crowding-out effects. To provide a decisive answer to this hypothesis, information on the grant size is needed, though. Second, the funding system is based on projects, while this research evaluates companies. It is not unlikely that a funded project is complementary to other projects and that positive spillovers between projects are generated. Therefore, additionality effects at the firm level may be induced by a funded project but originate from other projects within the company. It is not my aim to evaluate additionality effects at the project level, though, as the government's aim is to increase companies' R&D input and output, irrespective of how this increase is generated.

I urge for further elaboration of the current study, and more specific on three aspects, as this would significantly improve our insights into heterogeneous additionality effects of R&D subsidies due to the ownership structure. First, including additional information on the subsidy, i.e. the grant size, the granting authority, the specificities of the subsidy program, etc. will allow further refinement. Second, the international R&D activity is worth a closer look: the degree of independence of the head quarters as well as intra-group knowledge flows and resource utilization may explain the better innovative performance of foreign affiliates, as they are likely to be correlated with the access to knowledge in the group as well as the extent to which affiliates can determine own topics to investigate in their R&D labs and the kind of R&D which is conducted (home-base-augmenting versus home-base-exploiting). In this respect, also the validity of the economic argument should be tested. Finally, the public authority's interest into the total impact of funding foreign-owned companies on the host economy and its innovative potential remains a valuable issue. Other indicators may be introduced. Moreover, taking a measure of embeddedness into account would allow scholars to also measure the more indirect impact on the host economy.

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Appendix 1: Summary statistics

Variable	# obs.	Mean	Standard Deviation	Min	Max	# obs.	Mean	Standard Deviation	Min	Max
FUN	1441	0.217	0.412	0	1					
FOREIGN	1441	0.258	0.438	0	1					
NOT FUNDED										
	domestic					**foreign-owned**				
OUTCOME VARIABLES:										
RD (in mio EUR)	844	0.114	0.454	0	8.904	284	0.563	3.102	0	49.468
RDint (in %)	844	1.296	4.510	0	56.602	284	1.141	3.391	0	31.818
lnRD	844	-7.087	3.548	-9.509	2.187	284	-5.571	4.258	-9.509	3.901
lnRDint	844	-4.836	3.725	-7.405	4.036	284	-3.924	3.760	-7.405	3.460
CONTROL VARIABLES:										
P(X)	844	0.169	0.133	0.019	0.977	284	0.165	0.129	0.007	0.965
lnEMP	844	3.451	1.096	0	6.978	284	4.575	1.337	2.079	7.672
PROJ	844	0.092	0.423	0	4	284	0.085	0.357	0	3
PAT/EMP	844	0.083	0.768	0	16.552	284	0.146	1.151	0	17.107
EXQU	844	0.286	0.314	0	1	284	0.499	0.390	0	1
CAPINT/EMP	844	0.037	0.134	0	3.638	284	0.042	0.083	0	0.780
CASHF/EMP	844	0.014	0.024	-0.089	0.464	284	0.015	0.057	-0.233	0.821
SCOM	844	0.774	0.437	0	3	284	0.903	0.520	0	3
GROUP	844	0.339	0.474	0	1	284	1	0	0	1
YEAR	844	0.528	0.499	0	1	284	0.482	0.501	0	1
FUNDED										
	domestic					**foreign-owned**				
OUTCOME VARIABLES:										
RD (in mio EUR)	225	1.006	3.418	0	25.152	88	3.384	8.051	0	63.552
RDint (in %)	225	5.629	9.893	0	56.576	88	4.492	8.423	0	49.862
lnRD	225	-2.821	3.327	-9.509	3.225	88	-0.666	3.008	-9.509	4.152
lnRDint	225	-0.540	3.388	-7.405	4.036	88	-0.130	2.561	-7.405	3.909
CONTROL VARIABLES:										
P(X)	225	0.365	0.252	0.039	1	88	0.437	0.290	0.052	1
lnEMP	225	3.912	1.341	0.693	7.763	88	5.429	1.376	1.946	7.847
PROJ	225	0.733	1.892	0	24	88	1.886	4.853	0	32
PAT/EMP	225	0.858	2.928	0	20	88	0.617	1.841	0	8.921
EXQU	225	0.483	0.337	0	1	88	0.736	0.260	0	1
CAPINT/EMP	225	0.036	0.049	0.000	0.374	88	0.046	0.069	0.001	0.500
CASHF/EMP	225	0.033	0.277	-0.310	4.141	88	0.018	0.020	-0.020	0.103
SCOM	225	0.924	0.462	0	3	88	1.107	0.595	0	3
GROUP	225	0.520	0.501	0	1	88	1	0	1	1
YEAR	225	0.476	0.501	0	1	88	0.352	0.480	0	1

Note: the details of BR and BR_lnEMP are not presented here.