FACULTEIT ECONOMIE EN
BEDRIJFSWETENSCHAPPEN

KATHOLIEKE
UNIVERSITEIT
LEUVEN

ESSAYS ON THE ECONOMICS OF EVALUATION

Public Policy and Corporate Strategies in Innovation

Proefschrift voorgedragen
tot het behalen van de graad
van Doctor in de Toegepaste
Economische Wetenschappen

door

Kris AERTS

Nummer 288

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Daar de proefschriften in de reeks van de Faculteit Economie en Bedrijfswetenschappen het persoonlijk werk zijn van hun auteurs, zijn alleen deze laatsten daarvoor verantwoordelijk.

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Prof. dr. Reinhilde Veugelers	K.U.Leuven

Chairman:

Prof. dr. Siegfried Dewitte	K.U.Leuven

On résiste à l'invasion des armées;
on ne résiste pas à l'invasion des idées.
Victor Hugo *(1802-1885)*

فمن رفع الأسباب فقد رفع العقل. وصناعة المنطق تضع وضعا أن ها هنا أسبابا و مسببات، و أن المعرفة بتلك المسببات لا تكون على التمام إلا بمعرفة أسبابها. فرفع هذه الأشياء هو مبطل للعلم و رافع له. فإنه يلزم ألا يكون ها هنا شيء معلوم أصلا علما حقيقيا، بل إن كان فمظنون! ولا يكون ها هنا برهان ولا حد أصلا، و ترتفع أصناف المحمولات الذاتية التي منها تأتلف البراهين! و من يضع أنه ولا علم واحد ضروري، يلزمه أ لا يكون قوله هذا ضروريا!

تهافت التهافت

ابن رشد (١١٢٦-١١٩٨)

" [...] he who denies causes must deny the intellect. Logic implies the existence of causes and effects, and knowledge of these effects can only be rendered perfect through knowledge of their causes. Denial of cause implies the denial of knowledge, and denial of knowledge implies that nothing in this world can be really known, and that what is supposed to be known is nothing but opinion, that neither proof nor definition exist, and that the essential attributes which compose definitions are void. The man who denies the necessity of any item of knowledge must admit that even this, his own affirmation, is not necessary knowledge."

The incoherence of incoherence
Averroes *(1126 -1198)*

Silent gratitude isn't much use to anyone
Gladys Bronwyn Stern *(1890 - 1973)*

A word of thanks

This small booklet brings a five year project to a close. It took me through ups and downs and the necessary blood, tears and sweat were shed. Nevertheless, I look back with joy and satisfaction to this challenging period. Obviously, I cannot take all the credit on my own account; this final result was achieved standing on the shoulders of many other people. Therefore, I would like to seize this opportunity and express my gratitude to all of you.

First, I wish to thank my supervisor Dirk Czarnitzki for his coaching. He issued me with an extremely valuable researchers' starting kit and contaminated me with his appetite for research. A great deal of inspiration in this work is at his expense. He kept me on the right track, but at the same time left me with plenty degrees of freedom and forced me to unfurl my own creativity. Besides his valuable feedback during the elaboration of this PhD project, he also offered me the opportunity to work with him on various other research projects. Many publications sprang from this teamwork and embroidered my research experience. The first two chapters in this dissertation are adapted from our joint publications.

My scientific career started at the Steunpunt O&O Indicatoren (at that time the Steunpunt O&O Statistieken). The project work on the innovation and R&D surveys and related government requests energized my interest for research and the decision to start working on a PhD was quickly made. At the Steunpunt I very much appreciated the opportunity to work in close relationship with Koenraad Debackere and Reinhilde Veugelers and subsequently was thrilled when they agreed to be in my PhD committee. In a later stage of my PhD, I was very happy to welcome Kornelius Kraft and Pierre Mohnen as committee members and very much enjoyed receiving their valuable ideas and suggestions.

My gratitude also goes to the two co-authors who contributed significantly to my research experience and the research presented in this dissertation. During a short but highly productive visit to the Centre for European Economic Research (ZEW), I enjoyed the opportunity to work together with Tobias Schmidt on the paper which is presented here in the third chapter and which has recently been published in

Research Policy. This was a wonderful reward for our hard work. The sixth chapter in this dissertation is the result of a pleasant and fruitful research collaboration with Kornelius Kraft from the Technical University of Dortmund. He shared his precious insights with me and was always very eager to discuss the progress in our research. I am very grateful for his enthusiastic feedback and comments. Julia Lang acted as a conscientious middlewoman in facilitating access to the data used in this research and she deserves special thanks. I also gratefully acknowledge the German hospitality from the ZEW and the Technical University of Dortmund and my short-term colleagues, who turned these two research visits into a very enjoyable experience: many thanks to Bettina, Birgit, Christian, Christoph, Diana, Elisabeth, Georg L., Georg M., Hannes, Heide, Heidi, Heidrun, Helmut, Julia, Katrin, Michaela, Patrick, Stefan, Stefanie and Wolfgang,

After my first years at the Steunpunt, I joined the department of Managerial Economics, Strategy and Innovation and I nourish many warm memories of all colleagues, from discussions about work, joint complaint sessions, but also 'normal talks' about 'normal life': Anneleen, Annie, Arnold, Balázs, Bart L., Bart T., Bart V.L., Bruno, Cathy, Cédric, Elisa, Florence, Hanna, Isabelle, Italo, Ivanka, Jan, Jenne, Jesse, Julie, Karen, Katrin, Linda, Machteld, Mariette, Neus, Petra, Pluvia, Raymond, Rene, Sara, Shinya, Stephanie, Stijn, Susanne, Tom, Vincent, Wolfgang, Wouter and Xiaoyan. Ciao Dottore, I will miss our coffee breaks. Special thanks go to Dani: she has been an anchor in all administrative support.

My very first research interest was excited by Koen Vandenbempt and Paul Matthyssens from the University of Antwerp, during the completion of my Master thesis. I owe them many thanks for their guidance during my first steps in the world of research. The research presented here benefited from input from IWT (the Institute for the Promotion of Innovation through Science and Technology in Flanders). More specifically I would like to thank Donald Carchon and Eric Sleeckx for their time and valuable contributions. I am also grateful to the Institute for Employment Research (IAB) for access to their data. This PhD project was partly supported by the FWO (Fund for Scientific Research); its financial support is greatly acknowledged.

This brief moment also offers the right occasion to thank my family: my mom, for enduring my endless lamentations, my dad, for reminding me that a PhD project

typically consists of 90% transpiration and 10% inspiration, and my brother and Charlotte, for the welcome distraction and for sharing a passion for Arabic. I want to thank my grandparents for their support: bedankt moeke en voke; bedankt oma en opa! Dankjewel Ava en Roald: nu heb ik terug speeltijd! Also many thanks to Lena, Jean-Marie and Xavier for the numerous 'green breaks', which boosted my energy to continue and to Flap and Frodo for their soft fur and playfulness.

Working on a PhD can be a very lonely job. Fortunately, a great many of friends helped me through difficult moments, but we also lived through many thrilling adventures. Thanks to Maaike and Bjorn, for the joint sessions of cursing the rain or wind, but never giving in on our jogging date, to Aicha, Julie, Silvia and Tine for all desert fun, to Tineke and Tino for sharing their happiness, to Astrid, Kristof, Murielle, Tessa, Sebe, Klara, Joris, Jan, Lien, Frederik and Mieke for keeping our secondary school memories alive, to Pia for the nice cultural breaks, to Maaike and Davy, for the 'kotsupport' and to Petra and Piet for bringing Ghent alive.

Finally, I would like to thank Pascal, for knowing when to cheer me up or have a laugh but also when to avoid me, and even knowing this long before I do. You taught me that life is not always about research. You cured me of the reflex I caught during my academic career: sometimes you don't have to go looking for things and investigate reasons. Every now and then you just bump into nice things, without any explanation, for no reason at all; it just happens.

In the meantime I have tabbed a new barrel, which is at the same time very familiar. My very first research entailed business incubators. After that, I continued with investigating public and private tools to intervene in the market for innovation. I gained many relatively theoretical insights in the innovation system and its players. Now, I am very happy to get the opportunity to work at the Technology Transfer Office of the K.U.Leuven, K.U.Leuven Research and Development, and to dig into the 'real life' behind the theory. My new job experience will yield another interesting view on the fascinating world of new technologies and in a way, I go back to my roots of Commercial Engineer. I am grateful for the confidence I received and look forward to taking up new challenges.

Thank you all!

Kris Aerts
Leuven, October 2008

ESSAYS ON THE ECONOMICS OF EVALUATION

PUBLIC POLICY AND CORPORATE STRATEGIES IN INNOVATION

Preface

R&D and innovation foster economic growth and hence, the innovative capacity of economic actors has become a key asset in current economic systems, next to the traditional input factors labour and capital. Both on the public as well as on the private level, incentive structures have been introduced to stimulate innovative activity. The natural question which forces itself in this respect, sounds out to the effectiveness of these measures since, unlike the often widespread confidence in their merit, there are indications that in the end they may not bring about the desired added value. Therefore, it is imperative to evaluate the actual effectiveness of these measures.

This doctoral thesis attempts to advance the literature on evaluation economics both on the level of methodology as well as content. This research question entails one very specific problem, i.e. the issue of selectivity. Typically, the measure (or more formally 'treatment') does not apply randomly to all subjects. Moreover, what is even worse in the framework of evaluation economics, the treatment is often expected to be highly correlated with the impact the measure is intended to generate. This introduces endogeneity in the evaluation model and requires econometric correction. Different econometric methods have been developed to take the potential endogeneity in evaluation research into account, each with specific advantages and disadvantages. As many techniques will be employed in this dissertation, **Chapter 1** provides a concise summary of these econometric methods.

The main part of this work, covering chapters two to five, focuses on the perspective of public policy and evaluates the impact of public funding on private R&D activity. The so-called crowding-out hypothesis is assessed: do R&D grants crowd out private R&D activity? The last part of this dissertation, chapter six, zooms in on a particular corporate remuneration strategy: profit-sharing. The introduction of this incentive scheme, in addition to the going wage, is related to companies' innovative performance. In the remaining of this preface, a brief introduction to both parts is provided.

Public innovation policy

There are three main reasons why the market for R&D fails. First, the outcome of a company's R&D activities is always uncertain. Increased R&D expenditures increase the likelihood of obtaining successful R&D output, but nevertheless, the level of uncertainty remains significant (Dasgupta and Maskin, 1987). Second, if a company generates a positive outcome from its R&D activities, it will never be able to appropriate all returns, as other companies may use some of this knowledge, which is intangible and therefore diffuses very quickly and easily into the public domain (Arrow, 1962). Next to these negative externalities, companies may experience difficulties in raising external capital, due to moral hazard and asymmetric information (Himmelberg and Petersen, 1994).

These theoretical arguments predict that the actual level of R&D spending will be lower than what would be socially desirable. Hence, this argument justifies government intervention in the market for R&D. A strong education system, generating a large pool of highly skilled researchers, constitutes the ideal foundation for effective and efficient knowledge generation. Another essential publicly regulated measure to alleviate imperfections in the market for R&D is the protection of intellectual knowledge through the patent system. In the first part of this dissertation, I zoom in on yet another public measure, i.e. public funding of private R&D activity. There are two main intervention modes, i.e. direct funding through subsidies and indirect funding through tax credits. In this work, the attention is focused on the direct intervention tool: public R&D grants. An R&D subsidy reduces the price of an R&D project and may render its expected net profit positive, despite the market imperfections. Firms are expected to behave rationally and as a result, the firm is expected to conduct this socially valuable R&D project, which would never be undertaken in the absence of the subsidy.

However, companies behave rationally in another way as well: they may always apply for a subsidy, even when it would not be necessary. The government is disadvantaged by asymmetric information and may approve to fund this project. In that case, the company's R&D expenditure would not increase, although exactly this was the aim of the government. Hence, it is crucial to assess the effectiveness of public innovation policy. In the first part of this dissertation, the impact of public

R&D funding is looked into, assessing the crowding-out hypothesis: "Do companies replace (part of) their private R&D budget with the public R&D grant?".

This calls for a treatment effects analysis and entails a potential danger of selectivity. Subsidy receipt may be highly correlated with R&D activity, which would render the treatment endogenous. On the one hand, the government provides money and may try to maximize the rate of return on its investment. Therefore, it may cherry-pick companies performing well in R&D, as this will increase the expected net value from the R&D subsidy. On the other hand, also at the company side, selectivity may play. Very R&D active firms may be better aware of the public measures they qualify for, or they may be able to write better project proposals, both increasing the likelihood of receiving a public R&D grant. Obviously, the risk of endogeneity is significant and has to be addressed properly. **Chapter 1** concisely guides the reader through a selection of approaches which allow correcting for this potential selectivity. In part one, covering chapters two to five, the Flemish R&D funding system will be the main public intervention tool to be evaluated. Therefore, **Chapter 2** first provides an introduction into public innovation policy in general and more specifically, it also sketches the details of the policy framework in Flanders.

Additionality research has been undertaken in many countries in recent years, but the results remain unclear. Some reject, while others accept the crowding-out hypothesis. An important explanation can be found in the use of different datasets (David and Hall, 2000). Data are collected in different set-ups and periods, cover different observation windows and use different definitions. Different data call for different techniques to take potential selectivity into account, which implies caveats on the comparability of different research results. In **Chapter 3** of this thesis, together with my co-author, dr. Tobias Schmidt, I employ an identical methodology, using identical firm-level data for Flanders and Germany. We first employ the commonly used matching technique and then extend this methodology with the conditional difference-in-differences approach for repeated cross-sections, which has, until now, been unexplored in the domain of additionality research. R&D expenditure and R&D intensity, measured as R&D expenditure over sales, are our outcome variables of interest.

However, as David and Hall (2000) suggest: 'the more the better' is a questionable statement when it comes to R&D expenditure. Mere R&D expenditures may not constitute a sufficiently adequate measure to evaluate the effectiveness of R&D subsidies. The lack of qualified personnel is amongst the key factors hampering innovative activity (Mohnen et al., 2008). Moreover, mobility of R&D personnel is one of the main factors explaining (un)desired spillovers between companies (Mansfield, 1985). An adequate remuneration system may attenuate failure in the market for R&D as it may enable companies to attract, motivate and maintain a strong R&D workforce. Earnings are an important determinant in the remuneration system and researcher wages consume the lion's share of the total R&D expenditure. Therefore, it is highly relevant to introduce the close interconnectivity between scientific labour markets and R&D investment decisions in the evaluation process of public R&D policy. Goolsbee (1998) concluded that R&D subsidies are primarily translated into researcher wage increases, inflating positive additionality effects by 30% to 50%. Therefore I empirically analyze the effect of public R&D subsidies on private R&D investment, employment and wages in Flanders in **Chapter 4**. I employ parametric treatment effects models and instrumental variable methods for a sample of R&D active companies, and now, in contrast to the third chapter, also use information on the grant size. This allows a more profound testing of the crowding-out hypothesis: the existence of full as well as partial crowding-out effects can be assessed.

In addition to a high level of uncertainty and negative externalities, also capital market constraints may hamper private R&D effort (Himmelberg and Petersen, 1994). 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). Multinational enterprises (MNEs) are possibly less subject to these threats. Moreover, they are expected to have stronger capabilities in controlling knowledge flows and, as a consequence, keep uncertainty and externality risks to a minimum (see e.g. Veugelers and Cassiman, 2004). This may decrease the likelihood that MNEs apply for or receive public R&D subsidies. On the other hand, evidence suggests that a significant performance gap exists between foreign-owned and domestic firms, to the benefit of the former (see Bellak, 2004 for a survey). The government's desire to maximize the expected rate of return on public R&D funding may therefore conversely justify why governments would also provide public R&D funding to MNEs. MNEs expand their foreign activities especially in R&D intensive industries (Markusen, 1998). Flanders is a small, open economy and hosts a large share of foreign-owned MNE activity. Research on Flemish data 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 larger R&D grants and, aggregated, the lion's share of the total subsidy amount in Flanders. **Chapter 5** investigates whether these firm-specific characteristics introduce heterogeneity in additionality effects. First, the direct impact on R&D expenditure and intensity is estimated. Subsequently, the publicly induced R&D expenditure is disentangled from the privately financed R&D expenditure and their productivity with respect to innovative performance and economic return is estimated. I distinguish according to ownership to evaluate potential differences in additionality.

In this first part, on public innovation policy, the view on additionality effects from R&D subsidies is broadened. Different techniques are employed: matching, the conditional difference-in-differences estimator, treatment effects models and IV regressions. Both discrete and continuous treatment are assessed. Moreover, also the content is deepened, as the matter is looked into from different angles. First, we take an international perspective, comparing two countries. Second, the traditional indicators to be evaluated, R&D expenditure and R&D intensity, are extended with measures of R&D personnel and wages at the input side as well as innovative and economic performance at the output side. Third, firm heterogeneity is introduced, based on the ownership structure of the company.

Corporate strategies in innovation

Knowledge creation is a time and money consuming process, with an uncertain outcome (Dasgupta and Maskin, 1987). Optimal staff motivation is to the benefit of the expected success. On the other hand, knowledge transpires relatively quickly into the public domain once it has been created, allowing other companies to take advantage of the originating company's investments. A significant share of knowledge created in companies leaks out through employees (Mansfield, 1985).

Therefore, it is all the more important to attract valuable employees and curtail the staff turnover and, additionally, to motivate this highly qualified workforce. One important aspect here is employee remuneration. In **Chapter 6**, together with my co-author Prof. dr. Kornelius Kraft, I zoom in on a specific remuneration system, i.e. profit-sharing, and link it to companies' innovative performance. This area has been unexplored until now.

The direct aim of companies introducing profit-sharing in their remuneration policy is to stimulate staff performance. As profit maximization becomes a win-win strategy to all parties involved, i.e. both the employees and the firm owners, their mutual interests become aligned. If the incentive system works in an efficient way and if employees behave rationally, they increase their efforts, which should subsequently raise the company's performance.

This direct link between profit-sharing and output explains why traditionally productivity has by far been the most often investigated issue in this research domain. Scholars typically find positive to neutral impacts of profit-sharing on a firm's output. However, productivity measures only show part of the picture, as they merely reflect the result, without illuminating possible reasons explaining this productivity increase. An efficient incentive system is expected to affect workers' performance, but may additionally strengthen a company's innovative capabilities as theoretical arguments predict that potential resistance against innovative activity can be offset and, even more, employees may actively cultivate the company's innovative capabilities. We employ two variations of the conditional difference-in-differences technique on a panel dataset of German companies and empirically investigate the relationship between profit-sharing and innovative performance.

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Chapter 1. The issue of selectivity

Joint work[1] with Prof. dr. Dirk Czarnitzki[2]

For every measure which is introduced, the following question should naturally rise: "Does this measure actually generate the impact it was intended to generate?". Even when theoretical arguments justify the introduction of the measure, there are indications that some measures may not always succeed in realizing the added value they are accredited with. Therefore, an appropriate impact assessment is primordial.

The economics of evaluation entails one very specific issue, namely selectivity. Participation in the measure is often not determined randomly. Therefore, the effectiveness can not be assessed by just comparing subjects which do and do not participate. Participation is potentially endogenous and this has to be incorporated in evaluation models to assure a correct assessment of the measure. Different econometric methods have been developed for this purpose, each with specific advantages and disadvantages. As many techniques will be used in this dissertation, this section provides a concise summary of these econometric methods.

We enter the research domain of so-called treatment effects. Participation in a measure is labelled as receiving a treatment. This treatment can either be discrete (yes / no participation) or continuous (measuring the extent of the participation). Most common in the literature is the evaluation of discrete treatment. Therefore, this summary starts with such methodologies, and then briefly mentions possible extensions for multiple or continuous treatments.

Treatment effects analysis relies on compliance with the Stable Unit Treatment Value Assumption (SUTVA): the treatment of one subject should not affect the treatment effect on another subject (Rubin, 1990). Unfortunately, this cannot be tested. In the following sections compliance with the SUTVA is assumed.

[1] This chapter heavily draws from Aerts, K., Czarnitzki, D., Fier, A., 2007. Capítulo 3: Evaluación econométrica de las políticas públicas de I+D: situación actual, 79-104, in: Heijs, J., Buesa, M., (Eds.), La cooperación en innovación en España y el papel de las ayudas públicas, Instituto de Estudios Fiscales, Madrid.
[2] K.U.Leuven, Department of Managerial Economics, Strategy and Innovation (MSI).

1. Discrete Treatments

In this subsection, we focus on methods that are applicable to cross-sectional data, and second those that require panel data. Different kinds of treatment effects can be estimated: the average treatment effect, the local average treatment effect, the marginal treatment effect, the average treatment effect on the treated and the treatment effect on the untreated (see e.g. Heckman et al., 2001, for a discussion of treatment effects commonly used in program evaluation literature). Here, we focus on the treatment effect α_{TT} on the participating subjects, which targets the basic evaluation question: "What is the impact of the measure on the outcome variable in the group of treated subjects?", or expressed as the following equation[3]:

$$\alpha_{TT} = E(Y^T | S = 1) - E(Y^C | S = 1), \quad (1)$$

where Y^T represents the outcome of subjects that participate (T = treated), and Y^C refers to the situation where they do not participate (C = counterfactual). S refers to the treatment status (S = 1: treated; S = 0: untreated). Thus, α_{TT} results from comparing the actual outcome of participating subjects with their outcome in case of not participating. The approach of measuring potential outcomes goes back to Roy (1951). The outcome $E(Y^T | S = 1)$ can be derived from the sample mean of *Y* in the group of treated subjects. In order to identify $E(Y^C | S = 1)$ further assumptions have to be made.

The outcome variable Y is modelled as follows:

$$Y = \begin{cases} X\beta + S\alpha + U & \\ X\beta + U & \end{cases} \quad if \quad \begin{matrix} S = 1 \\ S = 0 \end{matrix}, \quad (2)$$

where X represents a set of exogenous variables and β their respective parameters. *U* is the error term with zero mean and U is assumed to be uncorrelated with *X*. In an experimental setting, without any selection bias and random participation in the measure, U and S are not correlated. However, in many program set-ups, it is not unlikely that U is correlated with S. This endogeneity would imply a selection bias in the estimation of the treatment effect, as the following equation does not hold:

[3] All variables are measured at the level of the subjects *i* (with *i* = 1,...,*N*), but we omit the index *i* for convenience.

$$E(Y^C \vert S=1) = E(Y^C \vert S=0) \,. \tag{3}$$

As a result, standard econometric methods, 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 covers a range of methods to this end (see e.g. the surveys of Heckman et al., 1999; Blundell and Costa Dias, 2000, 2002; Aerts et al., 2007). Examples are selection models and instrumental variable (IV) estimations, matching techniques and difference-in-differences estimations. In the remainder of this chapter, we briefly explain these methods.

The treatment allocation is modelled by the following selection equation:

$$S^* = Z\gamma + V \,, \tag{4}$$

where S* is an index, measuring the probability to participate in the measure, depending on a set of subject characteristics Z and their respective parameters γ, as well as an error term V. When S* is positive, the subject participates in the measure:

$$S = \begin{cases} 1 & \textit{if } S^* > 0 \\ 0 & \textit{otherwise} \,. \end{cases} \tag{5}$$

1.1. The Heckman Selection Estimator

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[4], resulting in the following conditional outcome equations:

$$
\begin{aligned}
E(Y|S=1) &= X\beta + \alpha + \rho\phi\left(\frac{Z\gamma}{\sigma_V}\right)\Phi\left(\frac{Z\gamma}{\sigma_V}\right)^{-1} \\
E(Y|S=0) &= X\beta - \rho\phi\left(\frac{Z\gamma}{\sigma_V}\right)\left[1-\Phi\left(\frac{Z\gamma}{\sigma_V}\right)\right]^{-1},
\end{aligned}
\qquad (6)
$$

where the last term in each equation represents the error term conditional on S. An important strength of this methodology lies exactly here: by 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. Several generalizations of the fully parametric model have been suggested in the literature. Among others, semi-parametric variations on the Heckman model include Gallant and Nychka (1987), Cosslett (1991), Newey (1999), or Robinson's (1988) partial linear model. Note, however, that in such models the intercept in the outcome equation is no longer identified. A precise estimate of the intercept is required for deriving α_{TT}. Heckman (1990) and Andrews and Schafgans (1998) developed estimators to identify α_{TT}. See Hussinger (2008) for applications of such estimators in an evaluation of public innovation policy.

1.2. Instrumental variable (IV) regressions

In the IV regression set-up, 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 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 are 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

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

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.

1.3. The matching estimator

The matching estimator is a non-parametric method and has one main advantage: 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 a correct sample counterpart for the treated subjects' outcomes if they had not been treated, by pairing each treated subject with members of a comparison group. Under the matching assumption, the only remaining difference between the two groups is the actual participation in the measure.

Rubin (1977) introduced the so-called conditional independence assumption (CIA) to comply with the equality of the two arguments in equation (3). This condition implies that the treatment and the potential outcome are independent for subjects with the same set of exogenous characteristics (X = x):

$$Y^T, Y^C \perp S \,|\, X = x \,. \qquad (7)$$

The CIA helps to overcome the problem that $E(Y^C | S = 1)$ is unobservable. If the conditional independence assumption is valid, $E(Y^C | S = 0, X = x)$ acts as a measure of the potential outcome for the treated subjects. However, the CIA is only fulfilled if all variables influencing both the outcome Y and the selection status S are known and available in the dataset. In that case, the equation

$$E(Y^C | S = 1, X = x) = E(Y^C | S = 0, X = x) \qquad (8)$$

holds. The average outcome of treated subjects in the absence of the measure can be calculated from a sample of comparable, i.e. matched, subjects.

Note, however, that matching requires a further assumption, namely:

$$0 < \Pr\left(S = 1 \mid X\right) < 1 . \qquad (9)$$

The probability of participating in the measure is restricted between zero and one, to guarantee that all treated subjects have a similar counterpart in the population of non-treated subjects, and that every subject constitutes a possible participant in the measure. This is not ensured in any sample. If the samples of treated and non-treated subjects would have no or only little overlap in the exogenous characteristics X, matching does not deliver consistent estimates. Therefore, matching requires a common support restriction, which excludes subjects for which no suitable matching partner can be found.

If the CIA holds and common support is given, the treatment effect on the treated can be estimated using the sample means of both groups:

$$\alpha_{TT}^{M} = E(Y^{T} \big| S = 1, X = x) - E(Y^{C} \big| S = 0, X = x) . \qquad (10)$$

Usually vector X contains a large number of variables. However, the high dimensionality of X can significantly complicate the matching. Rosenbaum and Rubin (1983 and 1984) have shown that conditioning the matching on a single index, i.e. the propensity score, which measures the probability to receive a treatment Pr(X), instead of the vector of exogenous characteristics X, is a valid procedure. This reduces the curse of dimensionality and makes matching a feasible approach. Lechner (1998) suggested a method of hybrid matching, where one conditions on Pr(X) and a subset of X. For example, when matching is employed on pooled cross-sectional data, including a variable indicating the year of observation in addition to Pr(X) ensures that a matched control observation is observed in the same wave as the treated subject.

The comparison group for each treated subject is selected on a predefined criterion of proximity. After the definition of the neighbourhood for each treated subject, the next issue is the choice of appropriate weights for non-treated observations h within the neighbourhood. The impact of the treatment on subject i is then obtained by computing:

$$\alpha_{i,TT}^{M} = Y_i^T - \sum_{h=1}^{N} w_{ih} Y_h^C \ . \qquad (11)$$

A common procedure is nearest neighbour matching, i.e. the weight is set to unit value for the closest match, and zero otherwise. So, the matching result is one single non-treated twin for each treated subject. The nearest neighbour can be selected with or without replacement. To obtain the best possible match, a large pool of controls is required. Therefore, matching with replacement is common practice. However, this introduces a bias in the ordinary t-statistic on mean differences, which has to be corrected for (Lechner, 2001). Also more than one neighbour may be selected, giving different weights to different control observations, depending on their proximity to the treated subject. Kernel matching uses all subjects in the control group for each participant, and assigns Kernel weights according to proximity in X or Pr(X) to each control observation. Stratification matching divides the observations into strata and eliminates the within-stratum differences in X to obtain an adequate control stratum for each treated observation.

1.4. The difference-in-differences (DiD) estimator

The difference-in-differences (DiD) estimator is based on the idea that a good approximation for the outcome in the absence of a treatment would be an observation of a treated subject in an earlier period where it did not participate in the measure. In order to control for macro-economic changes over time, DiD relates the development of treated subjects over time to a control group of non-participants. Hence, the DiD estimator compares participants i and a control group of non-participants h before (t_0) and after (t_1) the treatment:

$$\alpha_{TT}^{DiD} = \left(E(Y_{i,t_1}^T \middle| X_{i,t_1}, S_{i,t_1} = 1) - E(Y_{i,t_0}^C \middle| X_{i,t_0}, S_{i,t_0} = 0) \right) - \left(E(Y_{h,t_1}^C \middle| X_{h,t_1}, S_{h,t_1} = 0) - E(Y_{h,t_0}^C \middle| X_{h,t_0}, S_{h,t_0} = 0) \right) . \qquad (12)$$

The obvious disadvantage of this estimator is that panel data are required. Often it is very hard to satisfy this heavy data requirement, as not only at least two periods have to be available, but more in particular, the treated subjects should be observed in the previous period in a situation where they did not participate in the measure. As participation is typically for a longer time, and subjects may participate in multiple measures over time, the construction of a database, suitable for an appropriate application of DiD turns out to be very difficult in practice.

1.5. The conditional difference-in-differences (CDiD) estimator

One underlying assumption in the DiD estimator is that treated and non-treated subjects react similar to shocks occurring over time (independently of the treatment). However, as evidence shows, treated and non-treated subjects often exhibit very different characteristics. This suggests that they may also react differently to macro-economic shocks. The conditional difference-in-differences estimator (CDiD) allows countering this potential bias. This approach combines matching and DiD techniques. Instead of using a general control group, a group of subjects h is selected, which is comparable to the treated subjects i in the period before participation in the measure. The treatment effect is then deducted from comparing the evolution of these two comparable groups over time:

$$\alpha_{TT}^{CDiD} = \left(E(Y_{i,t_1}^{T} \middle| X_{i,t_1} = x, S_{i,t_1} = 1) - E(Y_{i,t_0}^{C} \middle| X_{i,t_0} = x, S_{i,t_0} = 0) \right) - \left(E(Y_{h,t_1}^{C} \middle| X_{h,t_1} = x, S_{h,t_1} = 0) - E(Y_{h,t_0}^{C} \middle| X_{h,t_0} = x, S_{h,t_0} = 0) \right). \qquad (13)$$

Blundell and Costa Dias (2000) suggest employing CDiD for repeated cross-sections (CDiDRCS) if panel data are not available. Three matching algorithms are required. For every treated subject i in period t_1, a non-treated twin subject h has to be found in the same period t_1. In the next step, a control group has to be compiled: for each treated subject i and each selected non-treated subject h in period t_1 a twin observation, i.e. k and j respectively, has to be found in period t_0. The average treatment effect on the treated subjects can then be estimated as follows:

$$\alpha_{TT}^{CDiDRCS} = \left(E(Y_{i,t_1}^{T} \middle| X_{i,t_1} = x, S_{i,t_1} = 1) - E(Y_{k,t_0}^{C} \middle| X_{k,t_0} = x, S_{k,t_0} = 0) \right) - \left(E(Y_{h,t_1}^{C} \middle| X_{h,t_1} = x, S_{h,t_1} = 0) - E(Y_{j,t_0}^{C} \middle| X_{j,t_0} = x, S_{j,t_0} = 0) \right). \qquad (14)$$

2. Continuous Treatments

As mentioned earlier, the previous estimators focus on binary treatments, i.e. one merely distinguishes between participation and non-participation. However, the size of the treatment may have an important impact on the treatment effects. Extensions of the binary treatment case are only briefly referred to in this chapter.

Lee (1994) and Honoré et al. (1997) provide semi-parametric selection models when the treatment is not limited to a binary variable, but follows a tobit distribution, i.e. the treatment variable is zero for non-treated subjects but takes on positive continuous values for treated subjects, reflecting the extent to which subjects participate in the measure.

IV regressions are not limited to discrete treatment. The same procedure is valid if continuous treatment information is available. See e.g. Wooldridge (2002) for a comprehensive discussion on how to obtain treatment effects with IV regressions.

Imbens (2000) has introduced a treatment effects estimator that allows accounting for heterogeneous but still discrete treatments. The multiple treatments can either reflect participation in different programs, or the size of the treatment can be grouped into different classes, e.g. low, medium and high. Similarly, Gerfin and Lechner (2002) present a matching approach for heterogeneous treatments.

Recently, Hirano and Imbens (2004) suggested estimating dose-response functions using a generalized propensity score method. Like the matching approach, this also is a non-parametric method, which is suitable for continuous treatment, though.

3. Estimator selection

As this chapter shows, many different techniques exist to correct for the potential selection bias in evaluation economics. The most important methods are selection models, IV regressions, matching techniques and difference-in-differences estimations. Each approach has its advantages but definitely also disadvantages. For the application of selection models and IV estimators valid instruments are required, which often is not straightforward. The matching approach offers the advantage that no distributional assumptions have to be made, neither for the outcome equation itself, nor for the error terms of the selection and the outcome equation. Its disadvantage is that it only controls for observed heterogeneity among treated and untreated subjects. Any unknown or unobserved variable driving the participation decision will disturb the estimates. A rich dataset can offset this problem. The difference-in-differences method requires panel data with observations before and after the treatment, imposing a change of treatment status for the participating subjects. The conditional difference-in-differences method combines the advantages of DiD and matching and is applicable to panel data as well as repeated cross-sections. However, again, this approach requires a dataset which is suitable for its application.

The aim of every researcher in the domain of the economics of evaluation obviously should be to exclude any influence from the participation decision in the assessment of the impact of the measure. Therefore, he should use the most appropriate technique to control for this endogeneity. However, in practice, this choice is usually made ad hoc, due to data availability, and often the researcher's choice to employ a specific technique is driven by data constraints and a deliberation about the most accurate versus the most appropriate technique. This introduces considerable caveats when comparing various research results, stemming from different research set-ups and different methodologies.

In this dissertation different approaches are used to offset the potential selection bias which is inherent to participation in the measures we evaluate. Taken together, they offer a rich but nuanced view on the assessment of intervention tools in the market for R&D. In the first part, we look into the impact of public R&D funding on private R&D activity. To this end, we assess discrete treatment and apply the matching technique (the fifth chapter), and its extension in the CDiD approach (third chapter). In the fourth chapter, discrete as well as continuous treatment is evaluated in treatment effects and IV regression models. In the second part, a specific corporate measure, i.e. profit-sharing, is related to innovative performance. Here, the matching approach is employed in a panel dataset: we employ two variations of the conditional difference-in-differences technique.

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PART I. PUBLIC INNOVATION POLICY

Chapter 2. Public innovation policy: an introduction

Joint work[5] with Prof. dr. Dirk Czarnitzki[6]

This chapter introduces the reader in the domain of public innovation policy and illustrates the relevance of assessing the impact of public R&D funding on private R&D activity. First, the Science and Technology policy is discussed, with a focus on public R&D funding. We explain the rationale behind public R&D funding and briefly review the outcome of evaluation exercises which have been undertaken in the past. As in the following chapters the main focus will be on the Flemish R&D policy, the details of the Flemish subsidy system will be illuminated in the second section.

1. Science and Technology policy

The failure of the market for R&D results in underinvestment and this justifies government intervention. Governments design a Science and Technology policy to optimize the conditions for conducting research and development activities. A strong education system, generating a large pool of highly skilled researchers, constitutes the ideal foundation for effective and efficient knowledge generation. An important publicly regulated measure is the protection of intellectual knowledge in the patent system. In this dissertation, we zoom in on yet another public measure, i.e. public funding of R&D activities.

Public authorities can opt between two modes of transferring public money to the private R&D sector: either directly or indirectly. The main advantage of direct funding, i.e. R&D subsidies, is that governments are able to control the money flows and impose their own preferences (for example socially highly valuable projects), as they directly decide which companies and which projects receive public support. Indirect funding, i.e. tax credits, applies to all companies, ruling out

[5] Parts in this chapter draw heavily from Aerts, K., Czarnitzki, D., 2006. Benchmarking study: Distribution of the financial resources for science and innovation, Vlaamse Overheid, Brussels and Aerts, K., Czarnitzki, D., 2008. The returns on public funding of research, in: Soete, L., Muldur, U., Delanghe, H., (Eds.), The European Research Area, forthcoming.
[6] K.U.Leuven, Department of Managerial Economics, Strategy and Innovation (MSI).

preferential behaviour of the government, but at the same time offering certainty to applying companies, as this measure remains relatively stable over time. Van Pottelsberghe et al. (2003) add that direct subsidies offer the advantage that public authorities have more control over their budget. Conversely, fiscal measures are more accessible and the administrative costs can be very low. We now briefly discuss the main findings on the returns to both incentive measures.

1.1. Direct public R&D funding: subsidies

There is a vast body of literature on the additionality effects of direct R&D grants. 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, Turkey and the US have been subject to an evaluation exercise of their public R&D funding system and different estimators have been employed. However, the results on the effectiveness of public R&D funding remain ambiguous. Key reasons for these diverging conclusions are the use of different estimators, as well as the application for a broad range of countries, each with their own specific S&T policy (David and Hall, 2000).

Different impacts are evaluated. The predominant research question assesses the crowding-out hypothesis, i.e. do companies replace private R&D budgets with public R&D grants? The numerous studies estimating the impact on R&D expenditure excited the criticism that positive additionality may still hide a substantial level of crowding-out (see e.g. David and Hall, 2000). This would be the case if increased R&D expenditures are translated in increased R&D wages and not, or only to some extent, in real additional R&D effort. For example, Goolsbee (1998) calculates that this potential disorder may inflate positive additionality effects by 30% to 50%. Therefore, research on input additionality is completed by not only looking at the impact on R&D expenditure, but also on R&D personnel and the R&D wage structure.

While investigating potential crowding-out effects of public R&D funding on private R&D expenditure and personnel 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. Or, subsidies can be used to finance duplicate R&D, which may induce inefficiency in the national innovation system (Irwin and Klenow, 1996). Moreover, an actual reinforcement of private R&D activities may be directed towards more risky and consequently potentially 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, etc. Since then, researchers also have been evaluating measures on product and process innovations. More recent research extends the crowding-out question by linking privately financed R&D and publicly induced R&D to innovative activity (see e.g. Czarnitzki and Licht, 2006). A two equation model is considered: first, a treatment effects analysis on R&D expenditure is conducted using the matching approach. In the second equation, a knowledge production function is estimated, relating a measure of innovative output to the firms' R&D spending and other covariates. The first step allows disentangling total R&D spending into two components: first, that part of R&D that would have been conducted in the absence of subsidies, i.e. the estimated counterfactual situation. Second, the other part of R&D expenditure that has been induced by the receipt of subsidies, which comprises the amount of the subsidy itself, and the additionally stimulated privately financed R&D (the treatment effect). The two components add up to the total observed R&D spending, but the decomposition allows analyzing the productivity of privately financed versus additional, publicly induced R&D expenditure.

A recent stream of additionality research extends the evaluation criteria beyond the directly measurable input and output indicators and evaluates how subsidies affect companies' behaviour, e.g. the setting-up of collaborative R&D projects, changes in the nature and sustainability of such networking, changes in companies' R&D management, etc. This concept of behavioural additionality was introduced by Buisseret et al. (1995). Falk (2004) for example finds that supported companies enhance their innovative capabilities, improve competence building in general and employ new technologies and R&D procedures elsewhere. However, she refers to a major problem inherent to the concept of behavioural additionality, which is the lack of appropriate measures for the mostly intangible merits of behavioural additionality.

1.2. Indirect public R&D funding: tax credits

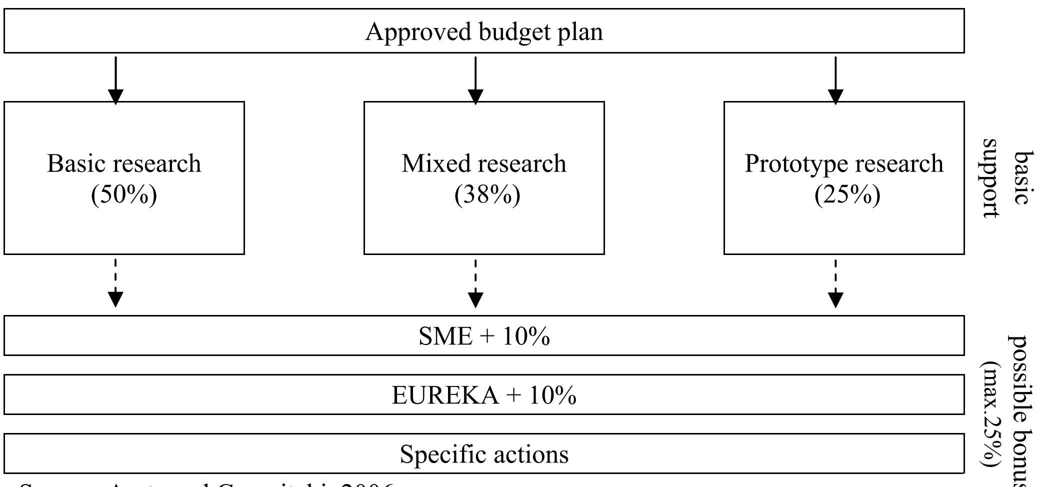
Hall and Van Reenen (2000) survey the literature on the effectiveness of R&D tax credits (see also Van Pottelsberghe et al., 2003). The pioneering research in this domain was initiated in the early eighties with US data (Eisner et al., 1983). The main explanation is that the US were among the first to introduce an R&D tax scheme (in 1981). Firm-level evaluations in other countries like Australia, Canada, France, Japan, the Netherlands and Sweden followed, but are less frequent. Furthermore, research was conducted at the macro level (see e.g. Guellec and Van Pottelsberghe, 1999). Different approaches can be found in the literature, but especially the estimation of the marginal cost of R&D to evaluate the impact of tax credits has become very popular in recent years. Although different methods and different datasets are employed and different schemes apply in different countries (see e.g. Van Pottelsberghe et al., 2003), the conclusions from empirical research leave little ambiguity: R&D tax credits stimulate private R&D spending. One crucial critique on the analysis of the impact of R&D tax credits is the relabeling issue, though. Firms eligible for R&D tax allowances can be expected to label any investment (slightly) related to the area of R&D as R&D expenditure. This may seriously distort the estimates of potential additionality effects.

2. Public R&D funding in Flanders

IWT, the Institute for the Promotion of Innovation through Science and Technology in Flanders, is a government institution, established in 1991 by the Flemish government, to support technological innovation projects in Flanders. It is an important player in the redistribution of Flemish funds for R&D and innovation. IWT grants financial support to companies and research institutions and other services in the area of technology transfer, partner search, preparation of projects in European programs, etc. IWT fosters close collaboration between all innovative agents in Flanders.

IWT acts as the single counter in Flanders where companies can submit a dossier and apply for a subsidy. This implies that all corporate subsidies, at the Flemish and Belgian level, as well as certain EU-funded projects[7] are evaluated and granted through IWT. The funding is project-based. Once the decision is made that a project will be funded, the percentage of the grant is fixed according to the schedule in Figure 1. First, the qualification for basic, prototype or mixed research funding is evaluated. Next, the project is evaluated on its eligibility for additional funding through the SME (Small and Medium Sized Company) or EUREKA (European) program and other possible specific actions. Next to this funding procedure especially SMEs can apply for a so-called 'subordinated loan' as additional financing resource when the grant application is approved[8]. The total funding (subordinated loan and subsidy) amounts to a minimum of 15% and a maximum of 80% of the total project costs and the yearly total amount of public funding is limited to 8 million EUR. These costs are based on the personnel costs. Other additional costs are a percentage of the personnel costs.

Figure 1: The subsidy procedure in Flanders



Source: Aerts and Czarnitzki, 2006a.

The so-called ICAROS database contains data on all projects that have been submitted to obtain a grant from IWT for an innovative company project since 1992, when IWT became active. In the following paragraphs the main

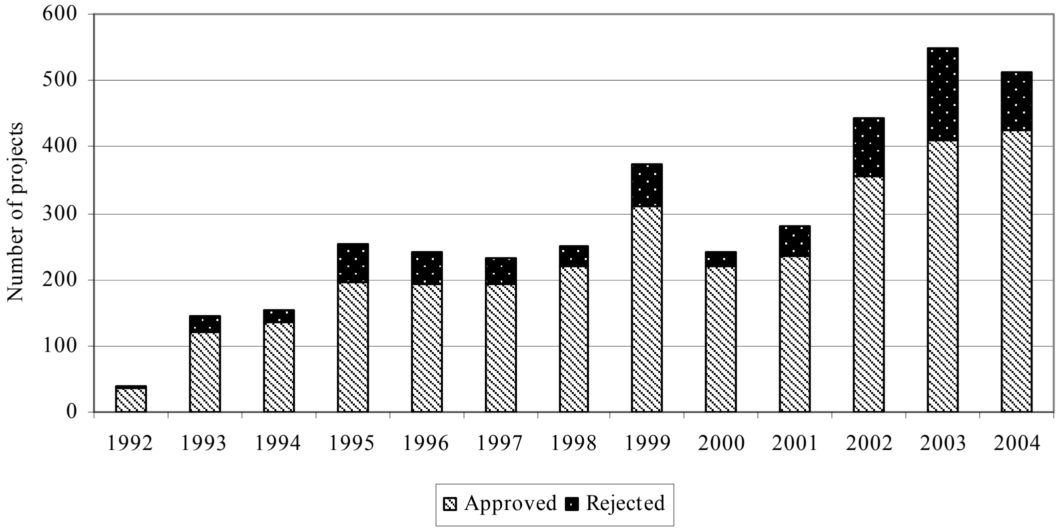
[7] The Framework Program projects are not managed through IWT. However, typically the scale of these projects is very large because these projects are often managed in international company consortia. As a result, the number of Flemish firms engaging in these programs is very limited.

[8] Since the launch of VINNOF, the Flemish Innovation Fund, in 2006, subordinated loans are no longer provided by IWT. The system of subordinated loans has been totally revised.

characteristics of public R&D funding in Flanders are presented[9], based on the ICAROS data.

Figure 2 shows the evolution of the number of project applications over time. Approved and rejected projects are disentangled. The general trend is that the number of project applications is rising; the number of project approvals and rejections follow this trend. On average, the project duration is about 20 months.

Figure 2: Total number of project applications at IWT: approved and rejected



Source: Aerts and Czarnitzki, 2006a

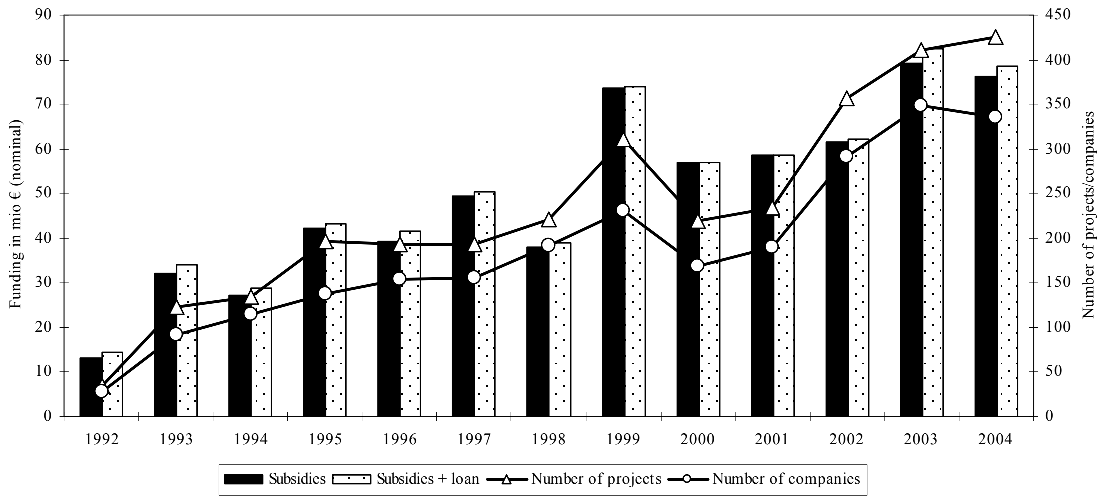
Overall, the total amount of subsidies granted by IWT (see Figure 3) is rising. At the start of IWT in 1992, the number of approved projects was 35; 28 companies received a total of 13 million EUR and together with the subordinated loan the amount was 14 million EUR. In 2004 IWT approved 425 projects and supported 335 companies with 76 (78 including loans) million EUR. The total funding budget is rising, but this is largely due to the increase in applications: the average funding per project and per company has remained the same or has even decreased a little.

In 2004, the average subsidy per project amounted to about 0.18 million EUR. In an international context, this amount varies significantly. The average subsidy per project was 0.089 million EUR in Germany in 2004 (BMBF Ministry only) (OECD, 2006), 0.6 million EUR in France in 1997 (Duguet, 2004) and 0.14 million

[9] The interested reader is referred to Aerts and Czarnitzki (2006a) for a more elaborate overview of public R&D funding in Flanders.

EUR in Finland in 2008 (TEKES, 2008).The main explanation for this divergence is the size of the receiving company as well as the sector affiliation. Moreover, the Science and Technology policy significantly differs between countries: different measures apply, work directly or indirectly, and fall under the responsibility of different agencies. Therefore, it is extremely difficult to make estimations on the average R&D grant companies receive from public institutions. This implies considerable caution in international comparisons.

Figure 3: Total amount of subsidies, projects and companies



Source: Aerts and Czarnitzki, 2006a

Both SMEs and large enterprises qualify for IWT funding. Large enterprises absorb the lion's share of the total public R&D budget allocated to the private sector, but the total number of projects submitted by SMEs is larger. Over the years, the proportion of SME funding has increased, relative to the share of the large enterprises, partially due to the lowering of barriers for SMEs to apply for subsidies. Moreover, a special SME program has been launched. As mentioned, also EUREKA projects are granted through IWT. After the project has been approved, the necessary eligibility criteria for EUREKA funding are evaluated. Only a small proportion of all Flemish innovation projects is funded through EUREKA. For example, in 2004, 34 out of 425 projects received EUREKA funding in addition to the basic grant.

In the submitted projects proposals, IWT distinguishes between technology domains: basic technologies, materials and chemistry, micro-electronics and systems, information technology and software, biotechnology and nourishment, energy and environment, use-diffusion-support and finally human sciences. In terms of the number of projects, basic technologies as well as materials and chemistry are important fields. On the other hand, the average funding amount is relatively highest in use-diffusion-support, micro-electronics and systems as well as in biotechnology and nourishment.

In addition to direct R&D support, mainly provided by the Flemish government, the Belgian government provides some fiscal measures. Until recently very few Belgian companies actually made use of these fiscal measures (Van Pottelsberghe et al., 2003). Main reasons are a low level of acquaintance with the system, complexity and high administration costs[10] and the fact that the measures are not significantly substantial[11]. However, after recent changes in the set-up of the measures, they are becoming increasingly popular, especially tax reduction measures for R&D employees. For this dissertation, these fiscal measures were not yet relevant; they will become so, however, in the future.

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[10] First, each year the company has to deliver a certificate. Second, the researcher should be full time employed in the research department of the same company to qualify. Third, the tax allowance is nominative, inducing a burden to keep track of all employees who benefited from the measure in the past.

[11] First, the amount of the exemption is not sufficiently significant. Second, the definition of highly qualified personnel is too strict, so that only very few employees qualify for the measure. Third, the tax exemption is a short term measure (it only relates to the first year of recruitment) while R&D typically is a long term process.

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Chapter 3. Two for the price of one? Additionality effects of R&D subsidies: A comparison between Flanders and Germany

Joint work[12] with dr. Tobias Schmidt[13]

1. Introduction

Especially against the background of the knowledge economy, innovation nowadays is deemed to be the main driving force of a country's competitive strength (see e.g. Griliches, 1986). The European Union aspires to become the most competitive economy in the world and proclaims innovation as one of the key pillars in its policy to achieve this (Commission of the European Communities, 2000). In the 2000 Lisbon Strategy an ambitious plan was initiated to leverage the EU R&D expenditure to 3% of the GDP by 2010; of which 2% should be privately financed. However, an intermediate evaluation revealed that instead of rising, the EU R&D expenditure is currently even declining. Recent statistics show that the EU25 spent 1.77% of its GDP on R&D activities in 2005. In the US the R&D expenditure amounted to 2.62% of the GDP and in Japan this number rose to 3.33% (OECD, 2007). Therefore, the European Commission recently launched an integrated innovation/research action plan, which calls for a major upgrade of the research and innovation conditions in Europe. Mobilizing EU funds and instruments to support research and innovation is one of the objectives formulated in this plan.

Government intervention in the domain of private R&D activities is justified by the argument of market imperfection and is since long time common practice in most industrialized countries. R&D entails the non-excludability characteristic of a public good (see e.g. Samuelson, 1954). Arrow (1962: 615) states that *"No amount of legal protection can make a thoroughly appropriable commodity of something as intangible as information. The very use of the information in any productive way is bound to reveal it, at least in part. Mobility of personnel among firms provides a*

[12] In a shorter version, this chapter has been published in Research Policy: Aerts, K. and Schmidt, T., 2008. Two for the price of one? Additionality effects of R&D subsidies: A comparison between Flanders and Germany, Research Policy 37(5), 806–822.
[13] Deutsche Bundesbank, Economic Research Centre.

way of spreading information. Legally imposed property rights can provide only a partial barrier, since there are obviously enormous difficulties in defining in any sharp way an item of information and differentiating it from similar sounding items."

Private investments in R&D can never be fully appropriated because other companies have the opportunity to free ride. This leads to underinvestment in R&D activities: the level of R&D expenditure will be below the socially desirable optimum. Public funding reduces the price of socially valuable R&D projects for private investors to a level at which it becomes profitable for companies to invest.

The big challenge for governments obviously is to allocate public funding only to those projects that are socially beneficial and would not be carried out in the absence of a subsidy. This is however not straightforward as companies always have an incentive to apply for public funding. It could be the case that a subsidy merely replaces, i.e. crowds out, private money and does not generate additional R&D investments. The key question in this evaluation problem is: "How much would a firm that has received a subsidy, have spent on R&D if it would not have been subsidized?". Several methods are developed to tackle this question. Examples are the so-called matching estimator and the conditional difference-in-differences method.

This chapter provides empirical evidence on the relationship between public R&D funding and private R&D efforts in Flanders and Germany. In a survey of the literature on additionality effects of R&D subsidies, David and Hall (2000) conclude that the results of evaluation studies in this field are inconclusive as some report crowding-out effects while others reject them. They attribute this to the fact that researchers use very different databases and econometric methods resulting from differences in information availability in different countries. Therefore it is useful to compare the impact of funding in different countries using similar methods and datasets.

After this brief introduction the reader is guided through the relevant literature. The selection bias and the methodology that we employ to circumvent this problem are explained in the subsequent section. The fourth section entails the description of the specific S&T policy conducted in both countries and the data which will be used. In the fifth section the empirical evidence is presented. The last section contains some concluding remarks.

2. Literature Review

Our paper is situated in the domain of input additionality and addresses the issue of crowding-out effects of subsidized R&D. David and Hall (2000) conclude in their review of evaluation studies on innovation input that the results on potential crowding-out effects are ambiguous, and they criticize that most existing studies neglect the problem of sample selection bias. That is, R&D intensive firms may well be more likely to apply for a subsidy. Moreover, the government may just as well be more inclined to grant them a subsidy. This makes R&D funding an endogenous variable, which should be tackled in an adequate way. We will extensively come back to this problem in the next section. 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 correcting for a potential selection bias tend to reject full crowding-out effects, the results remain ambiguous: Ali-Yrkkö (2004), Aerts and Czarnitzki (2004 and 2006a), Almus and Czarnitzki (2003), Clausen (2007), Czarnitzki (2001), Czarnitzki and Fier (2002), Czarnitzki and Licht (2006), 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) and Streicher et al. (2004) reject full crowding-out effects, while Busom (2000), Heijs and Herrera (2004), Kaiser (2004), Lach (2002), Suetens (2002) and Wallsten (2000) find indications that public R&D funding replaces private R&D investments to some extent. Key reasons for these diverging conclusions are the use of different estimators, as well as the application for 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.

All studies on German data reject the full crowding-out hypothesis. Different subsets are analyzed: the service sector (Czarnitzki and Fier, 2002), the manufacturing sector (Fier, 2002; Hussinger, 2008) or more specifically East-German manufacturing firms (Czarnitzki, 2001; Almus and Czarnitzki, 2003; Czarnitzki and Licht, 2006), using nearest neighbour matching approaches (Almus and Czarnitzki, 2003; Czarnitzki, 2001; Czarnitzki and Fier, 2002; Czarnitzki and Licht, 2006; Fier, 2002) as well as parametric and semi-parametric two-step selection models (Hussinger, 2008).

The results for Flanders are less clear. Suetens (2002) applies an IV framework on a panel of Flemish firms, but the results are by and large not significant and full crowding-out cannot be rejected. Aerts and Czarnitzki (2004) address the additionality issue with the nearest neighbour matching technique on a cross-section of Flemish manufacturing and selected service companies and extend their research in an IV framework adding information on the amount of subsidy (Aerts and Czarnitzki, 2006a). They find evidence that both full and partial crowding-out effects can be rejected.

The work of Görg and Strobl (2007) is of particular relevance for our research. They employ the conditional difference-in-differences technique using 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. They reject crowding-out of small/medium grants and find additionality effects of small grants. However, they cannot reject crowding-out for foreign plants.

We now briefly review the remaining relevant literature. Streicher et al. (2004) conduct fixed effects panel regressions and conclude that the private R&D expenditure increases due to subsidies in their set of Austrian companies. Kaiser (2004) employs a simultaneous probit model and Kernel matching for Denmark and does not find significant proof to reject the crowding-out hypothesis. Ali-Yrkkö (2004) employs simultaneous equation models and finds no evidence to support crowding-out effects in his sample of Finnish firms. Also Ebersberger (2005) investigates the effectiveness of Finnish R&D subsidies. From his matching exercise, supplemented with selection models, he confirms the results of Ali-Yrkkö

(2004). Hyytinen and Toivanen (2005) explore the relationship between R&D expenditure and R&D subsidies in Finland with a series of tobit estimates and conclude that the overall effects are positive, but that R&D subsidies are disproportionately to the benefit of companies in industries which are highly dependent on external finance. Duguet (2004) positively evaluates the French R&D subsidy system in a matching framework, with a large panel of manufacturing and service firms. Lach (2002) applies different estimators, such as difference-in-differences and dynamic panel data models and finds large additionality effects in small Israeli manufacturing firms, but none for large firms. Clausen (2007) employs an IV approach on a sample of Norwegian manufacturing and service firms and distinguishes between the impact of research versus development funding. He finds that research subsidies have a significant additionality effect on research expenditure, but that development subsidies are subject to crowding-out effects. Busom (2000), González et al. (2005), González and Pazó (2006) as well as Heijs and Herrera (2004) analyze Spain. Busom (2000) applies an econometric selection model on a cross-sectional sample of manufacturing firms and concludes that public funding induces more effort for the majority of firms in her sample, but for 30% of the participants, complete crowding-out effects cannot be ruled out. Heijs and Herrera (2004) also analyze a cross-section of manufacturing firms and although they find positive treatment effects, the overall additionality effect is small when the amount of subsidy is taken into account. González et al. (2005) and González and Pazó (2006) investigate subsidies in an unbalanced panel of manufacturing firms, employing nearest neighbour matching and a simultaneous equation model with thresholds. Their analysis rejects full crowding-out effects but does not confirm that public R&D subsidies stimulate private R&D expenditure. Lööf and Heshmati (2005) evaluate the Swedish subsidy policy with nearest neighbour and Kernel matching and reject crowding-out effects. Wallsten (2000) uses a simultaneous equations model and finds that US SBIR grants crowd out private investment dollar for dollar. However, he points out that the program still could have positive effects as the recipient firms might have been able to keep their innovation activities constant while in the absence of a subsidy they might have had to reduce them.

3. Methodology

As the literature overview shows, a range of econometric methods is available to correct for the selection bias. In the following subsections we first expound on this endogeneity problem and then we elaborate on the methods employed here, i.e. the matching estimator and the ordinary and conditional difference-in-differences method.

3.1. Selection bias

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

$$\alpha_{TT} = E(Y^T \mid S = 1) - E(Y^C \mid S = 1), \qquad (15)$$

where Y is the outcome variable (e.g. R&D expenditure) of the firm[14] 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 in our case). 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 $E(Y^T \mid S = 1)$ can be estimated by the sample mean of the outcome in the group of subsidized firms.

The counterfactual situation $E(Y^C \mid S = 1)$ 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:

$$E(Y^C \mid S = 1) = E(Y^C \mid S = 0). \qquad (16)$$

However, subsidized companies may well have been more R&D active than non-subsidized companies even without the subsidy program, which would imply a selection bias in the estimation of the treatment effect. Firms that already are

[14] All variables are measured at the firm level (with $i = 1,...,N$), but we omit the index i for convenience.

innovative and very R&D active may be more likely to receive an R&D subsidy, as governments want to maximize 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. Expression (16) 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). Examples of these methods are selection models, instrumental variable (IV) estimations (including simultaneous equation systems), difference-in-differences estimations and matching. For the application of IV estimators and selection models, valid instruments for the treatment variables are needed. In the case of R&D additionality analysis it is very difficult to find valid instruments, as these should determine the treatment (subsidy receipt) but not the outcome (R&D activities). The difference-in-differences method requires panel data with observations before and after (or during) the treatment. The matching estimator offers the advantage over IV and selection models that no assumptions have to be made, neither on the functional form of the outcome equation nor on the distribution of the error terms of the selection and outcome equation. The disadvantage is that it only allows controlling for observed heterogeneity among treated and untreated firms. To counter this problem and control for unobserved heterogeneity, the conditional difference-in-differences method was developed, which combines the ordinary difference-in-differences estimation with matching. In the following subsection we will expound the matching estimator, the difference-in-differences estimator and the combination of these two[15].

[15] See Aerts et al. (2007) for an explanation of other techniques used in evaluation econometrics.

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 a correct sample counterpart for the treated firms' outcomes if they had not been treated, by pairing each treated firm with members 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 the potential outcome are independent for firms with the same set of exogenous characteristics X=x:

$$Y^T, Y^C \perp S \middle| X = x . \tag{17}$$

This crucial conditional independence assumption (CIA) helps to overcome the problem that the counterfactual outcome $E(Y^C | S = 1)$ is unobservable. If the CIA holds, the expected outcome $E(Y^C | S = 0, X = x)$ 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

$$E\left(Y^C \middle| S = 1, X = x\right) = E\left(Y^C \middle| S = 0, X = x\right) \tag{18}$$

is valid and the average outcome of subsidized firms in the absence of a subsidy can be calculated from a sample of comparable, i.e. 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 a valid counterpart should be found in the non-treated population and every firm should represent a potential subsidy recipient. Therefore, we 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

$$\alpha_{TT}^{M} = E\left(Y^{T} \middle| S = 1, X = x\right) - E\left(Y^{C} \middle| S = 0, X = x\right), \tag{19}$$

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 procedure, since the equivalence of these extra variables is explicitly imposed, in addition to their value in the propensity score.

Having defined the neighbourhood of similar non-treated firms h for each treated firm i, the next issue is the choice of appropriate weights w_{ih} for non-treated observations h within the neighbourhood, so that the impact on firm i, i.e. $\alpha_{i,TT}$, can be computed as:

$$\alpha_{i,TT}^{M} = Y_i^{T} - \sum_{h=1}^{N} w_{ih} Y_h^{C} \; . \tag{20}$$

Two commonly used procedures are Kernel-based matching and nearest neighbour. In the Kernel-based matching, a treated firm is matched to all non-treated firms in the control group, but the controls are weighted according to the Mahalanobis distance between the treated firm and each non-treated firm. We will employ nearest neighbour matching. This technique matches a treated firm i to the non-treated firm h in the control group that is closest in terms of the Mahalanobis distance between the respective propensity scores and possible other matching arguments. The nearest neighbour can be selected with or without replacement. To obtain the best possible match, a large pool of controls is required. Therefore, we employ matching 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 for (Lechner, 2001). The detailed matching protocol is depicted in Table 1.

Table 1: Matching protocol (Nearest Neighbour matching)

Step 1	Specify and estimate a probit model to obtain the propensity scores $\hat{P}(X)$.
Step 2	Restrict the sample to common support: delete all observations on treated firms with probabilities larger than the maximum and smaller than the minimum in the potential control group. This step is also performed for other covariates that are possibly used in addition to the propensity score as matching arguments.
Step 3	Choose one observation from the subsample of treated firms and delete it from that pool.
Step 4	Calculate the Mahalanobis distance MD between this firm and all non-subsidized firms in order to find the most similar control observation. $MD_{ih} = (Z_h - Z_i)'\Omega^{-1}(Z_h - Z_i)$ In the Flemish case, *Z* contains the estimated propensity score and the firm size (lnEMP) as additional arguments in the matching function. In the German case, also the dummy that indicates location in East Germany is an additional argument. Ω is the empirical covariance matrix of these arguments, based on the sample of potential controls.
Step 5	Select the observation with the minimum distance from the remaining sample. Do not remove the selected control from the pool of potential controls, so that it can be used again.
Step 6	Repeat steps 3 to 5 for all observations on subsidized firms.
Step 7	Using the matched comparison group, the average treatment effect on the treated can thus be calculated as the mean difference of the matched samples: $\hat{\alpha}_{TT}^{M} = \frac{1}{n^T}\left(\sum_i Y_i^T - \sum_i \hat{Y}_i^C\right)$ with $\hat{Y}_i^C$ being the counterfactual for firm *i* and n^T is the sample size (of treated firms). Note that the same observation may appear more than once in that group.
Step 8	As we perform sampling with replacement to estimate the counterfactual situation, an ordinary t-statistic on mean differences is biased, because it does not take the appearance of repeated observations into account. Therefore, we have to correct the standard errors in order to draw conclusions on statistical inference. We follow Lechner (2001) and calculate his estimator for an asymptotic approximation of the standard errors.

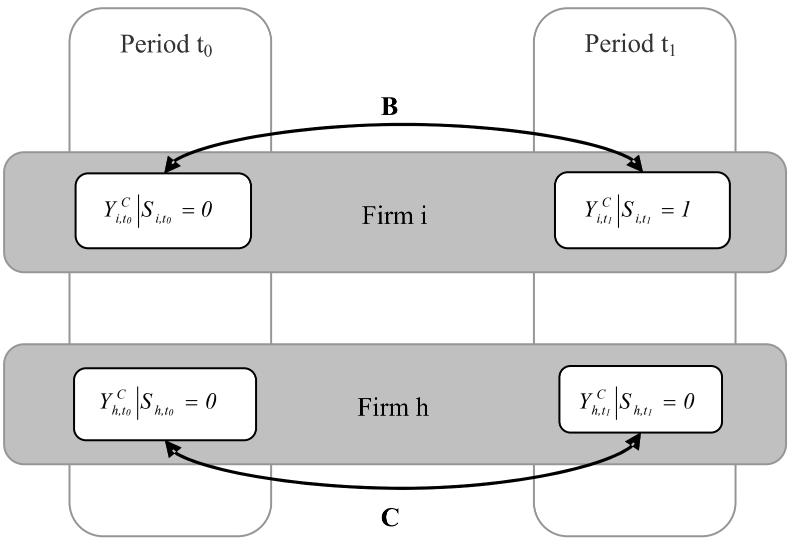
3.3. Difference-in-differences (DiD) estimator

In the difference-in-differences (DiD) model the estimation of the treatment effect is based on the idea that the counterfactual outcome of a subsidized firm i in period t_1 can be approximated by the outcome of that treated firm in an earlier period t_0 where it did not receive a subsidy. To control for macro-economic changes over time DiD relates the development of subsidized firms i to a control group of non-subsidized firms h and compares them before (t_0) and after (t_1) the treatment moment:

$$\alpha_{TT}^{DiD} = \left(E(Y_{i,t_1}^T \middle| X_{i,t_1}, S_{i,t_1} = 1) - E(Y_{i,t_0}^C \middle| X_{i,t_0}, S_{i,t_0} = 0) \right) - \left(E(Y_{h,t_1}^C \middle| X_{h,t_1}, S_{h,t_1} = 0) - E(Y_{h,t_0}^C \middle| X_{h,t_0}, S_{h,t_0} = 0) \right). \qquad (21)$$

Figure 4 depicts the DiD methodology. Evolutions B and C are evaluated over time. The DiD technique allows controlling for both common macro-economic trends and constant individual-specific unobserved effects. Besides the outcome and treatment variables, additional covariates X enter equation (21) to account for the possibility that the treated and non-treated samples have systematically different characteristics in t_0 and t_1 (see Wooldridge, 2002). Neither functional form nor regressor is required for the outcome measure. However, a big disadvantage is that panel data are necessary, including observations before and after (or while) the treatment. As subsidies often target longer term research projects, and firms may receive multiple grants over time, it is difficult to construct a database that is suited for an appropriate application of DiD. Another shortcoming of DiD is that strategic behaviour of firms to enter the subsidy program would lead to biased estimates. Moreover, if the companies that do and do not receive subsidies react differently to macro-economic changes, the estimates are biased.

Figure 4: DiD methodology



3.4. Conditional difference-in-differences estimator (CDiD)

The CDiD estimator combines the advantages of matching and DiD and eliminates some of their respective disadvantages. DiD controls for unobserved heterogeneity between treated and non-treated companies and the matching technique controls for potentially different reactions to macro-economic changes in the treated and the non-treated group. Heckman et al. (1998) show that CDiD based on a non-parametric matching provides an effective tool in controlling for selection on both observables and unobservables.

The control group used in the CDiD model is not general as in the ordinary DiD, but is a sample of non-treated firms h which is matched to the treated firms i in the period (t_0) before receiving the treatment (in period t_1). The effect of the treatment on the treated is estimated from the evolution of the two comparable groups over time. Blundell and Costa Dias (2000) suggest employing CDiD[16] for Repeated Cross-sections (CDiDRCS) if panel data are not available. However, the estimation of the treatment effect may be inconsistent if repeated cross-sectional data are used in a situation where the composition of the groups of treated and non-treated firms changes over time (due to some unknown and unobservable rule) and is affected by the treatment. In this case, the company-specific effect is no longer constant over time, causing a bias in the estimation. This bias adds to the potential residual problem of unobserved effects which is induced even when panel data are used (see Görg and Strobl, 2007). This imposes extra constraints on the data that can be employed. Nevertheless, Blundell and Costa Dias (2000: 437) indicate that "*there is a clear trade-off between the available information and the restrictions needed to guarantee a reliable estimator*". As there were no significant changes in the S&T policy between the years under investigation and we have a relatively rich dataset at our disposal, we feel confident in applying the CDiDRCS methodology here. As we will point out later, additional robustness checks support our audacity.

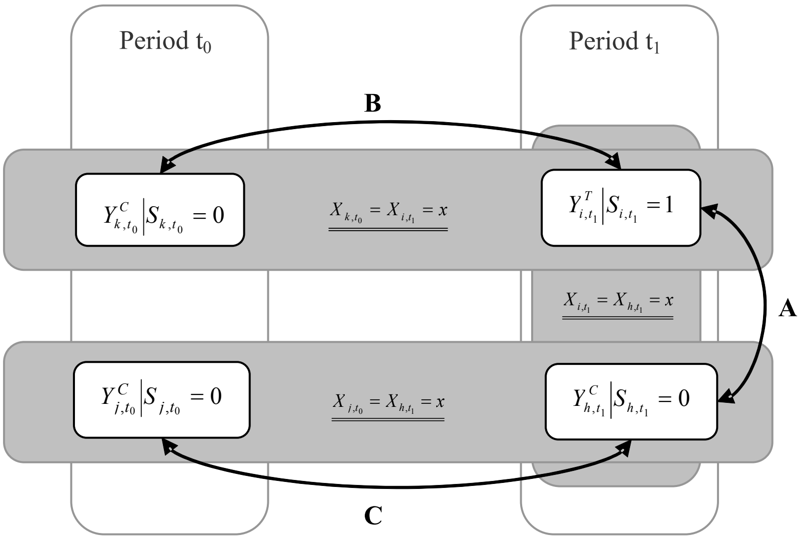
In the CDiDRCS three matching algorithms are required, as depicted in Figure 5. For every treated firm i in period t_1, a non-treated twin firm h has to be found in the same period t_1 (matching A). In the next step, a control group has to be compiled: for each treated firm i and each non-treated firm h in period t_1 a twin

[16] In Blundell and Costa Dias (2000), CDiD is referred to as MMDiD: method of matching with difference-in-differences.

firm, i.e. k and j respectively, has to be found in period t_0 (matching algorithms B and C). The average treatment effect on the treated firms then can be estimated as follows:

$$\alpha_{TT}^{CDiDRCS} = \left(E(Y_{i,t_1}^T \middle| X_{i,t_1} = x, S_{i,t_1} = 1) - E(Y_{k,t_0}^C \middle| X_{k,t_0} = x, S_{k,t_0} = 0) \right) - \left(E(Y_{h,t_1}^C \middle| X_{h,t_1} = x, S_{h,t_1} = 0) - E(Y_{j,t_0}^C \middle| X_{j,t_0} = x, S_{j,t_0} = 0) \right). \quad (22)$$

Figure 5: CDiDRCS methodology



4. The data

Before we come to the data which is employed in the empirical part of this article, we first go into the details of the public funding system in Flanders and Germany and sketch the innovation landscape in which this policy is embedded.

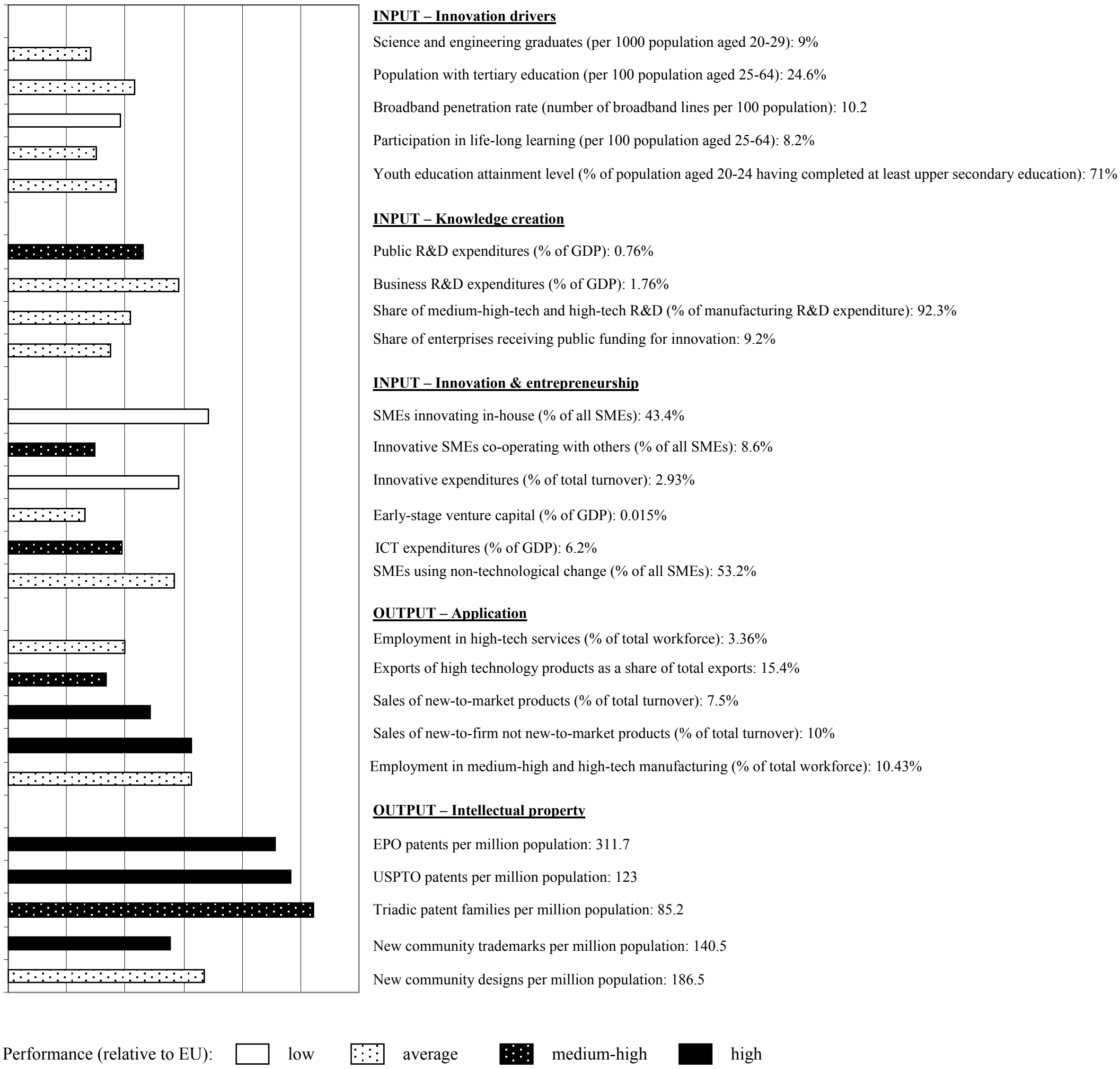
4.1. Public funding of R&D in Flanders and Germany

Germany conducts its Science and Technology (S&T) policy at the national level while policy makers in Flanders, the largest region in Belgium, operate at the regional level. However, a comparison between Germany and Flanders seems to be a reasonable choice. First, the Belgian S&T policy is highly regionalized: the Flemish Science and Technology policy falls entirely under the responsibility of the Flemish government and the impact of public R&D funding should therefore also be evaluated at the regional Flemish level. Moreover, the Flemish and German R&D policy do not differ substantially. In the following paragraphs we present the main characteristics of the German and Flemish innovation system and their respective Science and Technology policy.

German innovation system and Science and Technology policy

The European Union attaches high importance to innovative performance and extensive data collection is undertaken to assess this performance on a number of key indicators. Different dimensions are evaluated: innovation drivers, knowledge creation as well as innovation and entrepreneurship at the input side and application and intellectual property at the output side. A country level assessment is published yearly in the so-called European Innovation Scoreboard country reports. The 2007 report (PRO INNO EUROPE, 2007a) reveals that Germany is among the top performers in the EU27 (see Figure 6). The high level of R&D expenditure, a strong innovation orientation and efficient production processes strengthen the country's competitive position. Some main concerns, however, are the low quality of the innovation system, difficulties for start-ups and SMEs to find sufficient funding for innovation, decreasing propensity to perform R&D among small firms and the insufficient technology transfer between the business and science sector.

Figure 6: Innovation scoreboard: Germany



Source: PRO INNO EUROPE, 2007a.

The German context in which science policy is set and research is produced, is complex due to both the diverse and fragmented research provider base, and the federal system, which results in a split in responsibility for the Science and Technology policy between the federal government and the states (Länder).

The main actors in the public sector are presented below (all information as of 2000; BMBF, 2000 and 2004).

- **Universities and "Fachhochschulen"** (polytechnic colleges, or sometimes referred to as "Universities of Applied Sciences"): Germany hosts 344 institutions of higher education; among those, 75 are private.

- **Max-Planck Society**: The MPG (Max-Planck-Gesellschaft zur Förderung der Wissenschaften) comprises 74 research institutes covering several research fields. The research undertaken in this institution is mostly viewed as basic research complementary to university research. Researchers employed at MPG have a high degree of scientific and organizational autonomy. The MPG is funded 50% by the Federal Government, and 50% by the Länder.

- **Fraunhofer Society**: The FhG (Fraunhofer-Gesellschaft) maintains 48 research institutes with a budget over 500 million EUR. Their mission is a) contract research for the business sector including collaborative research, b) contract research for the Federal Government and the Länder in order to foster key technologies and innovation in fields of public interest, and c) defence research on behalf of the Ministry of Defence. Defence research is funded 100% by the Federal Government, and the rest is financed as follows: 64% own returns from contract research, 36% success-independent basic institutional funding, where 90% is funded by the Federal Government and 10% by the Länder. The research carried out at FhG clearly has an applied focus.

- **Helmholtz Society** (also referred to as "Großforschungseinrichtungen" = Big Science): The HGF (Helmholtz-Gemeinschaft Deutscher Forschungszentren) comprises 16 large research institutions that cover basic research and the investigation of key technologies. In 1998, the total budget was more than 2 billion EUR, and the HGF employed more than 21 thousand researchers. About one fourth of the employees is funded through contract research. Institutional funding is shared by the Federal Government (90%) and the Länder (10%).

- **Blue List** (also referred to as the name of the umbrella organization, the "Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz" = WGL): The WGL consists of 84 research institutions. The financing is shared by the Federal Government and the Länder (50%:50%). The WGL has more than 11 thousand employees in total, and a budget of more than 600 million EUR. The research fields covered are humanities, economics and social sciences, life sciences, mathematics, natural sciences and engineering, environmental sciences, and others.

- **Other institutions**:
  a) Federal institutions with research tasks: besides the main R&D-performing institutions, the federal government maintains a number of institution (or departments of ministries and similar entities) that are concerned with R&D tasks. In total those are more than 50 entities. The share of R&D in those institutions varies considerably: in some, R&D accounts only for 10% of the budget, but in others 100%. On average, the R&D expenses in total budgets amount to 43%. The total R&D budget is more than 600 million EUR, and is financed by the federal government.
  b) "Central information institutions" and scientific libraries: these institutions' mission is the collection and dissemination of literature and other information, development and supply of databases, and related tasks. In 2000, there were 29 such entities.
  c) Other institutions with research tasks.

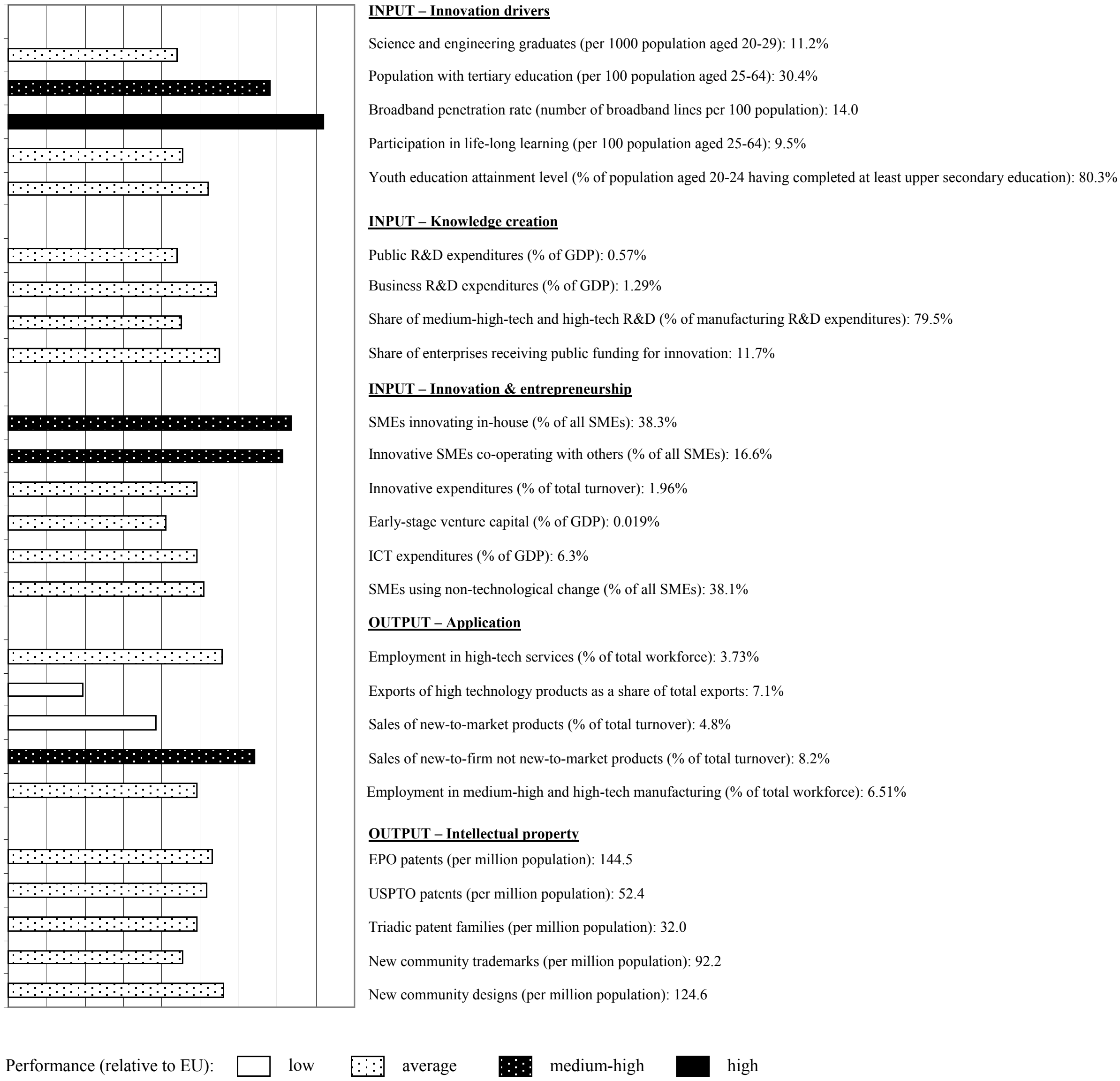
The German public R&D funding largely relies on direct funding of R&D projects of firms and on institutional funding of more basic research. Fiscal measures, like R&D tax credits, do not exist. There is no single, central body that determines research and funding policies. The responsibility for education, including higher education and research, lies solely with the Länder. They provide basic funding and institutional support for universities as well as a number of independent research institutes. The federal government (jointly with the Länder) provides R&D funding to companies as well as institutional funding for major players aside of universities in the innovation system, such as the Max-Planck Gesellschaft, the Helmholtz Association, and the Blue List. The most important federal agencies concerned with research funding are the Ministry for Education and Research (BMBF) and the Ministry for Economics and labour (BMWA). In addition, the Ministry for Defence (BMVg) also funds research.

Public R&D funding of private R&D activity is project-based, acts on a cost-sharing basis and depends on the technology field. Different agencies, at the national and at the Länder level, provide funding through different programs, each with specific eligibility criteria and application procedures. German companies obviously also qualify for European R&D funding.

Flemish innovation system and Science and Technology policy

The Flemish innovation system is embedded in the Belgian context. The country level assessment in the European Innovation Scoreboard country reports reveals that Belgium performs among the TOP10 in the EU27. However, it is also clear that the country lags behind in several indicators, which expose Belgium's weak competence in capitalizing the full benefits of above average levels of R&D and innovation expenditure in terms of innovative output. The main strength of the Belgian innovation system lies in its strong relative performance on human resources in innovation. However, there is a skill mismatch to some extent, and also a considerable outgoing brain drain.

Figure 7: Innovation scoreboard: Belgium



Source: PRO INNO EUROPE, 2007b.

The Belgian innovation system is highly regionalized. The main actors in the Flemish innovation system took up an engagement in the so-called Innovation Pact, which translates the Barcelona targets into the Flemish context. The Flemish Science Policy Council selected 11 key indicators to assess Flanders' innovative performance and the progress towards the targets which were stipulated. These indicators are presented in Table 2, including figures for Flanders and Belgium.

Table 2: Key indicators: Flanders and Belgium

	Flanders	Belgium	year
I. GERD (in % GDP)	2.09	1.82	2005
II. GBOARD (in % GDP)	0.71	0.57	2005
III. Total R&D personnel (in % of the workforce)	1.25	1.18	2005
IV. Science and engineering graduates (per 1000 population aged 20-29)	11.80	11.20	2004
V. Total number of innovating companies (in % of the total number):			2005
all	0.59	0.51	
industry	0.64	0.58	
services	0.54	0.45	
SMEs	0.57	0.50	
large companies	0.88	0.83	
VI. Early-stage venture capital (in % of GDP)		0.04	2005
VII. EPO patents (per million population)	169.20	144.50	2003
VIII. Sales of new products (in % of total turnover)	0.24	0.07	
IX. Employment (in % of the workforce):			
in medium high-tech and high-tech industries	0.08	0.07	2006
in high-tech services	0.04	0.04	2006
X. Regional domestic product growth (in current prices; reference year 1997)	1.42		2006
XI. Exports of high technology products as a share of total exports		7.10	2004

Source: Debackere and Veugelers, 2007

The main actors in the Flemish innovation system are (Debackere and Veugelers, 2007):

- **Universities**: Flanders has six universities: K.U.Brussel, K.U.Leuven, UHasselt, U. Antwerpen, UGent and V.U.Brussel; they are the main conductors of fundamental research.
- **Flemish research institutions**: 4 large research centres (Interuniversitair Micro-elektronica Centrum (IMEC), Vlaamse Instelling voor Technologisch Onderzoek (VITO), Vlaams Instituut voor Biotechnologie (VIB), Instituut voor Breedbandtechnologie (IBBT)) and a number of smaller institutions; these centres conduct research in strategic domains and complement the research conducted in the universities.
- **The collective centres**: 11 centres, founded by Belgian business federations, with a priority to conduct applied research which is relevant for the companies in their sector.
- **The Business sector**: Flemish companies conduct about 70% of the Flemish R&D activity, which makes them a vital component in the innovation system.

- **The Hogescholen (polytechnic colleges)**: they are stimulated to combine their first priority, i.e. education, with applied research.

- **Redistribution mechanisms:** IWT-Vlaanderen manages Flanders' technology policy and, more specifically, also the public funding of research with economic affinity; FWO-Vlaanderen distributes the resources for fundamental research in universities; Hercules finances medium-heavy and heavy research infrastructure and finally, the Bijzonder Onderzoeksfonds (BOF) provides further funding for academic scientific research.

- **The Flemish Department of Economy, Science and Innovation:** the department of the Flemish government with the main authority in conducting the Flemish Science and Technology policy.

- **The Flemish Science Policy Council:** formulates recommendations to the Flemish government and the Flemish Parliament, in the area of Science and Technology policy.

- **Advisory Bodies:** a.o. the Koninklijke Vlaamse Academie van België voor Wetenschappen en Kunsten, Flanders Social and Economic Council (SERV) and the Stichting Technology Vlaanderen (STV).

- **Steunpunten Beleidsrelevant Onderzoek: t**hese 14 Steunpunten provide stability in policy supporting research and support the development of knowledge indicators around key policy topics.

- **Specific actions to foster technology transfer and diffusion.**

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 corporate R&D subsidies, at the Flemish and Belgian level, as well as certain EU-funded projects[17] 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

[17] The Framework Program projects are not managed through IWT. However, typically the scale of these projects is very large because these projects are often managed in international company consortia. As a result, the number of Flemish firms engaging in these programs is very limited.

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[18]. Main reasons are a low level of acquaintance with the system, complexity and high administration costs[19] and the fact that the measures are not significantly substantial[20]. Direct R&D funding through IWT remains the largest source of public R&D grants in the private sector in Flanders[21].

Public R&D funding in Germany and Flanders

Table 3 presents some numbers on the public budgets for R&D in Germany and Flanders. First, it is obvious that there is a significant difference in size. The German GBAORD (Government Budget Appropriations or Outlays for R&D) amounts to almost a 15-fold of the Flemish GBAORD. A similar scale difference can be found in the GERD (Gross Expenditure for R&D) and BERD (Business Expenditure for R&D). When the R&D budgets are normalized by the GDP, the statistics reveal that in terms of R&D expenditure Germany is still far from the Barcelona Target of 3%, but Flanders is even further away. In terms of public funding of the R&D expenditure (which should be about one third according to the Barcelona Target), Germany stood at 28% and Flanders at 25% in 2005. When we also take the indicator reflecting the share of the BERD financed by the government into account, it becomes apparent that the Flemish government has a higher share, which has grown slightly over the years (to about 6.5% in 2006), while on the other hand, this share has been reduced over time in Germany (to a level of 4.5% in 2005). Although there is no information enabling a direct comparison of the amount of public funding in the private sector between the two countries, Table 3 seems to indicate that Flemish firms receive a larger share of direct public R&D funding. This is also confirmed in the dataset we will use to assess the impact of public

[18] Due to recent changes in the Science and Technology Policy, this situation has changed, though. In the current system, fiscal measures, and more specifically tax credits for R&D personnel, are becoming increasingly popular. However, this is not relevant in the current chapter, as our data was collected before the change.

[19] First, each year the company has to deliver a certificate. Second, the researcher should be full time employed in the research department of the same company to qualify. Third, the tax allowance is nominative, inducing a burden to keep track of all employees who benefited from the measure in the past.

[20] First, the amount of the exemption is not sufficiently significant. Second, the definition of highly qualified personnel is too strict, so that only very few employees qualify for the measure. Third, the tax exemption is a short term measure (it only relates to the first year of recruitment) while R&D typically is a long term process.

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

funding in both countries: in Flanders, about 20% of the firms indicated to have received R&D grants, while in Germany this number is somewhat lower, i.e. 14%.

Table 3: Public R&D budgets in Germany and Flanders

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Germany											
GBAORD (in mio EUR)	16461	16009	16017	16322	16253	16460	16737	17101	16943	17221	17810
GERD (in mio EUR)	41168	42859	44649	48191	50619	52002	53364	54539	54967	55739	58231
GERD (in % GDP)	2.19	2.24	2.27	2.40	2.45	2.46	2.49	2.52	2.49	2.48	2.51
GERD financed by the government (in % GERD)	38.1	35.9	34.8	32.1	31.4	31.4	31.6	31.2	30.5	28.4	..
BERD (in mio EUR)	27211	28910	30334	33623	35600	36332	36950	38029	38363	38651	40531
BERD financed by the government (in % GERD)	10.5	9.2	8.5	7.0	6.9	6.7	6.2	6.1	5.9	4.5	..
Flanders											
GBAORD* (in mio EUR)	636	700	747	801	831	865	947	1023	1070	1132	1219
GERD (in mio EUR)	1979	2190	2427	2602	2875	3234	3525	3317	3276	3347	3569
GERD (in % GDP)	1.83	1.92	1.99	2.11	2.24	2.38	2.17	2.09	2.03	2.09	..
GERD financed by the government (in % GERD)**	23.0	22.2	23.8	23.5	22.9	22.0	23.2	23.6	24.4	24.7	..
BERD (in mio EUR)	1472	1614	1804	1897	2119	2426	2659	2412	2332	2313	2441
BERD financed by the government (in % GERD)**	5.1	5.1	6.3	6.3	5.8	5.9	5.4	5.4	6.0	6.2	6.5

* R&D budget of the Government of Flanders + the Flemish share in the federal government R&D funds + the Flemish share in the funds for the EU research programmes (Framework Programmes).
** As these time-series indicator was not available for Flanders, we used information for Belgium as the best available approximation.
Source: OECD, 2007 and Debackere and Veugelers, 2007.

So, despite the fact that the funding schemes are very similar in the two countries, the different scale of the economy and corresponding science policy budget may induce different impacts of R&D funding.

4.2. Variables

The potential crowding-out effect of R&D subsidies is addressed empirically with data from the Flemish and German[22] Community Innovation Survey (CIS). The CIS covers most EU countries using a largely harmonized questionnaire[23]. First, a cross-sectional dataset, i.e. the CIS IV wave covering the years 2002 to 2004, is used. In a second step, data from the CIS III wave, referring to the years 1998 to 2000, is additionally plugged in into the analysis. Our sample covers the Flemish and German manufacturing sector and computer services, R&D services as

[22] Note that the German Community Innovation Survey data are part of the Mannheim Innovation Panel, the annual German innovation survey.
[23] Eurostat (2004) presents aggregate statistics and detailed descriptive survey results for all countries.

well as business related services. In accordance with the OECD/Eurostat (1997) guidelines for the CIS survey, the sample is restricted to companies with ten or more employees. The total sample consists of 4566 (1665) German (Flemish) observations on 3903 (1471) companies: the overlap between the two waves is very limited: only 663 (194) German (Flemish) firms are observed twice. These innovation data are supplemented with patent application data of German and Flemish firms from the European Patent Office, covering all applications from 1978 to 2004.

The receipt of subsidies is denoted by a dummy variable (FUN) indicating whether the firm, observed in the CIS IV (III)[24], 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 to a lesser, but nevertheless significant extent, sources of public R&D funding of Flemish companies (40% and 19% respectively). In the period 2002-2004 14% of German enterprises with innovative activities received public funding. 55% of these companies were funded by local or regional authorities. The national government financially supported 54% of these innovative companies and the EU government provided 29% of them with financial support for R&D activities.

We did not distinguish between the different funding sources; the funding impact is an average effect over the different funding schemes. We would also like to stress that the restriction to a dummy variable (instead of using full information on the amount of the subsidy) imposes a limitation on the interpretation of the results. We can only analyze whether there is full crowding-out, i.e. the subsidy fully replaces private money. In this case the actual and counterfactual R&D spending of funded firms would be equal. Partial crowding-out would mean that the subsidy partially replaces private money: the funded companies spend more on R&D, but the additional amount of R&D spending is smaller than the amount of the subsidy. In the case of additionality, funded companies spend their budgeted R&D expenditure and all additional public money or even more (the subsidy might help

[24] In the description of the variables, we always refer to two years, i.e. the year of the CIS-wave. For the ordinary matching approach, only the CIS IV is used. In the CDiDRCS approach, the CIS III wave adds a time dimension (two years earlier).

the company to bridge some threshold level and enable it to set up a larger R&D project than initially possible). Nor the hypotheses of partial crowding-out and additionality nor potentially heterogeneous size effects can be tested in the framework presented in this chapter. Moreover, the dummy variable implies a drawback on the comparability between the two countries: the effect of the subsidy may be heterogeneous in country size.

As the subsidy dummy covers a three year period, we 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.

We test the hypothesis of input additionality on two outcome variables. First, R&D expenditure[25] at the firm level in 2004(2000), RD, is evaluated. However, as the distribution of this indicator is very skewed in the economy, we also investigate the R&D intensity, RDint (R&D expenditure / turnover * 100). 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. Using the logarithmic transformation scales down the large values and reduces the problem with these skewed distributions. Therefore, the logs[26] of RD and RDint are additionally evaluated as outcome variables. All outcome variables refer to the year 2004(2000).

We use several control variables in our analysis which may affect both the probability to receive subsidies as well as R&D expenditure, respectively. Including the number of employees at the beginning of the period allows controlling for size effects, which are empirically often found to explain innovativeness (see e.g. Veugelers and Cassiman, 1999). Moreover, both the Flemish and German S&T policy put 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 potential estimation biases caused by skewness of the data.

Another important variable in our analysis is the firms' patent stock (PATST). 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

[25] In the CIS survey, R&D expenditure is defined in accordance with the Frascati Manual (OECD, 1993).
[26] We replaced zero values of RD and RDint with the minimum observed value in order to generate the log of the variables.

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, which includes, according to the Oslo Manual, the international handbook for conducting innovation surveys worldwide (OECD/Eurostat, 1997: 10), *"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"*. 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 have at our disposal. 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):

$$PATST_t = (1-\delta)PATST_{t-1} + PATA_t \,, \tag{23}$$

where PATST is the patent stock of a firm 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 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 to reduce the potential multicollinearity with firm size.

A dummy variable indicating whether a firm belongs to a group (GROUP) controls for different governance structures. Firms that belong 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 contrast, if firms belong to a group with a foreign parent (FOREIGN), it may be the case that the group tends to rather file subsidy applications in its home country.

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. In the German analysis we also include the variable EAST, indicating whether the firm is located in East Germany. There are strong indications that the innovation behaviour of East and West German firms may still be different (see e.g. Aschhoff et al., 2006; Sofka and Schmidt, 2004). Furthermore, special policy programs apply for East German firms, which is obviously important in the framework of additionality effects of R&D subsidies. Typically, companies in East Germany are younger and smaller. Again, we have to point out that the potential 'mismatch' between innovation and R&D activities induces that EXQU and EAST are an indication of a firm's R&D activity.

Finally, some industry dummies (BR) are included to allow for differences between different 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.

All variables described until now, are available in both the German and Flemish dataset (except for the EAST variable which is obviously only included for the German data) to enable a certain degree of comparison of the results. However, as was stressed in the methodological part of this chapter, the matching procedure crucially relies on the fulfilment of the Conditional Independence Assumption (CIA). Only in that case, the average outcome of subsidized firms in the absence of a subsidy can be estimated based on a sample of comparable, i.e. matched, firms. It is arguable that relevant values are missing in the analysis. Therefore, we add some variables in additional robustness analyses, which are unfortunately not available or perfectly comparable for both datasets. Four Flemish and three German variables are generated separately, in addition to the comparable variables described above. PROJ_PAST5YR is a count variable, reflecting the total number of project proposals each Flemish company submitted in order to obtain an R&D subsidy in the preceding 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. This is a very important control variable (unfortunately only available in the Flemish dataset) since it is very likely highly correlated with both the probability to receive a subsidy and the outcome variable. Companies which submitted many projects in the past are on the one hand more experienced in applying for a subsidy and therefore possibly more 'eligible' for a grant. On the other hand, they may be more innovative and therefore more likely to apply for a subsidy to support their extensive R&D activities. Next, variables reflecting the technological and financial quality of the company might be important. In the Flemish dataset, 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 to avoid multicollinearity with firm size. In the German dataset, information on factors hampering the innovative activity was used to construct measures of a company's technological and financial profile. TECHCONSTR is a four-point-Likert-scale variable (0: not relevant to 3: very important) indicating whether a lack of technological information hindered the company in its innovative activities; FINCONSTR is a four-point-Likert-scale variable reflecting whether the firm faced financial difficulties in its innovative activities, both internally (innovation activities were too expensive) and externally (difficulties to find external financing of the innovative activities). Finally, we were able to construct a variable SCOMNACE for both datasets, signalling to which extent information from competitors is absorbed by the company. To avoid potential endogeneity with the outcome variables, this variable was rescaled on the three digit (NACE3) industry level.

5. Estimates

We test the additionality hypothesis with two techniques. First, we employ the matching estimator, as common in the literature on the evaluation of R&D subsidies. In the second step, we control for unobserved heterogeneity effects by using the CDiDRCS estimator. This is new in the domain of R&D additionality research. A third section provides additional robustness checks to validate our results.

5.1. The matching estimator

In this subsection the matching estimator is applied to the data of the CIS IV cross-section to estimate the additionality effect of subsidies that were granted to Flemish and German companies between 2002 and 2004. Table 4 presents the descriptive statistics for the samples, which consist of 2374 (883) German (Flemish) companies, of which 503 (171) received public funding. A comparison between the two countries reveals three important differences: German firms tend to be larger, foreign ownership is less prevalent in Germany and German firms export more. In absolute terms (RD), German firms spend a much larger budget on R&D activities. However, when the scale difference is eliminated in the indicators measuring the intensity, the R&D activity (RDint) tends to be larger in the Flemish sample.

Table 4: Descriptive statistics of the Flemish and German sample

Variable	Subsidized companies		Potential control group Non-subsidized companies		p-values of two-sided t-test on mean equality
	Mean	Std. Dev.	Mean	Std. Dev.	
Flemish sample					
lnEMP	4.198	1.630	3.645	1.273	p = 0.0000
PATST	0.800	2.592	0.043	0.325	p = 0.0002
GROUP	0.602	0.491	0.449	0.498	p = 0.0003
FOREIGN	0.263	0.442	0.222	0.416	p = 0.2685
EXQU	0.026	0.092	0.018	0.086	p = 0.2916
$\widehat{P}(X)$	0.336	0.241	0.159	0.120	p = 0.0000
RD	2.002	4.972	0.228	1.166	p = 0.0000
RDint	8.046	14.425	1.096	3.783	p = 0.0000
lnRD	-1.200	3.513	-7.213	3.694	p = 0.0000
lnRDint	0.175	2.762	-3.855	2.806	p = 0.0000
Number of obs.:	171		712		
German sample					
lnEMP	4.443	1.679	4.206	1.468	p = 0.0041
PATST	0.806	2.127	0.298	1.245	p = 0.0000
GROUP	0.660	0.474	0.569	0.495	p = 0.0002
FOREIGN	0.127	0.334	0.094	0.291	p = 0.0393
EXQU	0.303	0.271	0.166	0.232	p = 0.0000
EAST	0.491	0.500	0.280	0.449	p = 0.0000
$\widehat{P}(X)$	0.351	0.190	0.173	0.145	p = 0.0000
RD	8.062	62.051	1.135	6.756	p = 0.0127
RDint	7.227	6.710	1.217	3.445	p = 0.0000
lnRD	-0.937	2.697	-4.521	3.054	p = 0.0000
lnRDint	0.376	2.914	-4.278	3.694	p = 0.0000
Number of obs.:	503		1871		

Note: the industry dummies BR and interaction terms BR_lnEMP are not reported here.

The two-sided t-tests indicate significant differences between the subsidized companies and the potential control group of non-subsidized companies. Flemish and German subsidized firms are larger, have a larger patent stock and are more likely to belong to a group. The dummies for foreign ownership and the export quota do not differ significantly between the Flemish groups. German subsidized firms are more likely to be foreign and have a significantly higher export quota. As expected, also the dummy for companies located in East Germany differs between the two groups. The industry dummies BR and interaction terms BR_lnEMP (not presented in Table 4) are significantly different both in the Flemish and German sample. The outcome variables show that the subsidized companies are significantly more R&D active. However, we cannot simply assign this difference to the subsidy receipt, due to the potential selection bias, which we already described before. Therefore, we have to select a control group that has similar characteristics compared to the group of funded companies.

This control group is selected in accordance with the matching procedure which was outlined in the methodological section of this chapter. The first step consists of estimating a probit model on the receipt of subsidies. The estimation results for the Flemish and German sample in Table 5 show that the most important variables are -as expected- size, the patent stock, the group and foreign dummy, the export quota and the East Germany dummy. Further tests show that the interaction terms BR_lnEMP are jointly significant ($\chi^2(11) = 31.51$ and $p = 0.0009$ for the German and $\chi^2(11) = 36.50$ and $p = 0.0001$ for the Flemish sample). As a result, these interaction terms are also included in the propensity score (this probit model is not presented in the chapter). In the second step, for each subsidized firm i a twin-firm h is selected from the control group of non-subsidized companies with the hybrid nearest neighbour matching technique. In both the Flemish and German S&T policy, size is an important determinant of the probability to receive a subsidy (e.g. given the subsidy programs especially designed for small and medium sized enterprises). Therefore it is explicitly taken into account, next to its implicit value in the propensity score. As mentioned before, this increases the accurateness of the matching. For the matching in the German sample, the dummy indicating whether the company is located in East Germany is included as an additional explicit matching variable. Due to the common support[27] requirement 4 (4) German (Flemish) non-funded firms and 25 (20) funded observations had to be deleted from the sample (CIS III and IV together). The likelihood to receive public funding (the propensity score, obtained from the probit model), firm size and for the German sample also the East Germany dummy, are used as arguments in the matching procedure. Table 4 shows that the propensity score is significantly different too between the group of subsidized companies and the potential control group for both samples.

[27] As this matching procedure within the CIS IV is the starting point for the CDiDRCS in section 5.2 where matches to the CIS III are added for the treated and selected non-treated firms from this section 5.1, we impose the simultaneous common support requirement for all three matching algorithms already in this first step.

Table 5: Probit estimates and marginal effects

	Flemish sample								German sample							
	Probit estimates				Marginal effects				Probit estimates				Marginal effects			
	Coef.		Std. Err.		dy/dx		Std. Err.		Coef.		Std. Err.		dy/dx		Std. Err.	
lnEMP	0.168	***	(0.046)		0.042	***	(0.011)		0.048	*	(0.025)		0.012	*	(0.006)	
PATST	0.373	***	(0.101)		0.092	***	(0.025)		0.061	***	(0.210)		0.015	***	(0.005)	
GROUP°	0.089		(0.134)		0.022		(0.033)		0.106		(0.072)		0.027		(0.018)	
FOREIGN°	-0.300	**	(0.151)		-0.068	**	(0.031)		-0.130		(0.107)		-0.031		(0.024)	
EXQU	-0.141		(0.623)		-0.035		(0.154)		1.091	***	(0.150)		0.275	***	(0.038)	
EAST°									0.787	***	(0.070)		0.223	***	(0.021)	
constant	-1.844	***	(0.187)						-1.954	***	(0.130)					
BR	$\chi^2(11) = 26.66$ p = 0.0052								$\chi^2(11) = 103.19$ p = 0.0000							
Log-Likelihood	-379								-1019							
Pseudo R²	0.076								0.147							
Number of obs.:	866								2348							

*** (**, *) indicate a significance level of 1% (5, 10%).
The marginal effects on subsidies are calculated at the sample means for continuous variables and for a discrete change of dummy variables (indicated by °) from 0 to 1. Their standard errors are obtained by the delta method.
The propensity score used in the matching algorithm takes the interaction terms between size and industry additionally into account. The coefficients change only marginally and are not reported in this chapter.

When we only take the selected control group into account in the t-tests (see Table 6) we no longer observe significant differences in the control variables size, patent stock, group, foreign ownership, export quota, location in East Germany, industry dummies and the propensity score. 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 and proportionally to the turnover. We can conclude that for both the Flemish and German sample the crowding-out hypothesis can be rejected: the average R&D expenditure and the average R&D intensity have increased due to the public funding of R&D.

Table 6: Descriptive statistics of the Flemish and German matched samples

Variable	Subsidized companies		Selected control group Non-subsidized companies		p-values of two-sided t-test on mean equality*
	Mean	Std. Dev.	Mean	Std. Dev.	
Flemish sample					
lnEMP	4.129	1.517	4.121	1.493	p = 0.969
PATST	0.228	0.788	0.135	0.577	p = 0.283
GROUP	0.573	0.496	0.567	0.497	p = 0.921
FOREIGN	0.248	0.433	0.197	0.399	p = 0.340
EXQU	0.024	0.087	0.015	0.064	p = 0.396
$\widehat{P}(X)$	0.289	0.175	0.285	0.170	p = 0.864
RD	1.287	3.070	0.450	1.184	p = 0.002
RDint	7.240	13.415	2.534	6.278	p = 0.000
lnRD	-2.283	3.484	-5.211	4.243	p = 0.000
lnRDint	-0.007	2.792	-2.341	3.265	p = 0.000
Number of obs.:	157		157		
German sample					
lnEMP	4.453	1.647	4.451	1.609	p = 0.985
PATST	0.695	1.777	0.522	1.548	p = 0.164
GROUP	0.659	0.475	0.688	0.464	p = 0.418
FOREIGN	0.126	0.332	0.145	0.352	p = 0.480
EXQU	0.291	0.263	0.302	0.300	p = 0.626
EAST	0.486	0.500	0.486	0.500	p = 1.000
$\widehat{P}(X)$	0.338	0.177	0.335	0.174	p = 0.834
RD	4.982	20.587	1.750	7.744	p = 0.002
RDint	7.033	9.662	1.707	4.002	p = 0.000
lnRD	-0.987	2.686	-3.667	3.457	p = 0.000
lnRDint	0.312	2.942	-3.486	3.899	p = 0.000
Number of obs.	484		484		

Note: the industry dummies BR and interaction terms BR_lnEMP are not reported here.
* t-statistics to test the mean equality between the sample of funded firms and the selected control group are based on Lechner's (2001) asymptotic approximation of the standard errors that accounts for sampling with replacement in the selected control group

The average treatment effects can be calculated from the sample means in Table 6 and are presented in Table 7. The absolute difference in RD in million EUR and RDint in % is converted into a relative difference, based on the values for RD and RDint of the treated group. Strictly speaking, the treatment effect which is calculated in the matching procedure can only be evaluated at the averages of the samples (see equation (19)). However, as the distribution of both R&D expenditure and intensity is very skewed, we also calculated the median differences. These results should be interpreted with caution, though. On average, a Flemish company that receives a subsidy, spends 0.837 million EUR (65%) more on R&D, compared to the situation where it would not have received the subsidy. The German subsidized firms spend, on average, 3.232 millions EUR (65%) more. The R&D intensity in absolute terms increases with about 5% in Flanders and Germany due to the subsidy. It would be interesting to test the presence of heterogeneous treatment effects: large subsidies could induce other effects than small subsidies. Unfortunately, the available data do not allow us to further investigate this issue.

Table 7: Average treatment effects on the treated companies

	Flanders				Germany			
	Absolute		Relative		Absolute		Relative	
	mean	median	mean	median	mean	median	mean	median
RD (in mio EUR)	0.837	0.211	65%	89%	3.232	0.401	65%	100%
RDint (in %)	4.669	1.484	64%	91%	5.327	3.219	76%	100%

5.2. The CDiDRCS Estimator

The matching estimator indicates that crowding-out effects can be rejected in the Flemish and German case. However, one critique to the matching approach is that it only controls for observed heterogeneity between the subsidized and non-subsidized companies. Therefore, we apply the CDiDRCS estimator, which combines matching with the DiD approach for a set of pooled cross-sectional data. The starting point is the matching result of section 5.1 (A in Figure 5). In the CDiDRCS approach, two additional matching algorithms (B and C in Figure 5) are conducted. For the treated (i) and selected non-treated (h) firms, twin firms (k and j respectively) are selected from the firms observed in the CIS III. The treatment effect is then calculated from the mean difference between the treated and non-treated firms over time. In this way, both unobserved heterogeneity and potentially different reactions to macro-economic changes in the treated and the non-treated group are more explicitly controlled for.

The two additional matching algorithms entail exactly the same procedure as the one conducted in section 5.1. However, when firms were present in the two waves of the CIS survey, they were matched to their own past observation. These firms were observed in the same (18 Flemish and 82 German non-treated firms) or opposite (26 Flemish and 36 German firms, non-treated in t_0, but treated in t_1) treatment status in the two surveys. The same outcome and control variables are analyzed in the same hybrid matching procedure as before. Therefore, the intermediate matching results are not reported in this chapter. The t-tests after the matching show that the selected control groups constitute a reliable match.

First, the final treatment effect estimates are presented for each matching separately (see Table 8). Estimation A is the result of the matching of treated (i) to non-treated (h) firms within CIS IV (period t_1); thus estimation A corresponds to the one presented in section 5.1. Estimation B results from matching treated firms (i) in

CIS IV (period t_1) to non-treated firms (k) in CIS III (period t_0). Finally, estimation C indicates the difference in outcome variables between non-treated firms (h) in CIS IV and non-treated firms (j) in CIS III. The treatment effects A and B are always significant. The treatment effect over time (t_1 versus t_0) is in line with the treatment effect in the same period (t_1). The correction for different reactions to macro-economic shocks between non-treated firms (h and j; estimation C) is never significant. The structure of the results is very similar in the Flemish and German sample.

Table 8: Treatment effect estimates in the three matching algorithms (difference in group means)

	------------A------------	------------B------------	------------C------------
Flemish sample			
RD	0.837 ***	0.900 ***	0.050
	(0.273)	(0.288)	(0.178)
RDint	4.669 ***	5.017 ***	0.203
	(1.246)	(1.429)	(1.190)
lnRD	2.923 ***	2.530 ***	-0.480
	(0.512)	(0.832)	(0.854)
lnRDint	2.334 ***	2.065 ***	-0.242
	(0.400)	(0.635)	(0.646)
German sample			
RD	3.232 ***	2.432 *	-0.262
	(1.049)	(1.433)	(2.027)
RDint	5.327 ***	5.717 ***	0.201
	(0.503)	(0.544)	(0.939)
lnRD	2.680 ***	2.956 ***	0.165
	(0.245)	(0.344)	(0.823)
lnRDint	3.798 ***	4.052 ***	0.125
	(0.274)	(0.386)	(0.935)

*** (**, *) indicate a significance level of 1% (5, 10%)
The standard errors (between brackets) are heteroskedasticly consistent and the t-statistics are based on Lechner's (2001) asymptotic approximation of the standard errors that accounts for sampling with replacement in the selected control group.

Second, we use the differences (graphically relation B in Figure 5 for the treated and relation C for the non-treated firms) in the variables as input in an OLS regression as we would do in an ordinary DiD approach, with the extra feature that we condition on the exogenous variables mentioned before[28]. The difference in each of the outcome variables over time is regressed on the difference over time in funding (FUNdif=0 for the non-treated/non-treated matched firms (*h* and *j*) and FUNdif=1 for the treated/non-treated matched firms (*i* and *k*)). As a time dimension

[28] As the coefficients for relationship C are not significant in our first outcome presentation (see Table 8), it is not possible to merely subtract coefficient C from coefficient B for each outcome variable to obtain a corrected coefficient; the difference-in-differences approach allows us to bring the matching procedures B and C together.

is included in the analysis, the monetary variables (RD and lnRD) are deflated (EconStats, 2007).

As the regression is performed on matched samples, the t-statistics may be biased downwards and result in misleading conclusions (see e.g. Heckman et al., 1998). In order to obtain unbiased standard errors we employ the bootstrap methodology (see e.g. Efron and Tibshirani, 1993). We used 200 replications of the procedure to estimate the bootstrapped standard errors.

Table 9 shows that the treatment effect (FUNdif) is always significantly positive, with one exception for the R&D expenditure in the Flemish sample; this insignificance however may be due to the skewed distribution of R&D expenditure and the relatively small sample size. When the R&D intensity or the logarithmically rescaled variable is evaluated, the additionality effect is again significantly positive. The coefficients are in line with the results that only take the evolution over time of the treated firms into account (estimate B in Table 8). Taking relationship C into account results in minor corrections. As a further robustness analysis we also include the difference in the other continuous variables[29]. For the German sample we can take the EAST dummy into account as well, as this dummy was included in the hybrid matching: only companies with the same value for EAST are matched. Although these extra variables add to the explanatory power of the model, they are not significant in the regression. The positive impact of public funding remains strongly significant, even if we control for the differenced exogenous variables. The difference in outcome variables is due to the receipt of a grant. In the German sample, some differenced exogenous variables are significant, but the main impact on outcome variables comes from the strongly significant relationship with the subsidy receipt. The funding systems in Flanders and Germany are very similar, with a main focus on direct R&D funding. Here we find that the additionality effects have the same structure, increasing the R&D intensity of funded firms with about 5%.

[29] Through the triple matching procedure, we explicitly condition the selection of non-treated firms on their exogenous characteristics. This however does not mean that no differences exist in the differenced exogenous variables.

Table 9: Treatment effect estimates: OLS in differences

Variable	----------RDdif----------		-----------RDintdif-----------		------------lnRDdif-----------		--------lnRDintdif---------	
Flemish sample (Number of obs.: 314)								
FUNdif	0.661	0.571	5.204 ***	5.158 ***	2.574 ***	2.444 ***	2.129 ***	2.144 ***
	(0.588)	(0.600)	(1.170)	(1.224)	(0.528)	(0.525)	(0.415)	(0.498)
lnEMPdif		1.505		-2.461		1.069		0.227
		(2.742)		(4.163)		(1.738)		(1.760)
PATSTdif		0.461		0.324		0.786		0.541
		(0.545)		(1.232)		(0.892)		(0.499)
EXQUdif		4.727		12.668		2.185		1.427
		(6.644)		(15.079)		(6.076)		(5.002)
R²	0.064	0.134	0.109	0.132	0.118	0.161	0.124	0.150
German sample (Number of obs.: 968)								
FUNdiff	2.922 **	3.529 **	5.509 ***	4.871 ***	2.856 ***	2.644 ***	3.877 ***	3.466 ***
	(1.187)	(1.351)	(0.598)	(0.699)	(0.249)	(0.296)	(0.316)	(0.362)
lnEMPdif		8.062		-2.886		0.054		-0.952
		(5.316)		(1.971)		(0.809)		(0.933)
PATSTdif		0.483		0.389		0.169		0.134
		(0.399)		(0.478)		(0.158)		(0.192)
EXQUdif		3.258		0.500		0.636		0.425
		(3.797)		(2.117)		(1.342)		(1.778)
EAST		-1.179		1.256 *		0.447		0.812
		(0.733)		(0.574)		(0.442)		(0.668)
R²	0.013	0.040	0.184	0.197	0.233	0.236	0.249	0.246

Bootstrapped standard errors (between brackets) are heteroskedasticly consistent.
*** (**, *): significant at 1% (5%, 10%).

5.3. Robustness checks

To support the evidence that the full crowding-out hypothesis can be rejected, we provide some extra robustness checks. First, we limit the sample to R&D active companies. Next, we add variables to the analysis.

Only R&D active companies

Czarnitzki (2006) shows that not only the R&D expenditure but also the R&D status may change when a subsidy is granted. Small firms and firms that can offer only limited surety may experience great difficulties in raising external capital for risky projects. Consequently, only a limited budget is available for R&D activities, which may be shut down as a result. As Lerner (1999) argued, the subsidy receipt may serve as a certification of the firm's activities, which could convince potential financiers. Up until now the switch of R&D status was taken into account, as we allowed for the possibility that a funded R&D active company was matched to a non-funded non-R&D active company. If we limit the sample to innovating companies only, the treatment effect may be underestimated. However, it provides a robustness check, so we conducted the same analysis, selecting only R&D active companies from the CIS IV wave. For both the Flemish and German sample the treatment effect remains significantly positive, but is –as expected– somewhat lower. The samples reduce to 415 (121) matched German (Flemish) companies. The R&D intensity in Germany increases with 3.7% (significant at 1%) and the Flemish R&D intensity is 2.8% higher (significant at 5%), compared to an additionality effect of 5% for both countries (both significant at 1%), when all firms are kept in the analysis.

Additional variables

As mentioned before, a weakness of the additionality analysis presented in this chapter, lies in the potential omittance of relevant variables, resulting in a violation of the Conditional Independence Assumption. The analyses presented below include more information (PROJ_PAST5YR, CAPint, CASHF, TECHCONSTR, FINCONSTR and SCOMNACE), which is however not available or perfectly comparable for both samples and therefore less interesting if the reader wants to compare the impact of the S&T policy in both countries. Nevertheless, the models remain comparable to a certain extent (as they reflect more or less the same information) and they provide compelling evidence, showing that the inclusion of more specific and fine-tuned information confirms the rejection of the full crowding-out hypothesis found earlier in this chapter.

The computation of the additional variables results in a total sample of 4184 (1605) German (Flemish) observations on 3903 (1418) companies; the overlap between the two waves if even more limited: only 281 (187) German (Flemish) firms are observed twice. Of these firms, 14 Flemish and 46 German firms were observed in the same non-treated status and 17 Flemish and 18 German firms in the switching status (non-funded to funded) and consequently matched to their own past observation. The monetary variables (RD, lnRD, CAPint and CASHF) are deflated in the CDiDRCS.

As the reduction of the dataset does not alter the descriptive statistics of the variables which were used in the initial analyses (see Table 4), we limit the descriptive statistics to the additional variables (see Table 10). The new probit model in Table 11 reveals the extent to which the additional variables are important factors in the selection process to receive a subsidy. Experience in applying for a subsidy clearly is a strong asset: it significantly increases the likelihood to receive a subsidy; unfortunately this variable is only available in the Flemish dataset. The financial and technological quality of the company do not seem to be of importance in Flanders, but are crucial features for German firms: financially constrained firms are more likely to receive a subsidy, while firms facing technological difficulties are less likely to be subsidized. Firms that absorb information of competitors more easily also have a significantly higher chance of receiving a subsidy. Table 12 shows the differences in the outcome variables after the matching (the t-tests on the other variables are not reported, as all differences were eliminated). The average treatment effects are calculated in Table 13: they remain significantly positive. Also after adding a time dimension to control for unobserved heterogeneity (Table 12), the conclusion remains stable: the hypothesis of full crowding-out can be rejected, both in the Flemish and German case.

Table 10: Descriptive statistics of the additional variables

Variable	Subsidized companies		Potential control group Non-subsidized companies		p-values of two-sided t-test on mean equality
	Mean	Std. Dev.	Mean	Std. Dev.	
Flemish sample					
PROJ_PAST5YR	1.329	3.546	0.063	0.302	p = 0.0000
CAPint	0.035	0.035	0.042	0.066	p = 0.0691
CASHF	0.013	0.047	0.016	0.115	p = 0.5743
SCOMNACE	1.080	0.456	0.853	0.471	p = 0.0000
Number of obs.:	167		696		
German sample					
TECHCONSTR	0.713	0.693	0.728	0.761	p = 0.6853
FINCONSTR	1.781	1.108	1.365	1.155	p = 0.0000
SCOMNACE	1.283	0.283	1.095	0.316	p = 0.0000
Number of obs.:	488		1643		

Table 11: Probit estimates and marginal effects

	Flemish sample						German sample					
	Probit estimates			Marginal effects			Probit estimates			Marginal effects		
	Coef.		Std. Err.	dy/dx		Std. Err.	Coef.		Std. Err.	dy/dx		Std. Err.
lnEMP	0.163		0.116	0.023	*	0.013	0.000		0.057	0.018	**	0.007
PATST	0.248	***	0.078	0.062	***	0.021	-0.001		0.002	-0.000		0.001
GROUP°	-0.066		0.154	-0.012		0.038	0.113		0.076	0.028		0.020
FOREIGN°	-0.530	***	0.179	-0.098	***	0.036	-0.064		0.113	-0.023		0.028
EXQU	0.686	***	0.207	0.199	***	0.048	1.078	***	0.154	0.292	***	0.040
PROJ_PAST5YR	0.856	***	0.110	0.210	***	0.031						
CAPint / TECHCONSTR	-1.868		1.335	-0.440		0.323	-0.126	**	0.048	-0.035	**	0.013
CASHF / FINCONSTR	-0.373		0.620	-0.058		0.162	0.230	***	0.031	0.062	***	0.008
SCOMNACE	0.246	*	0.149	0.059	*	0.036	0.726	***	0.143	0.191	***	0.037
EAST°							0.788	***	0.073	0.229	***	0.023
constant	-2.008	***	0.522				-2.609	***	0.276			
BR	$\chi^2(12) = 37.37$ p = 0.0002						$\chi^2(11) = 20.80$ p = 0.0355					
BR_lnEMP	$\chi^2(12) = 26.52$ p = 0.0091						$\chi^2(11) = 25.39$ p = 0.0080					
Log-Likelihood	-289						-926					
Pseudo R²	0.318						0.1927					
Number of obs.	863						2131					

*** (**. *) indicate a significance level of 1% (5. 10%). The restriction to common support is not yet being enforced here. The marginal effects on subsidies are calculated at the sample means for continuous variables and for a discrete change of dummy variables (indicated by °) from 0 to 1. The interaction terms BR_lnEMP are not taken into account in the calculation of the marginal effects. Their standard errors are obtained by the delta method.

Table 12: Outcome variables of the Flemish and German matched samples

Variable	Subsidized companies		Selected control group Non-subsidized companies		p-values of two-sided t-test on mean equality*
	Mean	Std. Dev.	Mean	Std. Dev.	
Flemish sample (Number of obs.: 136)					
RD	1.142	2.666	0.356	0.675	p = 0.001
RDint	7.080	13.637	1.913	3.779	p = 0.000
lnRD	-2.421	3.513	-4.406	4.113	p = 0.000
lnRDint	-0.142	2.826	-1.921	3.064	p = 0.000
German sample (Number of obs.: 474)					
RD	4.404	16.633	3.906	17.378	p = 0.720
RDint	7.191	9.677	2.524	5.197	p = 0.000
lnRD	-0.959	2.637	-3.178	3.493	p = 0.000
lnRDint	0.394	2.887	-2.763	3.996	p = 0.000

* t-statistics to test the mean equality between the sample of funded firms and the selected control group are based on Lechner's (2001) asymptotic approximation of the standard errors that accounts for sampling with replacement in the selected control group

Table 13: Average treatment effects on the treated companies

	Flanders				Germany			
	Absolute		Relative		Absolute		Relative	
	mean	median	mean	median	mean	median	mean	median
RD (in mio EUR)	0.786	0.141	69%	60%	n.s.	0.361	n.s.	84%
RDint (in %)	5.167	1.069	73%	72%	4.667	2.949	65%	91%

n.s.: not significantly different

Table 14: Treatment effect estimates: OLS in differences

Variable	RDdif		RDintdif		lnRDdif		lnRDintdif	
Flemish sample (Number of obs.: 272)								
FUNdif	0.269	0.253	4.101 ***	3.535 ***	1.593 **	1.547 *	1.471 ***	1.398 **
	(0.571)	(0.595)	(1.413)	(1.242)	(0.562)	(0.624)	(0.475)	(0.498)
lnEMPdif		0.736		-4.815		0.259		-0.554
		(1.347)		(4.086)		(1.737)		(1.294)
PATSTdif		0.438		0.683		0.521		0.396
		(0.723)		(1.484)		(0.885)		(0.740)
GROUP		0.097		2.386		0.828		0.730
		(0.406)		(1.798)		(0.808)		(0.696)
FOREIGN		0.477		1.977		-0.379		-0.365
		(0.898)		(2.911)		(1.486)		(1.219)
EXQU		-0.300		-0.466		1.591		1.073
		(0.831)		(3.012)		(1.315)		(1.065)
PROJ_PAST5YR		0.250		2.424		1.138 **		1.045 **
		(0.551)		(1.490)		(0.636)		(0.561)
CAPint		-4.869		-19.586		-6.763		-7.189
		(8.515)		(16.690)		(9.134)		(7.792)
CASHF		7.704		-4.648		3.503		0.550
		(9.325)		(32.289)		(11.249)		(9.739)
SCOMNACE		-0.109		-0.275		0.917		0.773
		(0.445)		(1.731)		(0.731)		(0.622)
R^2	0.000	0.050	0.047	0.170	0.037	0.153	0.045	0.181
German sample (Number of obs.: 948)								
FUNdif	2.009 **	2.305 **	5.384 ***	4.575 ***	2.571 ***	2.337 ***	3.464 ***	3.046 ***
	(0.883)	(1.143)	(0.515)	(0.581)	(0.272)	(0.312)	(0.353)	(0.387)
lnEMPdif		6.759		-2.815		0.398		-0.612
		(6.546)		(2.021)		(0.957)		(1.095)
PATSTdif		0.147		0.042		0.025		0.025
		(0.209)		(0.033)		(0.022)		(0.022)
GROUP		1.828		0.588		0.677		0.855
		(1.842)		(1.153)		(0.503)		(0.702)
FOREIGN		0.196		-0.770		-0.216		-0.646
		(2.926)		(1.030)		(0.594)		(0.686)
EXQU		4.496		4.051		1.959		2.111
		(5.078)		(2.098)		(1.184)		(1.569)
TECHCONSTR		-0.895		-0.265		0.030		0.134
		(1.137)		(0.471)		(0.250)		(0.330)
FINCONSTR		0.573		0.547		0.289		0.434
		(1.236)		(0.515)		(0.244)		(0.334)
SCOMNACE		6.014 *		4.495 ***		2.620 **		3.317 ***
		(4.216)		(1.556)		(0.943)		(1.140)
EAST		-0.882		1.636 **		0.466		0.887
		(0.749)		(0.677)		(0.415)		(0.630)
R^2	0.007	0.088	0.155	0.199	0.196	0.230	0.203	0.241

Bootstrapped standard errors (between brackets) are heteroskedasticly consistent. *** (**, *): significant at 1% (5%, 10%).

6. Conclusion

We empirically tested whether public R&D subsidies crowd out private R&D investment in Flanders and Germany, using data from the CIS III and IV waves. The main concern in evaluation analysis is to tackle the problem of the potential selection bias. Several methods are available to solve this problem, each with specific advantages and disadvantages. First, hybrid nearest neighbour matching was employed in the CIS IV cross-sectional sample. The sample contains information on the funding status and other covariates in the period 2002-2004. For both samples the crowding-out hypothesis was rejected: on average, the R&D intensity of German (Flemish) funded companies is 76% to 100% (64% to 91%) higher than the R&D intensity of non-funded companies. The disadvantage of the matching estimator is that it does not control for unobserved heterogeneity. Therefore, we applied a combination of the matching procedure and the difference-in-differences method, i.e. conditional difference-in-differences, using the two cross-sections CIS III and IV. This estimator allows correcting for both observed and unobserved heterogeneity. Also in this case, the crowding-out hypothesis can clearly be rejected; funded firms are significantly more R&D active than non-funded firms. Further robustness checks, like limiting the sample to R&D active companies only and taking additional, more fine-tuned variables into account, lead to the same results. The conclusions are in line with results from earlier studies on additionality in Flanders and Germany and also other European countries.

Two countries with a similar policy with respect to the public funding of R&D were compared, using identical techniques on similar data. We tried to set some first steps towards internationally harmonized additionality research. An assessment of the countries' innovative activity in the European Innovation Scoreboard (PRO INNO EUROPE, 2007a and 2007b) reveals that the innovation system is different to some extent. Both countries are among the top performers in the EU27. However, in comparison to other EU-countries, the German innovation system is rather weak at the input side (e.g. science and engineering graduates, R&D expenditure, innovative activity in SMEs, etc.), but highly performing on the output side (e.g. sales of new products, exports and employment in high-tech sectors, patent application, etc.) of the innovation system. The Flemish innovation system on the other hand, scores very well on the drivers of innovation (education in science and technology, R&D expenditure, innovating capacity in SMEs, etc.), but does not seem to be able to capitalize the benefits at the output side. This may introduce policy priorities in the subsidy system, which cannot be fully observed by the researcher: both countries emphasise the importance of innovative performance, of SMEs in R&D activities, of a strong supply of researchers, etc., but it is not clear how the differences in the innovation system precisely translate in different policy accents.

An in-depth analysis of policy differences as well as the combination of the firm-level data in one dataset would therefore yield a highly interesting starting point to assess the impact of policy heterogeneity on additionality effects. However, due to secrecy reasons, this has been impossible until now.

Only the funding status of firms is analyzed. Therefore it is not possible to indicate how much R&D expenditure is leveraged with 1 EUR extra funding. This has been tested for a cross-section of Flemish data (see Aerts and Czarnitzki, 2004 and Aerts, 2008). It would be interesting to employ continuous treatment analysis in a time series framework for both countries and in this way test for heterogeneous treatment effects of subsidies. Another appealing research question is the additionality effect on the output side. Input additionality is not necessarily translated into innovative output and economic welfare. Very recently, studies have been conducted on output additionality, measured in terms of patents, in German firms (Czarnitzki and Hussinger, 2004 as well as Czarnitzki and Licht, 2006). In addition to these studies, it would be interesting to look at other innovation indicators on the output side of the innovation process, such as the introduction of new products or processes. A first study using a dummy variable on the introduction of an innovation into the market has been conducted by Hujer and Radić (2005) for German data. Bérubé and Mohnen (2007) evaluate the effectiveness of direct R&D subsidies in addition to tax allowances in Canada employing other measures of innovativeness. However, long time-series data would give more insight and would allow testing different lag specifications between the moment of market introduction of new products or the implementation of new processes and the time period in which the corresponding R&D projects were actually conducted.

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Disclaimer

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Chapter 4. Who writes the pay slip? Do R&D subsidies merely increase researcher wages?

1. Introduction

R&D activity fosters economic growth (Romer, 1990) and is crucial in every modern economy these days. However, R&D is a high-risk activity entailing a substantial level of uncertainty (Dasgupta and Maskin, 1987). Large R&D investments may not (immediately) lead to results which contribute significant value to a company (Rosenberg, 1974). One of the main concerns of R&D managers therefore is to attract qualified and motivated personnel, apt to conduct R&D activities with a considerable degree of success. The lack of qualified personnel is an important bottleneck, seriously hampering innovative activity (Eurostat, 2004 as well as Mohnen et al., 2008). Moreover, sooner or later, knowledge created in the R&D process becomes available to other companies, which have the opportunity to free ride and exploit this knowledge (Arrow, 1962). Mobility of R&D personnel is one of the main factors explaining (un)desired spillovers between companies (Mansfield, 1985). Maliranta et al. (2008) mitigate this effect though, as they find that most of the knowledge which is transferred by employees, is knowledge which can be easily copied and implemented without substantial additional R&D efforts. An adequate remuneration therefore is crucial to attract, stimulate and retain highly competent R&D personnel. Earnings are an important determinant in the remuneration system, although also intrinsic motivations like job satisfaction and exciting job opportunities matter (Coombs and Gomez-Mejia, 1991). Researcher wages consume the lion's share of the total R&D expenditure of a company.

An adequate remuneration system may attenuate the free-rider problem, but also the government can play an important role through public intervention. Because of the negative externalities (see e.g. Arrow, 1962) in the R&D process, companies are expected to invest less than what is socially desirable and as a consequence some projects, despite their significant social benefit, will not be executed. An R&D subsidy lowers the cost of a private R&D project and possibly alters its outcome into an expected net profit, resulting in a positive decision to conduct the project. Subsidies for R&D projects by now have become a well-established government intervention tool in the private R&D sector. However, companies may well replace their own, private money with the grant they received from the government, which would in the end not increase total private R&D expenditures. Empirical research on this crowding-out hypothesis is vast (see e.g. Aerts et al., 2007 for a survey of the empirical evidence) and many researchers reject, while others support it. However, as David and Hall (2000) suggest: 'the more the better' is a questionable statement when it comes to R&D expenditure. Mere R&D expenditures may not constitute an adequate measure to evaluate the effectiveness of R&D subsidies. They advise to introduce the close interconnectivity between scientific labour markets and R&D investment decisions into the evaluation process of public R&D policy. Goolsbee (1998) came to the conclusion that R&D subsidies are primarily translated into researcher wage increases, inflating positive additionality effects by 30% to 50%. Wallsten (2000) and Suetens (2002) agree as their data refute the argument that R&D subsidies stimulate the demand for R&D personnel. Yet other researchers find positive estimates for increases in the R&D staff due to a subsidy (Üçdoğruk, 2004; Ali-Yrkkö, 2005; as well as Reinthaler and Wolff, 2004).

This chapter empirically analyzes the effect of public R&D subsidies on private R&D investments, employment and wages in Flanders, employing parametric treatment effects models and IV methods. In the next section, the relevant literature will be discussed. Subsequently, I come to a brief explanation of 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

The evaluation of public R&D policy has been extensively addressed in empirical research. David and Hall (2000) conclude in their review of evaluation studies on innovation input that the results on potential crowding-out effects are ambiguous, and they criticize that most existing studies neglect the problem of sample selection bias: it is not implausible that an endogenous relationship exists between R&D investments and the receipt of public R&D grants. On the demand side of public funding, R&D intensive firms may well be more likely to apply for a subsidy: they are more apt to market their project as being highly interesting for society and exhibiting a high expected rate of success. Moreover, they may be better acquainted with the eligibility criteria and the procedures to apply for a subsidy. On the supply side of the public funding system, the government may just as well be more inclined to grant them a subsidy, as R&D intensive firms exhibit a higher expected rate of success. This makes R&D funding an endogenous variable, which may seriously distort evaluation results. In the next section, I expound on the methodological consequences of this endogeneity problem. More recent research takes this potential sample selection bias into account through selection models, instrumental variable (IV) estimations (including simultaneous equation systems), difference-in-differences estimations and matching techniques. 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. These studies tend to reject full crowding-out effects but the results are ambiguous[30]. Key reasons for these diverging conclusions are the use of different estimators, as well as the application for a broad range of countries, each with their own specific S&T policy (David and Hall, 2000).

However, more private R&D investments do not necessarily translate into more R&D output. Moreover, even if an increase in private R&D activity is confirmed, it may not be beneficial for the society. Inefficiencies may rise from duplicate research (Irwin and Klenow, 1996 as well as David and Hall, 2000), though Dasgupta and Maskin (1987: 582) state that "*parallelism need not imply waste*". The additional R&D budget may be allocated to more risky and therefore potentially less successful projects (Setter and Tishler, 2005). Romer (2000) denounces the mismatch between policy measures stimulating the private demand for scientists and engineers and the incapability of the educational system to provide

[30] 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. (2005), 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. The interested reader is referred to Aerts et al. (2007) for a survey of the recent literature on the evaluation of public innovation policy.

a positive supply response. Consequently, David and Hall (2000) advocate the introduction of labour market dynamics into the additionality issue.

Although the development of econometric methods (see Heckman et al., 1997 and Heckman et al., 1999 for a survey) to counter the difficulties in measuring the effectiveness of policy programs originated in labour market economics (the evaluation of labour programs including public job training and active labour market policies), the main research issue in additionality research of R&D subsidies became to find out how much more private R&D investments were made, due to the provision of public money for private R&D activities. The impact on the R&D workforce has been ignored to a large extent.

To the best of my knowledge, only a limited number of studies explores this research path, either on the macro (Reinthaler and Wolff, 2004) or micro (Goolsbee, 1998 for individuals and Wallsten, 2000; Suetens, 2002; Üçdoğruk, 2004 and Ali-Yrkkö, 2005 for firms) level. The empirical evidence is not unanimous, however. One explanation can be found, by analogy with diverging results in the more traditional R&D additionality research, in the use of different datasets, covering different regions and time windows and the application of various methodologies. Another explanation is the behaviour of the inputs of the R&D process, including the supply of R&D personnel. Different hypotheses are put forward in the literature, predicting the elasticity of the supply of researchers and their wages. A subset of the studies mentioned above additionally substantiates proof on the impact of public R&D funding on R&D wages (Goolsbee, 1998; Reinthaler and Wolff, 2004; Üçdoğruk, 2004 and Ali-Yrkkö, 2005). An overview of the main characteristics of these articles is presented in Table 15. In the following subsections a synopsis of the literature on additionality effects on R&D employment as well as R&D wages is presented and the hypotheses, which will be tested in the empirical part, are derived.

Table 15: The impact of public R&D funding on employment and wages: literature overview

Author(s)	Country	Funding source	Time window	Unit of observation	Sample size	Methodology	Dependent variable	Impact of R&D subsidies on: R&D employment	R&D wages	R&D labour supply elasticity
Ali-Yrkkö (2005)	Finland	Tekes	1997-2002	firms	187 (panel)	employment equation IV	R&D employment	+	+	
Ebersberger (2004)	Finland	Tekes	1996-2000	R&D active firms	?	Kernel matching difference-in-differences	(R&D) employment*	0	0	large
Goolsbee (1998)	US	Federal R&D expenditure	1968-1994	scientists and engineers	17,700	OLS	income wages hours worked	0	+	very low
Reinthaler and Wolff (2004)	OECD countries	public R&D expenditure	1981-2002	countries	15 (panel)	fixed effect panel regressions	R&D employment and wages	+	+	low, but larger than Goolsbee's estimate
Seutens (2002)	Flanders	regional, national, EU government	1992-1999	innovative (large) firms	262 (panel)	production function with R&D equation IV	R&D employment	0		
Üçdoğruk (2004)	Turkey	TTGV	1993-2000	manufacturing R&D active firms	314 (panel)	labour demand function	R&D employment	+	+	
Wallsten (2000)	US	SBIR	1990-1993	SBIR small high-tech firms	481	IV-3SLS	(R&D) employment*	0		

*Note: although Wallsten (2000) measures the impact on total employment in a dataset of small high-tech SBIR funded firms, he (2000: 89) signals that "*most employees in these small firms are likely to be scientists, engineers, or others who are directly involved in R&D*". Also Ebersberger (2004) studies the impact on firms' employment. However, he adds that, as the subsidy program under investigation targets R&D activities, the impact of the program can be evaluated in terms of R&D labour demand. Therefore, I consider their studies being comparable with the other studies listed, which explicitly measure the impact of public R&D funding on R&D employment.

2.1. Public R&D funding and R&D employment

Applying fixed effect panel regressions on a panel dataset containing data on 15 OECD countries from 1981 to 2002, Reinthaler and Wolff (2004) estimate positive additionality effects for R&D investments, as well as a smaller, but still significant increase in national R&D employment. Goolsbee (1998) investigates survey data on the income of 17,700 scientists and engineers in the U.S. from 1968 to 1994. He relates the total and federal R&D expenditure to income as well as wages and hours worked in an OLS framework. The impact of federal R&D expenditure on the number of hours worked is not significant.

Suetens (2002), Üçdoğruk (2004) and Ali-Yrkkö (2005) all apply a production function framework, taking information on subsidy receipt into account. Suetens (2002) uses panel data on Flemish firms observed between 1992 and 1999 to estimate an R&D personnel equation and an output (added value) equation with instrumental variables and finds that crowding-out effects cannot be rejected offhand. Üçdoğruk (2004) employs a panel dataset on Turkish R&D active manufacturing companies, observed between 1993 and 2000. She concludes that R&D support programs significantly increase the demand for R&D personnel, especially for researchers holding a graduate degree. However, she does not correct for the potential endogeneity bias embodied in the relationship between the demand for R&D personnel and public R&D funding. In his set of Finnish firms, observed between 1997 and 2002, Ali-Yrkkö (2005) estimates significantly positive effects on R&D employment.

Wallsten (2000) and Ebersberger (2004) present two studies which are closely related to this research issue and which are therefore included as well. Wallsten (2000) evaluates the impact of US SBIR grants to small high-tech firms on their total employment in an IV approach. Although this funding is not explicitly intended to support R&D activities, the author signals (Wallsten, 2000: 89) that "*most employees in these small firms are likely to be scientists, engineers, or others who are directly involved in R&D*". He finds that larger firms are more likely to receive a grant, but additionality effects on employment cannot be confirmed. Ebersberger (2004) investigates the impact of two-year grants, allocated in 1996, on the total labour demand in Finnish companies employing matching and difference-in-differences methods. He claims that, as the subsidy program under investigation targets R&D activities, the impact of the program can be evaluated in terms of R&D labour demand. His estimates demonstrate no significant impact. From this review of research on R&D subsidies and R&D employment, it becomes clear that the evidence is mixed: both neutral as well as positive effects are found.

Two elements may introduce some dynamics into the subsidy-employment relationship. First, increased R&D investments due to a subsidy may stimulate company growth and only in a second phase lead to increased R&D employment. See e.g. Chennels and Van Reenen (1999) for a survey of studies on the impact of technological change on employment. Second, as Reinthaler and Wolff (2004) suggest, technology spillover effects may exist: a subsidy may induce the development of a new technology, which nevertheless draws heavily on knowledge incorporated in existing technologies, and may therefore stimulate other firms to build on that technology. As a result, one could expect that the impact of public R&D funding is larger in the long than in the short run. Positive long-run effects on R&D employment are found by Lerner (1999), Ebersberger (2004) as well as Reinthaler and Wolff (2004).

2.2. Public R&D funding and R&D wages

R&D wages absorb a significant share of the total R&D expenditure (e.g. in Flanders on average around 67% in Czarnitzki et al., 2006). Therefore, also the cost of the input factor of R&D personnel, i.e. R&D wages, plays an important role in additionality research on R&D employment: R&D wages may adversely interact with Science and Technology policy measures introduced by the government. This may provide a sound explanation to why the publicly induced increase in R&D staffing does not keep up with the induced increase in R&D expenditure.

Reinthaler and Wolff (2004) observe a simultaneous increase in national R&D investment and R&D employment. The increase of the R&D staff is smaller, though, which brings them to the conclusion that also scientists' wages experience an increase. Goolsbee (1998) concludes that increases in R&D expenditure are mainly allocated to researcher wages and not to research effort. Ebersberger (2004) claims that the Finnish innovation system provides an adequate inflow of researchers, and that therefore an increase in R&D investments is fully absorbed by an increase in R&D employment, but he does not put his statement to the test. This is however done by Ali-Yrkkö (2005), who concludes that R&D subsidies have, in addition to a positive effect on the number of R&D employees, also a significantly positive effect on researcher wages. Üçdoğruk (2004) finds indications that in Turkey, R&D subsidies significantly increase researcher wages. So, although there is substantial ambiguity concerning the impact of R&D subsidies on R&D employment, there is consensus on the fact that researcher wages increase when a company receives an R&D subsidy.

Also few attempts have been made to assess the impact of R&D tax credits on private R&D wages. Although in this chapter, the explicit focus is on direct R&D funding, the main results are briefly mentioned. Marey and Borghans (2000) estimate the wage effect of R&D tax incentives in the Netherlands and estimate average elasticities of R&D wages to the total sectoral R&D expenditure of 0.52 in the short run and 0.38 in the long run. Lokshin and Mohnen (2008) estimate a short run elasticity of 0.10 and a long run elasticity of 0.12 in the Netherlands. Haegeland and Møen (2007) assess the Norwegian R&D tax credit measure and estimate an elasticity of 0.33.

The latter studies typically conclude that the increase of R&D wages provokes a significant inflation problem in additionality research: it is criticized that a substantial part of the subsidised money dissipates, as it perishes into mere R&D wage increases, without any actual impact on R&D activity. Goolsbee (1998) estimates that, as a result of R&D wage increases, additionality effects of R&D subsidies may be overestimated by 30% to 50%. The indirect impact of this wage increase may be even worse, since an increase in researcher wages may also affect non-funded firms, as they have to downsize their R&D activity (Goolsbee, 1998 and Hinloopen, 2004).

Inelastic labour supply

The argument of inflated additionality effects is typically based on the underlying hypothesis that the supply of R&D personnel is inelastic. An inelastic labour supply increases the search costs for competent scientists and engineers and strengthens the bargaining power of R&D employees in wage negotiations (Lokshin and Mohnen, 2008).

Goolsbee (1998) provides evidence that the supply of scientists and engineers is relatively inelastic. Reinthaler and Wolff (2004) make a stand against a priori expectations about the elasticity of the R&D labour supply. An elastic supply curve can be expected when considering the large pool of university graduates available to R&D companies on the one hand and the number of researchers actually employed as R&D staff on the other hand. Lundborg (2005) concludes that supply is not a restrictive variable, as the underutilization of potential R&D employees is substantial. However, Goolsbee's findings (1998) on an inelastic labour supply curve are not unrealistic when R&D is performed by thin on the ground experienced and highly specialized scientists. Trajtenberg (2000) also claims that shortages of highly skilled personnel in cutting edge technologies are a pervasive phenomenon in Israel. By contrast, Ebersberger (2004: 22) rejects the existence of this problem in Finland, as "*the Finnish innovation system has been able to constantly increase the supply of science and technology graduates*". The reader should bear in mind however, that Goolsbee (1998) runs his analysis on survey data on the income of scientists and engineers, including both public and private R&D staff. One could expect that the researcher supply elasticity is highly dependent on the sector. Research in universities versus companies may require and/or attract a different kind of researcher. Reinthaler and Wolff (2004) compute elasticities of the labour supply in 15 OECD countries. Their estimates are rather low, but significantly larger than the estimates of Goolsbee (1998). They find an additional explanation for a potential underestimation of the labour supply elasticity in Goolsbee's exercise (1998) in the fact that he uses data from a period exhibiting extraordinary government intervention. Moreover, the supply elasticity is measured in a different way: Goolsbee (1998) calculates the increase in the average working time in reaction to higher wages, while Reinthaler and Wolff (2004) also allow for the additional employment of R&D workers.

Upskilling process

Nevertheless, Goolsbee's (1998) pessimism may be alleviated, as R&D wage increases do not necessarily equate a loss of R&D effort. For example, in a general employment context, Merito et al. (2007) test the impact of public funding and record positive effects on SME wages on the short (two years) and long term (four years) and conclude that the simultaneity of increased R&D staffing and higher wages signals an 'upskilling' process: the employment structure is shifted towards more skilled employees. Katz and Murphy (1992) also found that rapid growth in the demand of skilled workers appears to be the driving force behind changes in the wage structure. Translated into an R&D environment, this would render the R&D effort of an equally large R&D staff more efficient. Moreover, the population of (potential) R&D employees is not homogeneous. Zucker and Darby (1996: 12709) state that "*scientific breakthroughs are created by, embodied in, and applied commercially by particular individuals responding to incentives and working in specific organizations and locations*". As a result, in high-tech firms intellectual capital of key personnel is far more important than physical assets (Darby et al., 1999). Therefore, partial or even full crowding-out of additional R&D investments into higher wages is not necessarily bad: if companies are able to allocate a larger budget to their human capital, this may strengthen their power in the competition to attract top researchers.

Determinants of R&D wages

Wage dispersion may originate in employee as well as employer specificities. Individual worker characteristics, among which gender and age are most important, determine a significant share of wage dispersion. Also, considerable disparities in the pay slip are due to differences in the workplace. A large share of the literature on wages focuses on the positive correlation between company size and wages as well as the impact of sector affiliation. Larger companies typically write higher pay slips. Different explanations can be found: higher wages may serve as a compensation mechanism for a more complex working environment in larger companies; act as an instrument to increase the workforce's motivation; or reflect differences in the composition of the workforce. Heterogeneity in the composition of the workforce, generating a larger share of skilled workers in the larger firms, can originate in different capital intensities (skilled workers work in more capital intensive sectors; larger companies are typically more capital intensive), scale advantages (employing skilled workers implies a substantial amount of fixed costs), the hierarchical structure (larger companies are structured more hierarchically, requiring the employment of more managers) and the employees' seniority (larger companies can offer more promotion and education possibilities and face a lower risk of bankruptcy, implying a higher level of seniority and subsequently higher wages) (Plasman et al., 2008).

Next to size, also sector affiliation is found to drive a significant share of wage differences (see Plasman et al., 2008). A growing body of the literature investigates the underlying reasons behind this strong correlation. First, the weight of wage bargaining differs significantly between the sectors. In some sectors (e.g. sectors with a large share of small companies), sectoral bargaining is absent and wages are settled at the company level. Furthermore, some sectoral agreements only determine minimum wages, as increases in the actual wages are only negotiated at the company level. Therefore, a strong centralization of the wage bargaining process reduces wage differences. This argument is strongly linked with the second: different sectors exhibit different productivity and profit levels (Plasman et al., 2006). Moreover, differences in the way the profit gains are redistributed in the company also drive inter-firm wage differences. Rusinek and Rycx (2008) find that, the more this redistribution occurs on the company level, the larger the wage differences become. A last argument is the power of unions: they can put pressure on companies to increase the wages and close sectoral wage gaps.

In this chapter we specifically look at R&D wages in the private sector. Typical factors influencing the general average wage level and dispersion are expected to play here, too, and interact with the factors explaining R&D activity. First, size seems to be an important driver of inter-firm[31] R&D wage differences: the annual R&D expenditure per R&D employee increases significantly with firm size (Czarnitzki et al., 2006). Also sector affiliation interacts with R&D wages. The annual R&D expenditure per R&D personnel and the share of personnel costs in the total R&D expenditure vary over the different sectors (Czarnitzki et al., 2006). Capital intensity is expected to have an impact, as well as the share of highly skilled employees. Productivity and, more specifically, R&D productivity may be correlated positively with R&D wages, as well as the level of international

[31] As only information about the average R&D wage is available, intra-firm R&D wage dispersion can not be investigated. It is beyond the scope of this chapter, but remains an interesting and challenging issue for further research.

competition, and (foreign) group membership. Last, also the scope of the union's power in the wage bargaining process may generate inter-firm R&D wage differences.

2.3. Hypotheses

In the empirical part of this chapter, I first assess the impact of public R&D funding on private R&D expenditure. In the next step, the typical testing of the crowding-out hypothesis in terms of R&D expenditure is extended with respect to the R&D workforce: if a subsidy stimulates private R&D expenditure, does this publicly induced increase in R&D expenditure generate additional R&D employment? In the last step, the wage structure is analysed with respect to R&D subsidies.

The literature shows that long term effects may be significantly different from the effects found in the short run. However, this chapter focuses on the short term effects; potential long term effects are beyond its scope and left for further research.

3. 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, I briefly explain the methodology which will be employed to eliminate the potential bias caused by this selectivity problem.

The outcome variable Y (e.g. R&D expenditure, R&D personnel, etc.) can be modelled as follows[32]:

$$Y = \begin{cases} X\beta + S\alpha + U & \\ X\beta + U & \end{cases} \quad if \quad \begin{matrix} S = 1 \\ S = 0 \end{matrix}, \tag{24}$$

where X represents a set of exogenous variables and β 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, it is not

[32] I omit firm indices for the sake of readability.

unlikely that U is correlated with S: subsidized companies may well be more R&D active than the non-subsidized companies, even without the subsidy program. 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. This would imply a selection bias in the estimation of the treatment effect. 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., 2007). Examples of these methods are difference-in-differences estimations, matching, selection models and instrumental variable (IV) estimations (including simultaneous equation systems). I 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:

$$S^* = Z\gamma + V , \qquad (25)$$

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

$$S = \begin{cases} 1 & if\ S^* > 0 \\ 0 & otherwise \end{cases} . \qquad (26)$$

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[33], resulting in the following conditional outcome equations:

$$\begin{aligned} E(Y|S=1) &= X\beta + \alpha + \rho\phi\left(\frac{Z\gamma}{\sigma_V}\right)\Phi\left(\frac{Z\gamma}{\sigma_V}\right)^{-1} \\ E(Y|S=0) &= X\beta - \rho\phi\left(\frac{Z\gamma}{\sigma_V}\right)\left[1-\Phi\left(\frac{Z\gamma}{\sigma_V}\right)\right]^{-1}, \end{aligned} \qquad (27)$$

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 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[34]. 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

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

[34] 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).

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.

4. The data

This section first sketches the contextual framework. Next, I come to a description of the data and the variables which are employed in the empirical part.

4.1. Contextual framework

The particularities of public R&D funding and the process of wage settlement in Flanders are briefly explained.

Public R&D funding in Flanders

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 and Belgian level, as well as certain EU-funded projects[35] 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

[35] The Framework Program projects are not managed through IWT. However, typically the scale of these projects is very large because these projects are often managed in international company consortia. As a result, the number of Flemish firms engaging in these programs is very limited.

Pottelsberghe et al. (2003) indicate, very few Belgian companies actually make use of these fiscal measures[36]. Main reasons are a low level of acquaintance with the system, complexity and high administration costs[37] and the fact that the measures are not significantly substantial[38]. Direct R&D funding through IWT remains the largest source of public R&D grants in the private sector in Flanders[39].

Wage settlement in Flanders

In Flanders, wages are typically settled through collective bargaining. This usually occurs hierarchically, on three levels, which implies that bargaining at lower levels can only affect wages upwards (Plasman et al., 2007). At the top level, wages are settled through inter-sectoral agreements at the national level: minimum wages are fixed, as well as a margin for wage increases. Second, additional sectoral agreements may be negotiated, setting industry standards (minimum wages by category of worker) for most of the employees in the industry concerned. Finally, in a third bargaining round, single-employer agreements may be settled at the firm level. The bargaining process at the firm level has gained importance over time. Strong wage increases may reduce the national competitiveness and hence also reduce employment rates. Therefore, the government froze the private-sector wages several times; e.g. in 1996, a wage standard was introduced, imposing an upper limit to wage increases, coupled to the wage margins in France, Germany and the Netherlands. However, international comparisons reveal that labour is still significantly expensive in Flanders. Nevertheless, wage settlement in Flanders is far from a centralized and tight system and leaves considerable margin for inter-firm wage dispersion; Anglo-Saxon countries exhibit higher dispersion rates, while wages are distributed more equally in the Scandinavian countries (Plasman et al., 2008).

[36] Due to recent changes in the Science and Technology Policy, this situation has changed, though. In the current system, fiscal measures, and more specifically tax credits for R&D personnel, are becoming increasingly popular. However, this is not relevant in the current chapter, as our data was collected before the change.
[37] First, each year the company has to deliver a certificate. Second, the researcher should be full time employed in the research department of the same company to qualify. Third, the tax allowance is nominative, inducing a burden to keep track of all employees who benefited from the measure in the past.
[38] First, the amount of the exemption is not sufficiently significant. Second, the definition of highly qualified personnel is too strict, so that only very few employees qualify for the measure. Third, the tax exemption is a short term measure (it only relates to the first year of recruitment) while R&D typically is a long term process.
[39] The interested reader is referred to Aerts and Czarnitzki (2006) for a detailed overview of the public R&D funding system in Flanders.

4.2. Variables

The potential crowding-out effect of R&D subsidies in Flanders is addressed empirically with data from the biannual Research and Development Survey. This mainly quantitative survey covers most EU countries with a by and large harmonized questionnaire and the collected data are, among other things, used to compose the European Innovation Scoreboard (see e.g. PRO INNO EUROPE, 2008). The set-up of the Flemish R&D survey is inventory-based: all potentially R&D active companies are identified and surveyed. In terms of R&D expenditure, the collected data cover a sample of companies, which are, in total, responsible for about 80% of the total R&D expenditure in Flanders (Debackere and Veugelers, 2007). Therefore, the sample is close to the population of all R&D active companies in Flanders. I pool two consecutive waves, i.e. the 2004 and 2006 R&D surveys[40]. 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.

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 reflect a company's R&D[41] activities. First, I test the impact of an R&D subsidy on R&D expenditure (RDX, in million EUR). As the distribution of RDX is highly skewed, the R&D expenditure intensity, RDXint (RDX / turnover * 100) is included as well. Second, I test how the R&D staffing changes when a subsidy is granted to a company. RDP is the number of R&D personnel (in full time equivalents, or FTEs). Again, to complete the picture of the

[40] 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.

[41] R&D is defined in accordance with the Frascati Manual (OECD, 2002: 30): "*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*".

impact of R&D subsidies on R&D activities in spite of the skewed distribution of R&D activities, R&D personnel intensities are calculated: RDPint (RDP / total number of employees * 100). The third set of outcome variables disentangles a company's R&D expenditure into the share allocated to personnel costs on the one hand and the share allocated to all other costs (investments and operational costs) on the other hand. These variables are normalized by the number of R&D employees. Hence, RDX_P/RDP reflects the company's R&D wage structure. RDX_O/RDP measures the R&D expenditure per R&D employee, leaving out the personnel costs. These variables will allow us to test whether potential additionality effects on the R&D expenditure are partially or fully absorbed by an increase in R&D staff wages. In that case, the effectiveness of the public R&D funding system could be questioned. The Flemish R&D activities are highly skewed. That is why one should also consider the logarithmically rescaled values of the measures of R&D activity: lnRDX and lnRDP; of course, also the amount of funding is rescaled in these models (lnAMT).

In the literature on additionality assessment of public R&D funding, different authors have used different sets of exclusion restrictions and instrumental variables. Busom (2000) introduced selection models in additionality research and used the age of the company, reflecting its overall experience, as an exclusion restriction. She argues that more experienced firms are more aware of the value of innovation and may write better project proposals, both increasing the likelihood of receiving a subsidy. Kaiser (2004) uses a set of dummies reflecting competition (local, national or multinational orientation), ownership ((partly) publicly owned) and cooperation behaviour (external partners or academia involved in new product or process development). He argues that the firm may not care where the competition comes from, while governments may want to strengthen the technological competitiveness of domestic firms in the perspective of foreign competition. Moreover, the explicit policy aim of the Danish government to foster R&D cooperation may increase the likelihood that R&D cooperation projects are publicly funded. Ebersberger (2005) uses the share of R&D employees as exclusion restriction; as he uses a sample of innovative firms only, funding decisions have no influence on R&D status, but do influence the intensity of conducting R&D activity. Hussinger (2008) generates an artificial exclusion construct, including information on the legal form of the company, foreign ownership and the existence of an own R&D department within the company. Wallsten (2000) was the first to employ instrumental variable regressions. His instrument, the budget which is potentially available for a firm in a certain industry or technological area, has become very popular and was picked up by several authors (Hyytinen and Toivanen, 2005; Clausen, 2007 and Ali-Yrkkö, 2004 and 2005). Ali-Yrkkö (2004) additionally experimented with the amount of funding the company has applied for in the year of the funding receipt. Aerts and Czarnitzki (2006) use the number of past project applications. Suetens (2002) and Gonzáles et al. (2005) introduce the lagged value of the subsidy as instrumental variable in their regression.

Building on the existing research summarized above, I introduce two new variables. They are supposed to have an impact on the funding status, but not on the outcome. 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 provide a vector of instruments. They are computed from the company's subsidy history. AMT/PROJ_past5yrs (in million EUR) contains the total public R&D funding the company received in the preceding five 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 per employee each company submitted in order to obtain an R&D subsidy in the preceding five years. These variables seem to be 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.

I use several control variables which may affect both the subsidy receipt and R&D effort. 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 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[42]. 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 firm as the depreciated sum of all patents filed at the EPO from 1978 until 2001(1997):

$$PAT_t = (1-\delta)PAT_{t-1} + PATA_t, \tag{28}$$

where PAT is the patent stock of a firm 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 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.

[42] 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).

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. Foreign affiliates may be more likely to apply for a subsidy in their home country. Twelve industry dummies (BR) are included to allow for differences between sectors. On the one hand, some sectors may exhibit a larger R&D intensity. On the other hand, governments may favour certain sectors in their R&D policy, which increases the likelihood of receiving subsidies for firms in these industries.

From the theoretical evidence on R&D wages, different factors are derived which could possibly drive inter-firm dispersion. Most of these are already reflected in the variables described above. Size (lnEMP) and sector (BR) may determine R&D wages. Also capital intensity is expected to have an impact. Productivity and more specifically R&D productivity may be correlated positively with R&D wages. This productivity is captured by the patent stock (PAT/EMP). Internationally competing firms may pay higher wages (EXQU). Moreover, also group membership (GROUP) and foreign ownership (FOREIGN) may play. Besides these variables, which are also included in the models assessing the impact of public funding on R&D expenditure and R&D employment, two other variables are defined to refine the assessment of additionality effects on R&D wages. First, the percentage of highly skilled employees is included as the share of R&D employees with a doctoral or university degree (UNI). Second, the impact of the union in the wage bargaining process may be an influencing factor. This parameter is computed following Vandenbussche et al. (2001). The idea is to maximise the union's utility function $U(w,L) = w.L$, explained by wages w and employment L, with respect to the wages:

$$\underset{w}{Max}\ \Omega = U^{\beta} \,.\, \pi^{(1-\beta)}\ . \qquad (29)$$

The parameter β reflects the bargaining strength of the union, and has a value between zero, i.e. in the absence of a union: all rents are absorbed by the firm, and unit value, i.e. with a 'monopoly union': the union determines the wages unilaterally. Wages are modelled according to the following equation:

$$w = w^{a} + \frac{\beta}{1-\beta}\frac{\pi^{0}}{L^{0}}, \qquad (30)$$

where the employee's wage is the sum of his alternative wage w^a and a fraction of the firm's profit per employee π^0/L^0. For each sector, an unbalanced firm-level panel was constructed, containing balance sheet information from the National Bank of Belgium (Belfirst), covering all Belgian firms in the sector, with non-missing values for the period 1998-2006. The profit π^0/L^0 was computed as the value added minus the labour costs, divided by the number of employees, and normalized by the consumer price index (obtained from Eurostat, 2008). The average wage w was generated dividing the total labour costs of the firm by the number of employees. The alternative wage w^a was set to zero[43]. As this model may be subject to endogeneity, the regression is instrumented by the profit per employee in the previous period $\pi_{t-1}^{0} / L_{t-1}^{0}$ and year dummies. The monetary values were deflated (EconStats, 2007). Table 16 shows the estimated bargaining power coefficients β for the sectors in the dataset. Parameter β is additionally included in the equations where the impact of funding on R&D wages is estimated, in the variable BARG.

[43] Vandenbussche et al. (2001) alternatively suggest to set the alternative wage w^a at the sectoral minimum wage, but as this did not change their results, I also use a zero value for w^a.

Table 16: Estimated bargaining power coefficients

Nace	β	Number of companies	Nace	β	Number of companies
All sectors	**0.0623**	**224613**			
Manufacturing	**0.0890**	**148564**	27	0.1015	3794
15	0.1172	22345	271	0.0636	1565
16	n.s.	184	274	0.1415	765
17	0.0993	8355	28	0.0693	29427
18	0.1617	4819	29	0.0481	12105
19	0.1130	945	30	n.s.	941
20	0.1007	9113	31	n.s.	5270
21	n.s.	2913	32	n.s.	2463
22	0.0322	15396	321	n.s.	827
23	0.1885	352	33	n.s.	4240
24	0.1343	6971	34	n.s.	3276
244	0.1160	1358	351	0.1209	752
25	0.1108	6288	353	n.s.	283
26	0.0689	9367	355	n.s.	152
Services	**0.0146**	**76049**			
72	0.0325	18893			
722	n.s.	10603			
73	n.s.	1185			
74	0.0489	39684*			

*To facilitate computation, for sector 74 only a randomly selected subset of the total population (110846) companies was used. Note: in the models only twelve industry dummies are included, as some sectors were aggregated. However, as information on the exact 2-digit (for some subgroups 3-digit) sector affiliation is known for the companies, I decided to use all available information.

To test the presence of upskilling effects, a subgroup of the total R&D personnel, i.e. researchers (RDPR, in FTE) as well as the share of these researchers in the total R&D staff (RDPR/RDP, in %) are included as dependent variables.

As I 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[44] were deflated (EconStats, 2007). Extreme outliers with respect to the funding amount, R&D expenditure, R&D personnel and R&D wages were removed. The final sample consists of 470 observations. The summary statistics of the variables used to evaluate the input additionality of Flemish R&D subsidies are presented in Table 17.

[44] AMT, RDX, RDX_P/RDP, RDX_O/RDP, AMT/PROJ_past5yrs, CAPint and CASHF/EMP.

Table 17: Summary statistics dataset

	All companies									
	# Obs.	Mean	St. Dev.	Min.	Max.					
TREATMENT VARIABLES										
FUN (dummy)	470	0.3957	0.4895	0	1					
AMT (in mio EUR)	470	0.0744	0.1761	0	1.3284					
	Funded companies					**Non-funded companies**				
	# Obs.	**Mean**	**St. Dev.**	**Min.**	**Max.**	**# Obs.**	**Mean**	**St. Dev.**	**Min.**	**Max.**
OUTCOME VARIABLES										
RDX (in mio EUR)	186	0.9122	1.1911	0.0074	5.6797	284	0.5375	0.7699	0.0092	5.6544
RDXint (in %)	186	0.0987	0.1509	0.0004	0.7219	284	0.0499	0.0984	0.0000	0.7635
RDP (in FTE)	186	11.9277	14.8525	0.2000	72.4000	284	7.1340	9.8024	0.1000	79.8000
RDPint (in %)	186	0.2228	0.2586	0.0053	1	284	0.1321	0.1970	0.0019	1
RDX_P/RDP (in mio EUR / FTE)	186	0.0538	0.0282	0.0129	0.2157	284	0.0528	0.0290	0.0118	0.2118
RDX_O/RDP (in mio EUR / FTE)	186	0.0265	0.0258	0	0.1267	284	0.0217	0.0284	0	0.1800
INSTRUMENTS										
AMT/PROJ_past5yrs (in mio EUR)	186	0.0157	0.0579	0	0.5462	284	0.0014	0.0091	0	0.0889
PROJ/EMP_past5yrs (in number / FTE)	186	0.1355	0.3216	0	2.7500	284	0.0412	0.1710	0	2.0000
CONTROL VARIABLES										
lnEMP (in FTE)	186	4.0436	1.5037	0.69315	8.1928	284	4.2080	1.3968	0.69315	7.6159
PAT/EMP (in number / FTE)	186	0.4613	1.1672	0	7.2847	284	0.2882	0.9227	0	8.7338
EXQU (in %)	186	0.6135	0.3412	0	1	284	0.5768	0.3444	0	1
CAPint (in mio EUR / FTE)	186	134.8062	490.8716	1.26242	4856.3270	284	80.9283	125.6292	0.37779	790.2966
CASHF/EMP (in mio EUR / FTE)	186	16.0572	45.0683	-181.41	325.5137	284	17.3998	47.6177	-509.71	400.9867
GROUP (dummy)	186	0.5645	0.4972	0	1	284	0.6549	0.4762	0	1
FOREIGN (dummy)	186	0.2204	0.4157	0	1	284	0.2465	0.4317	0	1
YEAR (dummy)	186	0.5161	0.5011	0	1	284	0.5317	0.4999	0	1
ADDITIONAL VARIABLES										
UNI* (in %)	171	0.5874	0.2911	0	1	256	0.5700	0.3218	0	1
BARG (index)	186	0.0490	0.0485	0	0.1617	284	0.0629	0.0504	0	0.1885
RDPR** (in FTE)	175	7.0906	10.6564	0	60.0000	266	3.9445	6.5300	0	48.0000
RDPR/RDP** (in %)	175	0.5803	0.3229	0	1	266	0.5581	0.3479	0	1

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

5. Estimates

This section presents empirical evidence on the impact of R&D subsidies on R&D expenditure, employment and wages in Flanders. I employ parametric treatment effects models as well as IV regression models. First, the impact of the funding status is evaluated in a treatment effects framework. Table 18 reports the estimates of the selection equations. The amount of funding received as well as the number of projects submitted 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.

Table 18: Treatment effects model: selection equations

	Probit estimates			Marginal effects			Probit estimates			Marginal effects		
AMT/PROJ_past5yrs	17.2055	(5.1059)	***	6.6760	(2.0125)	***						
PROJ/EMP_past5yrs	0.9137	(0.3595)	**	0.3545	(0.1397)	**						
lnAMT/PROJ_past5yrs							0.1958	(0.0953)	**	0.0742	(0.0363)	**
lnPROJ/EMP_past5yrs							0.2473	(0.0310)	***	0.0937	(0.0117)	***
lnEMP	0.0407	(0.0625)		0.0158	(0.0242)		0.0904	(0.0639)		0.0343	(0.0242)	
PAT/EMP	0.0268	(0.0680)		0.0104	(0.0264)		-0.0099	(0.0694)		-0.0038	(0.0263)	
EXQU	0.3598	(0.2057)	*	0.1396	(0.0799)	*	0.3752	(0.2188)	*	0.1422	(0.0829)	*
CAPint	0.0005	(0.0003)		0.0002	(0.0001)		0.0006	(0.0004)		0.0002	(0.0002)	
CASHF/EMP	-0.0003	(0.0014)		-0.0001	(0.0006)		-0.0001	(0.0015)		0.0000	(0.0006)	
GROUP°	-0.2299	(0.1528)		-0.0896	(0.0596)		-0.0540	(0.1637)		-0.0205	(0.0623)	
FOREIGN°	-0.2347	(0.1767)		-0.0894	(0.0658)		-0.1949	(0.1852)		-0.0725	(0.0673)	
YEAR°	-0.0572	(0.1261)		-0.0222	(0.0489)		-0.0759	(0.1325)		-0.0288	(0.0502)	
CONSTANT	-1.0552	(0.3649)	***				1.2089	(0.6561)	*			
BR	$\chi^2(11) = 20.13$		**				$\chi^2(11) = 14.72$					
Log-Likelihood	-278.8042						-247.2025					
Pseudo R²	0.1163						0.2164					
# obs.	470						470					

° 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.

Next, the outcome equations are estimated, taking the estimated coefficients from the selection equation (Table 18) into account. In doing so, the actual treatment effect is separated from the potential selection bias (in the HAZARD coefficient). In Table 19 the outcome estimates are presented. The receipt of a public R&D grant clearly has a positive impact on a company's R&D effort.

The results confirm positive additionality effects of R&D subsidies on R&D expenditure in Flanders, which is in line with previous analyses for Flanders (Aerts and Czarnitzki, 2004 and 2006 as well as Aerts and Schmidt, 2008). Funded companies spend more (RDX***) on R&D than their non-funded counterparts. Also, funding is positively correlated with the company's R&D expenditure intensity (RDXint***). However, as David and Hall (2000) put forward well-founded, this significantly positive impact on R&D expenditure may well be fully absorbed merely by researcher wage increases if the labour supply of R&D staffing is inelastic. Additional R&D expenditure would then not be translated into more R&D activity. The current analysis allows completing the additionality picture with information on the impact of public R&D grants on R&D employment and wages. First, we look at the impact on R&D staffing. Table 19 shows that similar companies with an opposite funding status significantly differ in terms of the R&D personnel they employ: the number of R&D employees (RDP***) as well as R&D personnel intensity (RDPint***) are significantly higher after the receipt of a subsidy. Hence, in Flanders, public R&D funding is actually translated into more R&D activity. These results suggest that the supply of R&D personnel in Flanders is not fully inelastic: companies are able to attract more R&D personnel when they have a larger R&D human resources budget at their disposal. This result contrasts with the findings of Suetens (2002), who could not provide evidence to support positive additionality effects of R&D subsidies to Flemish companies, evaluating the R&D staffing employed. This may, however, be due to the fact that the dataset as well as the analysis framework differ significantly (see David and Hall, 2000). Lastly, we turn to the potential impact of public R&D funding on a company's R&D wages (RDX_P/RDP). The estimates reveal that, in addition to a significantly positive impact on R&D expenditure and R&D staffing, also the wage structure reacts to an R&D subsidy: the average personnel cost per R&D employee (RDX_P/RDP*) increases, while the average operational costs and investments per R&D employee (RDX_O/RDP) do not change.

Table 19: Treatment effects model: outcome equations

	RDX [a]			RDXint [b]			RDP [a]			RDPint [b]			RDX_P/RDP [a]			RDX_O/RDP [a]		
HAZARD	-0.5911	(0.1968)	***	-0.0349	(0.0141)	**	-6.7083	(2.4905)	***	-0.0524	(0.0230)	**	-0.0114	(0.0067)	*	-0.0027	(0.0062)	
FUN	1.2007	(0.3180)	***	0.0768	(0.0217)	***	14.0455	(4.0166)	***	0.1259	(0.0352)	***	0.0181	(0.0108)	*	0.0101	(0.0099)	
lnEMP	0.3247	(0.0370)	***	-0.0273	(0.0044)	***	4.2379	(0.4671)	***	-0.0849	(0.0071)	***	0.0032	(0.0012)	**	0.0003	(0.0011)	
PAT/EMP	0.0292	(0.0415)		0.0019	(0.0048)		0.5808	(0.5240)		0.0062	(0.0078)		-0.0012	(0.0014)		-0.0015	(0.0013)	
EXQU	0.0855	(0.1358)		0.0471	(0.0154)	***	0.4880	(1.7134)		0.1032	(0.0251)	***	0.0060	(0.0046)		0.0086	(0.0042)	**
CAPint	0.0004	(0.0001)	**	-0.0000	(0.0000)		0.0031	(0.0018)	*	-0.0000	(0.0000)		-0.0000	(0.0000)		0.0000	(0.0000)	
CASHF/EMP	0.0031	(0.0009)	***	0.0001	(0.0001)		0.0220	(0.0113)	*	0.0005	(0.0002)	***	0.0001	(0.0000)	*	0.0001	(0.0000)	***
GROUP	0.1728	(0.1007)	*	0.0191	(0.0116)	*	1.5964	(1.2699)		0.0253	(0.0188)		0.0045	(0.0034)		0.0082	(0.0031)	***
FOREIGN	0.2157	(0.1070)	**	0.0138	(0.0126)		1.7087	(1.3500)		0.0076	(0.0205)		0.0042	(0.0036)		-0.0006	(0.0033)	
YEAR	-0.0203	(0.0790)		-0.0054	(0.0093)		0.6038	(0.9964)		0.0075	(0.0152)		-0.0055	(0.0027)	**	-0.0010	(0.0024)	
CONSTANT	-1.6781	(0.2228)	***	0.0801	(0.0256)	***	-19.5058	(2.8099)	***	0.3632	(0.0416)	***	0.0161	(0.0075)	**	0.0070	(0.0069)	
BR	$\chi^2(11) = 42.07$		***	$\chi^2(11) = 110.11$		***	$\chi^2(11) = 51.83$		***	$\chi^2(11) = 99.68$		***	$\chi^2(11) = 31.82$		***	$\chi^2(11) = 14.92$		

Note: the industry dummy coefficients are not shown here; the test on their joint significance is reported, though. The standard errors (between brackets) are heteroskedasticly consistent.
The selection equation includes: [a] AMT/PROJ_past5yrs and PROJ/EMP_past5yrs - [b] lnAMT/PROJ_past5yrs and lnPROJ/EMP_past5yrs. Number of obs.: 470.

Table 20: IV regressions on the receipt of a subsidy

	RDX [a]			RDXint [b]			RDP [a]			RDPint [b]			RDX_P/RDP [a]			RDX_O/RDP [a]		
FUN	1.1852	(0.4087)	***	0.0797	(0.0273)	***	11.7621	(5.3633)	**	0.1581	(0.0837)	*	0.0290	(0.0128)	**	0.0124	(0.0085)	
lnEMP	0.3247	(0.0431)	***	-0.0273	(0.0044)	***	4.2396	(0.5819)	***	-0.0850	(0.0092)	***	0.0032	(0.0013)	**	0.0003	(0.0010)	
PAT/EMP	0.0297	(0.0384)		0.0018	(0.0036)		0.6619	(0.4653)		0.0051	(0.0060)		-0.0016	(0.0011)		-0.0016	(0.0014)	
EXQU	0.0879	(0.1412)		0.0466	(0.0181)	***	0.8282	(1.6535)		0.0984	(0.0288)	***	0.0044	(0.0055)		0.0082	(0.0044)	*
CAPint	0.0004	(0.0001)	***	-0.0000	(0.0000)		0.0035	(0.0018)	**	-0.0000	(0.0000)		-0.0000	(0.0000)		0.0000	(0.0000)	
CASHF/EMP	0.0031	(0.0013)	**	0.0001	(0.0002)		0.0217	(0.0135)		0.0005	(0.0003)	**	0.0001	(0.0000)	*	0.0001	(0.0000)	**
GROUP	0.1713	(0.0855)	**	0.0194	(0.0123)		1.3773	(1.1210)		0.0284	(0.0198)		0.0056	(0.0035)		0.0084	(0.0032)	***
FOREIGN	0.2151	(0.1270)	*	0.0139	(0.0146)		1.6280	(1.5233)		0.0088	(0.0198)		0.0046	(0.0038)		-0.0005	(0.0036)	
YEAR	-0.0207	(0.0772)		-0.0053	(0.0089)		0.5518	(0.9572)		0.0082	(0.0154)		-0.0052	(0.0029)	*	-0.0009	(0.0024)	
CONSTANT	-1.6748	(0.2538)	***	0.0795	(0.0213)	***	-19.0212	(3.3051)	***	0.3563	(0.0547)	***	0.0138	(0.0069)	**	0.0065	(0.0065)	
BR	$\chi^2(11) = 48.26$		***	$\chi^2(11) = 83.70$		***	$\chi^2(11) = 59.97$		***	$\chi^2(11) = 95.06$		***	$\chi^2(11) = 32.25$		***	$\chi^2(11) = 14.86$		
Instrument tests:																		
Anderson	$\chi^2(2) = 21.518$		***	$\chi^2(2) = 103.293$		***	$\chi^2(2) = 21.518$		***	$\chi^2(2) = 21.518$		***	$\chi^2(2) = 21.518$		***	$\chi^2(2) = 21.518$		***
Hansen-Sargan	$\chi^2(1) = 1.141$			$\chi^2(1) = 0.032$			$\chi^2(1) = 0.430$			$\chi^2(1) = 1.050$			$\chi^2(1) = 0.001$			$\chi^2(1) = 1.814$		
Centered R^2	0.2689			0.3561			0.3200			0.4736			-0.1040			0.1038		

Note: the industry dummy coefficients are not shown here; the test on their joint significance is reported, though. The standard errors (between brackets) are heteroskedasticly consistent.
The instruments used are: [a] AMT/PROJ_past5yrs and PROJ/EMP_past5yrs – [b] lnAMT/PROJ_past5yrs and lnPROJ/EMP_past5yrs. Number of obs.: 470.

The parametric treatment effects models reveal that the Flemish R&D policy stimulates private R&D activity, both in terms of expenditure and employment. In a next step, the evaluation of the funding status (FUN) is introduced in an IV framework. As discussed before, both the amount of funding received and the number of projects submitted by the company in the preceding five years are expected to be reliable instruments in an IV approach of the additionality issue. Table 20 shows the regression results. The coefficient of FUN is again highly significant and positive for R&D expenditure, personnel, intensity and wages. Moreover, the tests on the quality of the instrumental variables confirm that the model requirements hold. Compared to the treatment effects model, the coefficients are very similar.

In the last step, I extend the analysis of the funding status and take the amount of funding (AMT) into account. This enables a more profound insight into the nature of the additionality effects found in the discrete models. These latter models reject full crowding-out effects. However, it is still possible that funded companies to some extent replace private money with the public grant. This would mean that a subsidy partially crowds out companies' private R&D effort.

Again, funding is instrumented with both the amount of funding received and the number of projects submitted by the company in the preceding five years. The estimates for different R&D expenditure measures are presented in Table 21. The coefficient of AMT 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 1.793 million EUR. The Flemish R&D activities are highly skewed, however. That is why one should also consider lnRDX and RDXint. The coefficients of the log-log specification can be interpreted as elasticities. Here, the picture looks a little less attractive: the elasticity of the R&D expenditure merely amounts to 12%.

Table 21: IV regression: R&D expenditure

	----------RDX [a]----------			----------lnRDX [b]----------			----------RDXint [b]----------		
AMT	1.7927	(0.6528)	***						
lnAMT				0.1244	(0.0268)	***	0.0114	(0.0039)	***
lnEMP	0.3044	(0.0390)	***	0.4950	(0.0421)	***	-0.0282	(0.0043)	***
PAT/EMP	-0.0244	(0.0502)		0.0605	(0.0373)		-0.0020	(0.0036)	
EXQU	0.1703	(0.1170)		0.8621	(0.1401)	***	0.0512	(0.0181)	***
CAPint	0.0006	(0.0001)	***	0.0002	(0.0001)	***	-0.0000	(0.0000)	
CASHF/EMP	0.0034	(0.0011)	***	0.0034	(0.0011)	***	0.0002	(0.0002)	
GROUP	0.0666	(0.0599)		0.2690	(0.1045)	**	0.0164	(0.0120)	
FOREIGN	0.1464	(0.1065)		0.0546	(0.1218)		0.0102	(0.0145)	
YEAR	0.0315	(0.0673)		0.1417	(0.0889)		0.0034	(0.0095)	
CONSTANT	-1.3650	(0.1932)	***	-3.8667	(0.2830)	***	0.1642	(0.0342)	***
BR	$\chi^2(11) = 50.26$		***	$\chi^2(11) = 173.01$		***	$\chi^2(11) = 85.32$		***
Instrument tests:									
Anderson	$\chi^2(2) = 97.635$		***	$\chi^2(2) = 215.930$		***	$\chi^2(2) = 215.930$		***
Hansen-Sargan	$\chi^2(1) = 0.983$			$\chi^2(1) = 0.318$			$\chi^2(1) = 0.310$		
Centered R²	0.5134			0.5572			0.3777		

Note: the industry dummy coefficients are not shown here; the test on their joint significance is reported, though. The instruments used are: [a] AMT/PROJ_past5yrs and PROJ/EMP_past5yrs - [b] lnAMT/PROJ_past5yrs and lnPROJ/EMP_past5yrs. The standard errors (between brackets) are heteroskedasticly consistent. Number of obs.: 470.

Also the evaluation of the impact of public funding on R&D employment leads to similar results as the discrete treatment analyses. Again, the absolute increase is very high: a subsidy of 1 million EUR would result in the hiring of 17 additional R&D employees. The elasticity is 11%.

Table 22: IV regression: R&D personnel

	----------RDP [a]----------			----------lnRDP [b]----------			----------RDPint [b]----------		
AMT	17.2735	(9.7748)	*						
lnAMT				0.1069	(0.0242)	***	0.0166	(0.0057)	***
lnEMP	4.0445	(0.5595)	***	-0.5784	(0.0390)	***	-0.0863	(0.0087)	***
PAT/EMP	0.1519	(0.6825)		0.0821	(0.0362)	**	0.0010	(0.0060)	
EXQU	1.6734	(1.4056)		0.5722	(0.1202)	***	0.1112	(0.0255)	***
CAPint	0.0055	(0.0013)	***	0.0002	(0.0001)	*	0.0000	(0.0000)	
CASHF/EMP	0.0245	(0.0134)	*	0.0018	(0.0009)	**	0.0006	(0.0002)	**
GROUP	0.3353	(0.8877)		0.1273	(0.0929)		0.0200	(0.0186)	
FOREIGN	0.9537	(1.4098)		0.0563	(0.1109)		0.0020	(0.0185)	
YEAR	1.0472	(0.9753)		0.2027	(0.0813)	**	0.0199	(0.0148)	
CONSTANT	-15.9628	(2.6074)	***	-0.4785	(0.2496)	*	0.4891	(0.0550)	***
BR	$\chi^2(11) = 62.38$		***	$\chi^2(11) = 190.68$		***	$\chi^2(11) = 120.75$		***
Instrument tests:									
Anderson	$\chi^2(2) = 97.635$		***	$\chi^2(2) = 215.930$		***	$\chi^2(2) = 215.930$		***
Hansen-Sargan	$\chi^2(1) = 0.919$			$\chi^2(1) = 0.986$			$\chi^2(1) = 1.118$		
Centered R²	0.4588			0.6479			0.5282		

Note: the industry dummy coefficients are not shown here; the test on their joint significance is reported, though. The instruments used are: [a] AMT/PROJ_past5yrs and PROJ/EMP_past5yrs - [b] lnAMT/PROJ_past5yrs and lnPROJ/EMP_past5yrs. The standard errors (between brackets) are heteroskedasticly consistent. Number of obs.: 470.

Table 23 confirms the earlier conclusion that also the wage structure is influenced by the R&D subsidy policy in Flanders. In the first model, only variables used in the models for RDX and RDP are included. The second model additionally includes two variables which may also exert a particular influence on R&D wages, i.e. the share of highly skilled R&D employees (UNI) and the union's strength in the wage bargaining process (BARG). The composition of the workforce (UNI***) indeed seems to drive a share of inter-firm wage dispersion, but the union (BARG) does not significantly affect R&D wages. This is not too surprising, as R&D employees are typically white-collar workers, who often receive pay supplements outside of collective agreements (Rusinek and Rycx, 2008). Therefore, the union's bargaining power is not relevant. This was already suggested in Table 16, where the bargaining power is less significant in sector 73: Research and Development. Obviously, the bargaining power is calculated from the total population of employees, but the share of R&D employees is expected to be high in this sector.

Table 23: IV regression: R&D wage structure

	---------RDX_P/RDP [a]---------			---------RDX_P/RDP [b]---------			--------RDX_O/RDP [a]--------		
AMT	0.0370	(0.0138)	***	0.0357	(0.0153)	**	0.0079	(0.0101)	
UNI				0.0124	(0.0050)	**			
BARG				0.0852	(0.0787)				
lnEMP	0.0028	(0.0012)	**	0.0028	(0.0013)	**	0.0002	(0.0010)	
PAT/EMP	-0.0026	(0.0014)	*	-0.0029	(0.0017)	*	-0.0016	(0.0014)	
EXQU	0.0068	(0.0048)		0.0037	(0.0050)		0.0097	(0.0042)	**
CAPint	-0.0000	(0.0000)		-0.0000	(0.0000)		0.0000	(0.0000)	
CASHF/EMP	0.0001	(0.0000)	**	0.0001	(0.0000)	**	0.0001	(0.0000)	**
GROUP	0.0030	(0.0030)		0.0042	(0.0030)		0.0072	(0.0030)	**
FOREIGN	0.0030	(0.0035)		0.0020	(0.0036)		-0.0011	(0.0036)	
YEAR	-0.0043	(0.0028)		-0.0038	(0.0029)		-0.0009	(0.0024)	
CONSTANT	0.0211	(0.0060)	***	0.0059	(0.0115)		0.0094	(0.0061)	
BR	$\chi^2(11) = 34.73$		***	$\chi^2(11) = 29.57$		***	$\chi^2(11) = 13.91$		
Instrument tests:									
Anderson	$\chi^2(2) = 97.635$		***	$\chi^2(2) = 81.767$		***	$\chi^2(2) = 97.635$		***
Hansen-Sargan	$\chi^2(1) = 1.194$			$\chi^2(1) = 1.166$			$\chi^2(1) = 2.719$		
Centered R^2	0.0762			0.0877			0.1101		

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 heteroskedasticly consistent. Number of obs.: [a]470 [b]427.

So, bringing the results together, it is clear that public R&D funding induces additional R&D expenditure. Moreover, funded companies enlarge their R&D workforce. However, at the same time, the average R&D wage increases. Two potential explanations are advanced. On the one hand, the R&D wage increase may not involve any difference in productivity and result from an inelastic R&D labour supply. However, as the increase in R&D personnel after receiving a subsidy is considerable, the R&D labour supply in Flanders seems not to be fully inelastic. On the other hand, this R&D wage increase could signal an 'upskilling' process, i.e. the R&D workforce composition is shifted upwards with respect to its qualification. As only information on the average R&D wage is available, it is not possible to directly test this hypothesis. However, to some extent, a change in workforce composition can be assessed through other approximating variables. First, we look at the number of researchers. Compared with technicians and other R&D employees, it can be expected that they typically are more likely to be highly skilled. If we take into account that the total number of R&D employees increased with about 17.3 FTEs and compare this to the increase in the number of researchers only, which is about 16.7 (see RDPR in Table 24), it appears that the increase in R&D employment mainly comes from an increase in researchers. Further analyses (not shown here) indeed confirm that there is no significant increase in the number of technicians and other R&D employees. Second, I assess the impact of the subsidy on the share of researchers in the total R&D workforce (see RDPR/RDP in Table 24). Also here, a significantly positive impact can be found. In a cautious conclusion, one could therefore collect some evidence that the increase in R&D wages is not that detrimental, as the quality of the R&D employees tends to increase, which in turn increases the quality of the R&D activity, as well as the expected output.

Table 24: IV regression: number of researchers and their share in the total R&D workforce

	---------RDPR---------			---------RDPR/RDP---------		
AMT	16.7069	(7.6660)	**	0.3719	(0.1273)	***
lnEMP	2.5592	(0.4882)	***	-0.0284	(0.0143)	**
PAT/EMP	0.2066	(0.5348)		0.0146	(0.0159)	
EXQU	0.4368	(1.1295)		0.0322	(0.0564)	
CAPint	0.0010	(0.0007)		-0.0000	(0.0000)	
CASHF/EMP	0.0192	(0.0100)	*	0.0002	(0.0002)	
GROUP	0.1144	(0.6702)		0.0130	(0.0397)	
FOREIGN	-0.0039	(1.0194)		-0.0161	(0.0409)	
YEAR	0.9278	(0.7326)		0.0604	(0.0320)	*
CONSTANT	-10.5676	(2.0651)	***	0.6360	(0.0859)	***
BR	$\chi^2(11) = 47.62$		***	$\chi^2(11) = 12.59$		
Instrument tests:						
Anderson	$\chi^2(2) = 88.458$		***	$\chi^2(2) = 88.458$		***
Hansen-Sargan	$\chi^2(1) = 0.000$			$\chi^2(1) = 0.101$		
Centered R^2	0.3970			0.0693		

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 heteroskedasticly consistent. Number of obs.: 441.

6. 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. In the first place, one could ask whether R&D grants actually stimulate private R&D investments: companies may simply replace private R&D budgets with the public money provided by the government. This is the main question to which researchers try to find an answer in additionality research. However, even if an increase in private R&D investment is confirmed (as concluded by many scholars), this may not automatically induce more R&D activity: the additional R&D budget may be crowded out by duplicate or more risky research, or a mere increase in researcher wages without any impact on the R&D activity of a company and as a result render an R&D grant, although to the benefit of private R&D expenditure, ineffective.

This chapter provides insights into the impact of R&D grants, giving audience to the appeal of David and Hall (2000) to include labour market dynamics in the traditional application of treatment effects models in additionality research. I empirically analyze the effect of public R&D subsidies on private R&D investments, employment and wages in Flanders, 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 with information on the company's subsidy history, I conclude that R&D subsidies in Flanders bring about positive additionality effects, measured in R&D expenditure. Moreover, this public R&D funding is translated into more R&D activity: funded companies employ more R&D personnel, suggesting that the supply of R&D personnel in Flanders is not fully inelastic. Full crowding-out effects are rejected. However, partial crowding-out cannot be ruled out: funded companies do not add the whole subsidy amount to their private R&D budget. This analysis highlights the importance of evaluating the effectiveness of the R&D policy in terms of both the funding status and the grant size. The estimates indicate that, to some extent, the private R&D activity is reduced and replaced by the subsidy. The results for the impact on R&D expenditure and employment are very comparable; they change likewise.

However, next to a significantly positive impact on R&D expenditure and R&D staffing, also an increase in R&D wages is found in firms receiving R&D subsidies. A mismatch between the demand and supply of R&D employees may enforce an increase in labour costs for the companies, which translates in increased R&D remuneration. In the European Innovation Scoreboard (EIS) country reports, the drivers of innovative activity are assessed at the country level (PRO INNO EUROPE, 2007). Belgium is among the TOP10 in the EU27. Although it is clear that its performance lags behind in several indicators, and Belgium's weak competence in capitalizing the full benefits of above average levels of R&D and innovation expenditure in terms of innovative output is exposed, the main strength of the Belgian innovation system seems to lie in its strong relative performance on human resources in innovation. Despite a small shortage of skilled technical staff in specific industries, especially in the Walloon region, and a considerable outgoing brain drain, which are denounced in the EIS report, the analysis in this chapter shows that the Flemish human resources in innovation seem to be sufficiently strong to withstand an increase in the demand for R&D employees and to provide a significantly large supply in response. Conversely, also an upskilling process could be an underlying explanation for an increase in R&D wages after the receipt of a subsidy. As the increase in R&D employment is significant and as mainly the number of researchers is increased after a subsidy receipt, I tend to believe that a change in the composition of the workforce towards more highly skilled employees is the main force driving inter-firm R&D wage dispersion between funded and non-funded firms.

In these last paragraphs, I come to some final caveats which the reader should bear in mind and which give way to further research. First, 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. Second, the literature review implies that the effect of an R&D subsidy may be very different in the long run. Here, short term effects were investigated. However, the increase in R&D activity on the short run may induce different effects on the long run. The impact on the R&D personnel demand may become even larger, when, as one could expect, the elasticity of labour supply is larger in the long run: more R&D personnel becomes available as idle R&D educated people switch to R&D jobs and new R&D educated people become available on the job market. Research on the long term effects would therefore add much value to the existing studies. Third, a profound analysis of the determinants of R&D wages is highly relevant. The composition of the workforce was revealed as a very important factor, while the union's bargaining power does not seem to play. However, an extension of the current model, including other potential determinants, seems a promising research field. Fourth, the variables reflecting the wage structure do not capture other benefits to reward R&D personnel. Examples are stock options or other fringe benefits. Taking these rewards additionally into account could refine the analysis currently presented here. However, this information is very difficult to obtain and highly company-specific. Last, it would be highly interesting to evaluate the R&D output effects of the increase in R&D activity. Some work has been done in this respect, using patenting activity (Czarnitzki and Licht, 2006 as well as Schneider, 2008) or the introduction of new products (Aerts, 2008; Hujer and Radić, 2005 as well as Bérubé and Mohnen, 2007), but the topic deserves further elaboration. Also, the relationship between researcher wages and innovative performance seems to be a valuable research domain.

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Chapter 5. Carrying Flemish coals to Newcastle? R&D subsidies and foreign ownership

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 showing 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, resulting in 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 just as well be 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 workforce 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 grants and, aggregated, the lion's 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 chapter: 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 literature streams are relevant for this research. First, the literature on the evaluation of public R&D funding is reviewed. Second, we dive into the literature on the internationalization of R&D activities and more specifically, the different roles 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 private R&D investment: does public money replace (or crowd out) private expenditure on R&D? After an extensive review of the literature, David and Hall (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, 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[45].

[45] 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. (2005), 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. The interested reader is referred to Aerts et al. (2007) for a survey of the recent literature on the evaluation of public innovation policy.

Aerts and Czarnitzki (2004) address the additionality issue using a cross-section of Flemish manufacturing and selected service companies with the nearest neighbour matching approach. Next, they extend their research in an 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) employ matching and 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 employees. David and Hall (2002) emphasize the importance of differentiating between the impact of subsidies on expenditure and employment, as companies may increase their R&D spending, but 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 significantly positive R&D expenditure increases, a smaller, but still positive impact on the number of R&D employees. This coincides with an increase of R&D wages, which tends to reflect an upskilling process.

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, the public 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 actually 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 indisputably is 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. Or, subsidies can be used to finance duplicate R&D, which may induce inefficiency in the national innovation system (Irwin and Klenow, 1996). Moreover, an actual reinforcement of private R&D activities may be directed towards more risky and consequently potentially 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, etc. Since then, researchers also have been evaluating measures on product and process innovations. More recent research extends the crowding-out question by linking privately financed and publicly induced R&D expenditure to innovative activity (Czarnitzki and Hussinger, 2004 as well as Czarnitzki and Licht, 2006). A two equation model is considered: first, a treatment effects analysis on R&D expenditure is conducted using the matching approach. In the second equation, a knowledge production function is estimated, relating a measure of innovative output to the firms' R&D spending and other covariates. The first step allows disentangling total R&D spending into two components: on the one hand, that part of the R&D expenditure that would have been invested in the absence of subsidies, i.e. the estimated counterfactual situation. On the other hand, the remaining part of the R&D expenditure that has been induced by the receipt of subsidies, which comprises the amount of the subsidy itself, and the additionally stimulated privately financed R&D (the treatment effect). The two components add up to the total observed R&D spending, but the decomposition allows analyzing the productivity of privately financed versus the additionally induced R&D by public subsidies.

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 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 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 initially are not familiar with the host country's context, they are disadvantaged, relative to domestic firms. Firm-specific advantages enable multinationals to overcome this initial 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 et al., 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 et al. (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 subsections 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, i.e. 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:

$$\alpha_{TT} = E(Y^T | S = 1) - E(Y^C | S = 1), \tag{31}$$

where Y is the outcome variable (e.g. R&D expenditure) of a firm[46], 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 $E(Y^T | S = 1)$ can be estimated by the sample mean of the outcome in the group of subsidized firms.

The counterfactual situation $E(Y^C | S = 1)$ 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:

$$E(Y^C | S = 1) = E(Y^C | S = 0). \tag{32}$$

However, 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. Ex ante innovative and R&D intensive firms may be more likely to receive an R&D subsidy, as

[46] For the sake of readability we omit these firm indices in the equations.

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 (32) 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 policies.

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 with members 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 the potential outcome are independent for firms with the same set of exogenous characteristics X=x:

$$Y^T, Y^C \perp S \mid X = x \,. \tag{33}$$

This crucial conditional independence assumption (CIA) helps to overcome the problem that the counterfactual outcome $E(Y^C | S = 1)$ is unobservable. If the CIA holds, the expected outcome $E(Y^C | S = 0, X = x)$ 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

$$E\left(Y^C | S = 1, X = x\right) = E\left(Y^C | S = 0, X = x\right) \qquad (34)$$

is valid and the average outcome of subsidized firms in the absence of a subsidy can be calculated from a sample of comparable, i.e. 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 a valid counterpart should be found in the non-treated population and every firm should represent a potential subsidy recipient. Therefore, a so-called common support restriction is imposed. 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

$$\alpha_{TT}^{M} = E\left(Y^T | S = 1, X = x\right) - E\left(Y^C | S = 0, X = x\right) \qquad (35)$$

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 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 procedure, since the equivalence of these extra variables is explicitly imposed, in addition to their weight 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 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 into 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 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 25.

Table 25: 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

The particularities of public R&D funding and foreign multinational activity in Flanders are briefly explained first. Next, I come to the description of the data and the variables used to conduct an assessment of R&D subsidies in Flanders.

4.1. Contextual framework

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 and Belgian level, as well as certain EU-funded projects[47] 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[48]. Main reasons are a low level of acquaintance with the system, complexity and high administration costs[49] and the fact that the measures

[47] The Framework Program projects are not managed through IWT. However, typically the scale of these projects is very large because these projects are often managed in international company consortia. As a result, the number of Flemish firms engaging in these programs is very limited.
[48] Due to recent changes in the Science and Technology Policy, this situation has changed, though. In the current system, fiscal measures, and more specifically tax credits for R&D personnel, are becoming increasingly popular. However, this is not relevant in the current chapter, as our data was collected before the change.
[49] First, each year the company has to deliver a certificate. Second, the researcher should be full time employed in the research department of the same company to qualify. Third, the tax allowance is nominative, inducing a burden to keep track of all employees who benefited from the measure in the past.

are not significantly substantial[50]. Direct R&D funding through IWT remains the largest source of public R&D grants in the private sector in Flanders[51].

De Backer and Sleuwaegen (2005) confirm Belgium's weak FDI outward position relative to its FDI inward position: there is a strong presence of foreign multinational activity in Flanders. In 2001, 2,958 foreign affiliates employed 293,409 people and created an added value of about 25 billion EUR (Sleuwaegen et al., 2004a). These affiliates usually are owned in a structure of a foreign majority share holder; head quarters are mostly located in the Netherlands (34%), France (19%), the US (10%) or Germany (8%) (Vanweddingen, 2006). In terms of the number of companies, this foreign presence is strongest in the service sector (75% of the foreign affiliates), and more specifically in wholesale trade and other business services. However, a limited number of foreign-owned companies realizes a considerable share of the added value and employment in industry (especially in chemicals, automotive and metals): they represent 8% in the total number of foreign companies, but 60% and 51% in terms of the added value and employment, respectively, created by all foreign affiliates. (Sleuwaegen et al., 2004a)

A comparison of the presence of foreign-owned versus domestic companies (Sleuwaegen et al., 2004b) learns that foreign affiliates are especially active in the high-tech and medium-high-tech sectors, while in comparison, Flemish firms are rather active in the medium-low-tech sectors. Performance indicators show that foreign-owned companies outperform domestic companies in terms of profitability and added value per employee (Sleuwaegen et al., 2004b) as well as innovative capabilities (De Backer and Sleuwaegen, 2005).

Although Flanders is moving towards a knowledge economy, it is strongly dependent on multinational activity in this respect. In the chemical, automotive and metal industries as well as in the telecommunication sector, there is a strong sensitivity to delocalisation: the presence of foreign affiliates is considerable and delocalisation would imply serious decreases in the number of companies, employment and added value in these sectors in Flanders. In a dynamic analysis, Sleuwaegen et al. (2004b) look at the evolution of the number of jobs and added

[50] First, the amount of the exemption is not sufficiently significant. Second, the definition of highly qualified personnel is too strict, so that only very few employees qualify for the measure. Third, the tax exemption is a short term measure (it only relates to the first year of recruitment) while R&D typically is a long term process.
[51] The interested reader is referred to Aerts and Czarnitzki (2006) for a detailed overview of the public R&D funding system in Flanders.

value between 1998 and 2002. They found that the number of jobs in foreign enterprises went down in the low-tech, medium-high-tech and medium-low-tech sectors; the number of jobs in the high-tech sectors increased in foreign affiliates because of new entrants. In the Flemish companies, employment in low-tech industries decreased (especially in textiles), but increased in medium-high and medium-low-tech industries. In this way, Flanders may start reducing its strong dependence on multinational activity.

With respect to R&D activity, it can be observed that in the foreign activity in the high-tech and medium-tech industries, especially Germany and the US are highly active (Sleuwaegen, 2004b). Also, these countries exhibit a high R&D-intensity: in 2006 the share of the GERD in the GDP was 2.51% in Germany and 2.62% in the US, compared to 1.85% in Belgium (OECD, 2007). So, next to the economic gains from multinational activity in terms of employment and added value, foreign multinationals can be an extremely valuable source of knowledge, in support of the local R&D activity. A primordial condition however, is the ability of the domestic companies to absorb and internalise this knowledge. Hence, the Belgian and Flemish government seem to follow a double strategy: on the one hand, it is important that the Flemish economy develops into a strong and healthy knowledge-intensive economy, reducing its dependence on foreign activity, while on the other hand, the government wants to promote Flanders as the ideal location for setting-up and expanding multinational activity.

The Belgian government stresses its non-discriminatory treatment: "*foreign companies, subsidiaries or branches, have the same legal obligations, but can also apply to all possible incentives, as domestic companies*" (FOD Economie, KMO, Middenstand en Energie, 2008). With different incentives, a considerable attempt was made to create a business-friendly environment. Besides their explicit claim of non-discrimination, the Flemish and Belgian government make substantial efforts to attract business activity from abroad, especially by providing clear information about different options and possibilities and thereby facilitating access to the Belgian and Flemish economic and technological potential.

The regions carry the full responsibility in granting direct financial incentives. Most of the tax incentives are provided through the federal government, but some aspects are left to the decision power of the regions. Employment and training incentives are provided at both the federal and regional level. The Belgian Science and Technology Policy is highly regionalized and the Flemish government has a large degree of control in this matter. Other policy areas are less regionalized. As multinational activity in high-tech industries is expected to generate high gains in terms of employment, added value, performance and innovative capacity, with large potential spillovers towards the local economy, foreign affiliates constitute an important player in the Flemish economy. The Flemish government has a strong power, especially in granting financial incentives for R&D activity and the provision of R&D subsidies may serve as an instrument to attract foreign activity in Flanders. So, especially here, this consideration becomes very relevant: through public R&D funding, the Flemish government may aspire to increase R&D activity, but also attract multinational (R&D) activity more in general. On the other hand, the total amount of public R&D funding which companies can receive is limited to 8 million EUR per year. In larger companies this amount typically represents only 5% to 10% of their total R&D expenditure. Hence, R&D grants are often regarded as 'structural support'. The Flemish government puts high value on the valorisation of the research results in Flanders. This is hard to enforce, though, especially in multinational companies. In this chapter, the impact of public R&D funding is looked into, in domestic versus foreign-owned companies and at both the input as well as output side of the R&D process.

4.2. Variables

The potential crowding-out effect of R&D subsidies in Flanders is addressed empirically with data from the Community Innovation Survey (CIS). 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, 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 to 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.

The receipt of subsidies is denoted by a dummy variable (FUN) indicating whether the firm, observed in the CIS IV (III)[52], 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 to a lesser, but nevertheless significant extent, 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[53]. In my sample, 26% of the companies is owned by a foreign mother company. The most important countries where head offices of Belgian subsidiaries in this sample are located, are the Netherlands, the US, Germany, France and Great Britain.

The outcome variables are twofold. First, R&D expenditure[54] (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[55] of RD and RDint are additionally evaluated as outcome variables. All outcome variables refer to the year 2004(2000).

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[52] In the description of the variables, I always refer to two years, i.e. the observation window of the CIS-waves.

[53] 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 the sample.

[54] In the CIS survey, R&D expenditure is defined in accordance with the Frascati Manual (OECD, 2002).

[55] Zero values of RD and RDint were replaced by the minimum observed value to compute the logs.

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 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 preceding 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 controlling 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[56]. 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 innovative activities. I use all patent information in the EPO database and generate

[56] 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).

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

$$PAT_t = (1-\delta)PAT_{t-1} + PATA_t, \qquad (36)$$

where PAT is the patent stock of a firm 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 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 and 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 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 role 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.

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[57]. 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.

Twelve industry dummies (BR) are included to allow for differences between sectors. On the one hand, some sectors may exhibit a larger R&D intensity. On the other hand, governments may favour certain sectors in their R&D policy, which increases the likelihood of receiving subsidies for firms in these industries. 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 directly target 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 372 companies are owned by a foreign mother company. The summary statistics of the variables are presented in Appendix 1 (on page 167).

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, their 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

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

employee (TURNMAR/EMP) is tested. Second, the CIS V asks whether the company applied for a patent in the period 2004-2006. This information was translated into the dummy variable PATdum[58]. However, the variables TURNMAR, TURNMAR/EMP and PATdum 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 wave. 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 past 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 26.

Table 26: Summary statistics – output additionality

Variable	# obs.	Mean	St. Dev.	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.

[58] 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. However, in doing so, I can only assess a dummy variable and refrain from using information on the number of patent applications.

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 according to ownership and potential additionality effects are evaluated for foreign-owned versus domestic firms in two separate estimations. The propensity score $P(X)$ [59], lnEMP and YEAR[60] are used to select matched pairs with:

P(X) = f(FOREIGN, lnEMP, PROJ, PAT/EMP, EXQU, CAPint, CASHF/EMP, SCOM, GROUP, YEAR, BR, BR_lnEMP). (37)

Full sample

The summary statistics in Appendix 1 (on page 167) show that funded and non-funded companies seem to exhibit different characteristics for both the outcome and control variables. This is confirmed by two-sided t-tests (not reported here). 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 27). 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 chapter. Furthermore, size, experience in project applications, past innovative activity and international competition are important determinants increasing the likelihood of receiving 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.

[59] Obviously FOREIGN is only included in the full sample; GROUP is only included when domestic firms are in the sample.
[60] 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.

Table 27: 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	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 propensity score), is combined with lnEMP and YEAR to select pairs of subsidized and very similar non-subsidized companies. T-tests on the matched samples (not reported here) 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 (see Table 28): 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 28: 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, 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 $\alpha_{TT}^{M} / E\left(Y^T \mid S = 1, X = x\right)$. 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 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 29). Table 30 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 29: 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	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 30: 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, 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 $\alpha_{TT}^{M} / E(Y^T | S = 1, X = x)$. 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.

Domestic sample

In the last step, the additionality analysis focuses on the subsample of domestic firms. The probit model (see Domestic sample in Table 31) 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 32): 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 with the R&D activity and bias the 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[61]. The estimates for the propensity score (see "Domestic subsample" in Table 31) are slightly different, but the additionality effects remain strongly positive (see "Domestic subsample" in Table 32): 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%.

[61] 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 31: 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	-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 32: 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, 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 $\alpha^{M}_{TT} / E(Y^T | S = 1, X = x)$. 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 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[62], 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

[62] 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, I conducted the analysis presented in this chapter, 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.

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 estimating the impact on NAV_growth, the lagged value of the net added value per employee was included, to control for past 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 33. 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. Notably, 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 may 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, as it confirms 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 coefficients are directly comparable for the domestic and foreign-owned firms. The results (see Table 34) now demonstrate a more detailed picture and provide insight into 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. This 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 34. 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 33: 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	reg
NAV/EMP $_{t-1}$						-20.3390 **
						(9.0592)
DOMESTIC°	-0.3106 **	-0.1811	-1.6484 *	-0.8423	-0.3773 *	-0.0849
	(0.1322)	(0.1447)	(0.8648)	(0.6215)	(0.1958)	(0.3277)
RDC	0.3278 ***	0.3170 ***	0.7411 ***	0.683 ***	0.2023 *	0.4753 ***
	(0.0322)	(0.0473)	(0.2231)	(0.1669)	(0.1038)	(0.1680)
RDdif	0.3580 ***	0.3411 ***	1.0207 ***	0.8986 **	0.7322 **	0.2479
	(0.0324)	(0.0724)	(0.2271)	(0.4244)	(0.3199)	(0.2693)
EMP			-0.0053 ***	-0.0045 ***	0.0012 **	-0.0012
			(0.0019)	(0.0012)	(0.0004)	(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	$F(11. 137) = 1.73$	$F(11. 136) = 1.43$	$F(11. 136) = 0.74$	$F(11. 135) = 1.46$	$\chi^2(11) = 18.84$	$F(11.1437) = 2.88$
	$p = 0.0735$	$p = 0.1676$	$p = 0.6942$	$p = 0.1548$	$p = 0.0640$	$p = 0.0010$
Test			**RDC - RDdif = 0**			
	$F(1.137) = 0.48$	$F(1.136) = 0.09$	$F(1.136) = 0.95$	$F(1.135)= 0.29$	$\chi^2(1) = 2.76$	$F(11.1437)= 0.98$
	$p = 0.4918$	$p = 0.7672$	$p = 0.3313$	$p = 0.5942$	$p = 0.0964$	$p = 0.3329$
# obs.	151	151	151	151	360	1455
(Pseudo) R²	0.3453	0.7033	0.0473	0.2405	0.2435	0.1194

Standard errors (between brackets) are heteroskedasticly consistent.
*** (**, *): significant at 1% (5%, 10%).

Table 34: Additionality effects at the R&D output side II

Variable	TURNMAR (in mio €) cnreg	TURNMAR (in mio €) reg	TURNMAR/EMP (in thsd €) cnreg	TURNMAR/EMP (in thsd €) reg	PATdum (dummy) probit	NAV_growth (in mio €) reg
NAV/EMP $_{t-1}$						-19.7953 **
						(8.8982)
DOMESTIC°	-0.2700 *	-0.1623 **	-0.7252	-0.0977	-0.2078	0.0714
	(0.1450)	(0.0804)	(0.9456)	(0.6222)	(0.2287)	(0.2945)
RDCDOM	0.3421 ***	0.3368 ***	0.5719 **	0.5431 ***	0.4369 *	0.4564 ***
	(0.0348)	(0.0490)	(0.2453)	(0.0921)	(0.2422)	(0.1647)
RDCFOR	0.2959 ***	0.2620 ***	1.6535 ***	1.4371 *	0.2705 *	0.6086 *
	(0.0747)	(0.0387)	(0.4910)	(0.2130)	(0.1443)	(0.3245)
RDdifDOM	0.3279 ***	0.3109 ***	0.9445 ***	0.8305 ***	0.3551 *	-0.0393
	(0.0345)	(0.0550)	(0.2340)	(0.4381)	(0.1992)	(0.1533)
RDdifFOR	0.5110 ***	0.4999 *	1.4757 ***	1.3004 **	4.5903 ***	0.8596 *
	(0.0785)	(0.2572)	(0.5618)	(0.5381)	(1.4261)	(0.5043)
EMP			-0.0055 ***	-0.0047 ***	0.0012 ***	-0.0014
			(0.0019)	(0.001)	(0.0005)	(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	F(11.134) = 1.45	F(11.134) = 0.84	F(11.133) = 1.54	$\chi^2(11)$ = 20.54	F(11. 1435) = 2.91
	p = 0.1347	p = 0.1593	p = 0.5968	p = 0.1252	p = 0.0384	p = 0.0008
Tests			**RDCdom - RDdifdom = 0**			
	F(1.135)= 0.09	F(1.134)= 0.12	F(1.134)= 1.37	F(1.133)= 0.44	$\chi^2(1)$ = 0.08	F(1.1435) = 8.32
	p = 0.7678	p = 0.7289	p = 0.2439	p = 0.5076	p = 0.7809	p = 0.0040
			RDCfor – Rddiffor = 0			
	F(1.135)= 4.30	F(1.134)= 1.00	F(1.134)= 0.06	F(1.133)= 0.06	$\chi^2(1)$ = 9.56	F(1.1435) = 0.33
	p = 0.0399	p = 0.3200	p = 0.7995	p = 0.8036	p = 0.0020	p = 0.5639
			RDCdom – RDCfor = 0			
	F(1.135)= 0.32	F(1.134)= 1.59	F(1.134)= 4.03	F(1.133)= 14.50	$\chi^2(1)$ = 0.33	F(1.1435) = 0.20
	p = 0.5755	p = 0.2102	p = 0.0466	p = 0.0002	p = 0.5631	p = 0.6517
			RDdifdom – Rddiffor = 0			
	F(1.135)= 4.55	F(1.134)= 0.53	F(1.134)= 0.82	F(1.133)= 0.52	$\chi^2(1)$ = 8.60	F(1.1435) = 2.95
	p = 0.0347	p = 0.4699	p = 0.3664	p = 0.4723	p = 0.0034	p = 0.0860
# 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 heteroskedasticly consistent.
*** (**, *): significant at 1% (5%, 10%).

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's 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 in 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. However, the difference in additionally invested R&D budgets 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 various 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 seem to 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 chapter 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. A major concern of the Flemish government is that the valorisation of the induced R&D efforts is realized within Flanders. The analysis in this chapter shows that funded MNEs generate innovative output, which is also valorised in Flanders. This excellence in innovative efficiency may be driven by firm-specific assets encased in the MNE and easily accessible for 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 retain foreign multinational activity in Flanders, but the total amount which companies can receive is limited to 8 million EUR per year. In large MNEs, this is only a minor share of their total R&D expenditure and therefore, subsidies may be regarded as mere structural support. Hence, 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 chapter. First, only information on a company's funding status was used. This implies that the hypothesis is limited to assessing 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 specifically 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, international R&D activity is worth a closer look: the degree of independence from 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 in 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	St. Dev.	Min	Max	# obs.	Mean	St. Dev.	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	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	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.

PART II. CORPORATE STRATEGIES IN INNOVATION

Chapter 6. Let's get on the same page! Profit-sharing and innovation

Joint work with Prof. dr. Kornelius Kraft[63]

1. Introduction

Knowledge has become a fundamental economic asset (see e.g. Romer, 1990) and determines companies' competitive strength (Schumpeter, 1942). On the one hand, knowledge creation is a time and money consuming process, with an uncertain outcome (Dasgupta and Maskin, 1987). Optimal staff motivation is to the benefit of expected success. On the other hand, knowledge spreads relatively quickly into the public domain once it has been created, allowing other companies to take advantage of the originating company's investments. Mansfield (1985) showed that a significant share of knowledge leaks out through employees. Therefore, in knowledge creating companies, it is vital to attract valuable employees and curtail the staff turnover and additionally, to motivate this highly qualified workforce. One important aspect is employee remuneration. A vast body of research is devoted to investigating optimal remuneration systems and it appears that monetary as well as non-pecuniary incentives matter (see e.g. Coombs and Gomez-Mejia, 1991), jointly optimized in a stimulating work environment with an attractive remuneration system. In this chapter, we zoom in on one specific remuneration system, namely profit[64] sharing: employees share in the profit of a company, through the receipt of financial rewards, depending on the company's performance. Often, this financial incentive is disbursed as a supplement to the fixed base wage (see Kraft and Ugarković, 2007; Bhargava and Jenkinson, 1995 as well as Wadhwani and Wall, 1990).

The direct aim of companies introducing profit-sharing in their remuneration policy is to stimulate staff performance. As profit maximization becomes a win-win strategy to all parties involved, i.e. both the employees and the firm owners, their

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[64] Also 'capital sharing' exists, a system in which employees hold shares of the company and in this sense, become co-owners of the company. This issue lies beyond the framework of this chapter, though.

mutual interests become aligned. If the incentive system works in an efficient way and if employees behave rationally, they increase their efforts, which should subsequently raise the company's performance. Since a considerable time, profit-sharing has been the subject of many empirical studies (see e.g. Pérotin and Robinson, 2002 as well as Strotmann, 2002, for elaborate surveys of this literature stream). The direct link between profit-sharing and output explains why traditionally productivity has by far been the most often investigated issue in this research domain. Less frequently investigated topics are the effects on profitability and wages. The latter variable is investigated as Weitzman (1983) suggested using profit-sharing as an alternative, instead of a supplement to the going wage rate.

Scholars typically find positive to neutral impacts of profit-sharing on a firm's output. However, productivity measures only show part of the picture, as they merely reflect the final impact, without illuminating possible reasons explaining this productivity increase. An efficient incentive system is expected to affect workers' performance, but may additionally strengthen a company's innovative capabilities, as theoretical arguments predict that potential resistance against innovative activity can be offset and what is even more, employees may actively cultivate the company's innovative capabilities.

In this chapter, we introduce measures of technological progress in an attempt to unravel how the introduction of profit-sharing may interact with firm performance through the realisation of both product and process innovations. This area has remained by and large unexplored until now. We employ an extensive dataset on German firms. In order to eliminate possible selectivity effects, we apply conditional difference-in-differences methods. In the second section, we briefly summarise the history of research on profit-sharing and advance some theoretical considerations. The third section entails the strategy we follow in the empirical part, which is subsequently presented in two sections, covering the data description and the estimation results. The last section concludes with a summary of our findings, some limitations of our research set-up and lines for further research.

2. Literature summary and theoretical arguments

The literature on profit-sharing can be categorized into two substreams. The first substream, which is especially supported by the European Community (see the so-called Pepper reports: Commission of the European Communities, 1991 and 1996, and Lowitzsch, 2006), tries to provide a framework for international comparisons and to quantify the prevalence of profit-sharing in Europe and the US. However, definition problems and internationally different legislation schemes seriously complicate these studies and imply strong limitations with respect to their comparability.

The second substream of literature investigates the potential impact of profit-sharing on various company characteristics. As mentioned before, the traditionally most investigated variable in this domain is productivity. The interested reader is referred to FitzRoy and Kraft (1987) as one of the first studies, Doucouliagos (1995) for a meta-analysis and to Pérotin and Robinson (2002) as well as Strotmann (2002) for elaborate surveys of the extensive literature. Overall, the conclusions tend to confirm small but positive productivity increases as a result of profit-sharing. Other variables which are studied in relationship with the existence of profit-sharing are wages and labour demand (see Pérotin and Robinson, 2002), as well as profitability (Kraft and Ugarković, 2007). An important issue, which is nevertheless often ignored, is the fact that different selection mechanisms may play a part when studying profit-sharing and its impact. This may seriously distort evaluation exercises and undermines the validity of the results. In the methodological section, we will extensively come back to this issue of selectivity.

To the best of our knowledge, no studies exist on the impact of profit-sharing on the innovative performance of companies. However, in the subsequent paragraphs we will advance theoretical arguments and predict a potential positive impact of this specific remuneration system on the company's innovation process.

Although a high-quality workforce is expected to produce highly valuable R&D and innovative output, there are two main motives why employees may hamper innovative activity. First, employees are expected to dislike technological change if its introduction implies re-training, alternative work organizations and adaption costs, in addition to potential dismissals. Training will most likely be firm-specific and thus the risk for the workers increases, which may therefore excite opposition against innovative activities within the company. Schaefer (1998) found that these frictions do not necessarily obstruct innovative activity, but nevertheless may seriously slow down or change the innovation process. Zwick (2002) proves that internal resistance against innovation is more likely if it is uncertain whether the employees benefit from the investment. Our second argument as to why employees may negatively affect a company's technological progress and innovative capabilities works more directly. New technologies may enable companies to substitute labour by capital. This in turn may lower the demand for labour and therefore reduce employment and/or wages. As a result, employees may exhibit a substantial scepticism or even negative attitude towards technological progress. In that case, any attempt to modernize the company's technological equipment or to conduct process innovations will be distrusted or even opposed.

Profit-sharing can provide an effective remedy to counter or even upturn these frictions and the potential negative pressure of human capital on R&D. First, the premium offered through profit-sharing can be regarded as a compensation for the training and subsequent risk. Therefore, profit-sharing may moderate employee opposition against technological advancement. Second, profit-sharing may even stimulate the employees' incentives to actively support and contribute to process innovations. As profit-sharing entails an explicit commitment on behalf of the company owners to share part of the profits with the employees, their mutual interests are aligned towards one denominator: profit maximization. Process innovations are expected to increase a company's future profits, so technological progress is to the benefit of both parties. Employees are closely involved in the company's bench level expertise and may therefore possess an information advantage on potential weaknesses and inefficiencies of the technologies in use. Without profit-sharing there is hardly any incentive to disclose this information to the management. However, when employees participate in any profit increase, it is in their self-interest to fully exploit all available information. Hence, if the company employs a profit-sharing system, employees will be less averse towards strengthening the company's technological equipment, and, even more important, they may become a valuable asset in the process of technological progress. In this chapter, we therefore advance the hypothesis that profit-sharing fosters process innovation.

Less obvious but possibly also present is an effect of profit-sharing on product innovation. During the production process, employees go through a learning curve: they accumulate knowledge, gain experience and subsequently may come up with ideas to improve a product's quality. If a monetary incentive is coupled to the implementation of any useful suggestion on a product improvement, the likelihood that the employee discloses his ideas obviously increases. Similarly, employees may become aware of potentially interesting additional features of the produced goods. Hence, while it seems unlikely that employees can contribute significantly to the development of totally new products, they may possess a substantial potential to improve existing products to a significant extent. Moreover, some employees closely interact with the company's customers and as a result are well aware of their preferences. They gather information on potential shortcomings of the existing product range as well as the customers' needs and wishes concerning improvements of existing as well as desired features of future products. This valuable knowledge should be transferred to the company's R&D department, in order to develop products along these lines. If the company succeeds in complying with these requirements, its market success is expected to rise and consequently also its sales of improved or newly developed products. Profit-sharing generates clear incentives to share this information with the management as, in contrast to the traditional wage-based firm, its capitalization is shared with the source of information: the employee. In summary, our theoretical arguments predict that introducing profit-sharing has the potential to stimulate both process and product innovation.

3. Empirical Strategy: the treatment of selectivity

Although many empirical studies confirm the hypothesis that profit-sharing has a neutral to significantly positive effect on the company's performance, only a surprisingly small minority of firms actually employs this remuneration scheme. The percentage of firms with a profit-sharing system is quite low in the European Union, except in France and the United Kingdom, where financial participation in companies is supported by a legal framework and substantial tax advantages (see

Poutsma, 2001, for an extensive description of country differences in the European Union). This seems to indicate that profit-sharing is not a beneficial strategy to all companies, but only to certain firms. Strotmann (2002) denounces the fact that, even after the clear conclusion of FitzRoy and Kraft (1995) that different selectivity mechanisms may play a role in the evaluation of profit-sharing, many studies do not or not sufficiently control for the potential distortion of the results due to these selection biases. This section first clarifies the different arguments supporting expectations about the presence of selectivity. Next, we expound how this problem is solved in our empirical analysis.

A first reason for the rather low ratio of firms employing profit-sharing might originate in firm-specific advantages or disadvantages with respect to different incentive schemes. Companies presumably differ in a number of aspects. For instance, the respective workforces may exhibit different qualification levels. Furthermore, firms may differ in their capability to validate individual performance. Examples are highly structured work processes, e.g. in the extreme belt production, or a team-based production process, where only joint, i.e. not individual, output is observed. In general, smaller firms suffer significantly less from problems in measuring individual employee performance. Other differences may stem from turnover rates, the workforce's cultural and ethical background, industrial relations and many other characteristics. In these circumstances, it is reasonable to believe that firms that are able to capture specific advantages from profit-sharing are likely to introduce this incentive scheme in their remuneration policy, while others show no interest and rather rely on other motivational instruments like tournaments, piece rates or efficiency wages. A second kind of selectivity is driven by worker sorting. Performance oriented and cooperative workers probably prefer working in profit-sharing firms. These workers are presumably more productive, irrespective of the presence of a profit-sharing scheme. Moreover, the strong presence of productive and highly skilled employees may increase the productivity of less productive employees through mutual and cooperative learning efforts. In this case, these employee teams differ from teams in the more traditional firms paying fixed wages. This very likely causes differences in any performance measure, including innovativeness. Furthermore, it is quite realistic to assume that employees behave risk-averse and prefer a fixed wage over a variable, performance-related pay. If, for a moment, we set aside the argument raised before, i.e. that profit-sharing usually complements the fixed wage, instead of replacing it, firms paying a flexible wage presumably attract less risk-averse workers. It is not unreasonable to assume that these employees are also more productive. Finally, selectivity in innovation activities may arise. It is quite plausible that highly innovative companies also use efficient incentive systems, simply because they are managed in a better way. Hence, a positive correlation between innovative activity and the use of profit-sharing in the remuneration policy may be due to an unobserved third factor, while actually no causal relation exists.

If selectivity is at work, any empirical methodology neglecting this problem will produce biased results. Using the Heckman estimator, the early study of FitzRoy and Kraft (1995) confirms the strong presence of selectivity effects. Profit-sharing is proved to be endogenous with respect to any outcome measure. Another sophisticated method to deal with selectivity is the non-parametric matching approach, well known in the so-called treatment analysis. Treatment in our case is defined as the use of profit-sharing. This methodology goes back to Roy (1951) and Rubin (1974) and has also been labelled the potential outcome approach. A matching approach re-establishes the conditions of an experiment and compares treated and non-treated observations. The control sample of non-treated companies is selected carefully, to maximize its similarity with the population of treated companies. Every single treated company is related to non-treated units: conditioning on their similarity, a non-treated firm receives a high or low weight, or even is omitted. The determination of the control observation's importance (weight) depends on the selected matching estimator (see Heckman et al., 1997).

Rubin (1974) defines the impact of the treatment as the difference between the likely outcome Y of an establishment[65] introducing profit-sharing, Y^1, and the counterfactual outcome in the case of non-introduction, Y^0, given D=1:

$$\theta = E(Y^1 - Y^0 \mid D = 1) = E(Y^1 \mid D = 1) - E(Y^0 \mid D = 1) \quad (38)$$

where D is a binary assignment indicator determining whether the firm has introduced profit-sharing (D=1) or not (D=0). Parameter θ measures the average

[65] For the sake of readability we omit firm indices in the equations.

treatment effect on the treated firms and determines whether the introduction of profit-sharing has been beneficial to those establishments that introduced this incentive scheme in their remuneration policy.

The fundamental problem in evaluation econometrics arises from the fact that the second term on the right hand side, i.e. the counterfactual outcome $E(Y^0|D=1)$, is by definition not observable, since it describes the hypothetical outcome of a firm that actually introduced profit-sharing if it would not have done so. In the absence of selectivity, the following equality:

$$E(Y^0 \middle| D = 1) = E(Y^0 \middle| D = 0) \tag{39}$$

would hold and the average outcome of firms without profit-sharing would provide an estimate for $E(Y^0|D = 1)$. This assumption is valid in an experiment where randomisation of the treatment is given. However, as FitzRoy and Kraft (1995) have shown and as we argued before, it is quite unlikely that profit-sharing and non-profit-sharing firms do not differ with respect to certain characteristics: profit-sharing is endogenous, which introduces a bias in the estimates. The key to solve this evaluation problem is to approximate the counterfactual outcome. We chose to follow the potential outcome (i.e. matching) approach with a time dimension, the so-called conditional difference-in-differences technique. In the following paragraphs we explain the details of this methodology.

Rubin's (1977) conditional independence assumption (CIA) states that the treatment status and the potential outcome are independent for observations exhibiting the same observable set of characteristics X. The validity of the CIA depends on whether all determinants influencing the decision to introduce profit-sharing as well as the potential outcome are known and available for all observations. However, the CIA cannot be tested formally and as a result, the researcher is obliged to rely on the data quality. We believe that the IAB Establishment Panel, which will be described in more detail below, covers a wide array of information, ranging from general information on the establishments to questions on investment, business policy and development to employment-related questions, and therefore serves as a good basis to fulfil this requirement.

Hence, if sample selection is solely due to observable covariates (a vector X), the CIA applies and the following equation holds:

$$E(Y^0 \mid D = 1, X = x) = E(Y^0 \mid D = 0, X = x) \ . \qquad (40)$$

The treatment effect θ in the matching approach can consequently be estimated by comparing the outcome means of the two groups (Lechner, 1998):

$$\theta_M = E(Y^1 \big| D = 1, X = x) - E(Y^0 \big| D = 0, X = x) \, . \qquad (41)$$

In practice, ensuring the validity of the CIA imposes a major obstacle, since every additional exogenous variable in the vector X decreases the probability of finding an adequate control group. Rosenbaum and Rubin (1983) proposed a remedy to this dimensionality problem. As an alternative to matching on a large set of covariates, their idea is to match on one single index. This so-called propensity score is estimated with information on the exogenous characteristics X. Rosenbaum and Rubin (1983) show that, if the CIA is fulfilled, one does not need to condition on all covariates contained in X, but only on the propensity score. In our case, this index is estimated as the conditional probability to use profit-sharing, i.e. the probability to share profits with the employees, given a set of individual characteristics of a firm: pr(D=1|X=x). This propensity score is usually estimated in a probit model.

Several matching methods have been proposed in the literature on evaluation econometrics. We employ nearest neighbour matching, which comes down to a pair wise matching as it tries to select the most similar non-treated observation (ideally a "twin") for every treated observation. If the matching procedure was successful, i.e. the establishments that did (treated group) and did not (selected control group) introduce profit-sharing are ex ante equally likely to introduce profit-sharing, equation (40) holds and the causal effect is computed as indicated in equation (41), by comparing the outcome means of the two groups.

The matching approach accounts for the selection bias caused by observable factors. However, as we mentioned before, compliance with the CIA is crucial to obtain reliable estimates: all relevant information should be known and available for all observations. Although we strongly believe that our data at hand are very rich, nonetheless, unobservable factors may be at work and affect the outcome variable.

This could seriously bias the results. To correct for this potential selection on unobservables more strongly, the initial matching method can be extended with a time dimension.

This is exactly what we will do in the empirical part of this chapter, as we have a rich two-period panel dataset at our disposal. We present two evaluation methods, assessing the evolution of the outcome Y after treatment. Matching and difference-in-differences techniques are combined in this method, which is referred to as the conditional difference-in-differences (CDiD) or matched difference-in-differences approach (Heckman et al., 1997).

The general difference-in-differences (DiD) set-up relates the development of an outcome variable of treated observations to the evolution of this outcome variable in a control group of non-treated observations. The before-after change in the outcome of non-treated firms is subtracted from the before-after change in the outcome of the treated firms to obtain the average treatment effect θ:

$$\theta_{DiD} = E(Y_{t_1}^1 \big| D = 1 - Y_{t_0}^1 \big| D = 1) - E(Y_{t_1}^0 \big| D = 0 - Y_{t_0}^0 \big| D = 0)\,, \tag{42}$$

where D denotes whether the unit under consideration is treated (D=1) or not (D=0), Y is the outcome variable and t represents the moments in time before (t_0) and after (t_1) the introduction of the measure. The DiD estimator thus measures the excess outcome growth of the treated as compared to the non-treated group, correcting for any macro-economic change over time. If this method is generalized to include additional regressors X, the advantages of the matching and the DiD approach are combined (Blundell and Costa Dias, 2000). This conditional difference-in-differences (CDiD) approach eliminates time-invariant unobserved individual-specific effects as well as common macro trends. Several studies evaluating active labour market policies make use of this estimator (e.g. Kluve et al., 1999; Eichler and Lechner, 2002; Bergemann et al., 2004; Albrecht et al., 2005). The treatment and control group are matched on observable characteristics X such that:

$$\begin{aligned}\left(Y_{t_1}^1 \middle| D = 0, X = x\right) - \left(Y_{t_0}^1 \middle| D = 0, X = x\right) = \\ \left(Y_{t_1}^0 \middle| D = 0, X = x\right) - \left(Y_{t_0}^0 \middle| D = 0, X = x\right).\end{aligned} \tag{43}$$

To increase the accurateness and quality of the matching process, two additional activities were carried out. First, for all treated firms a valid counterpart should be found in the non-treated population and every firm should represent a potential profit-sharing company. 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. Hence, the so-called common support restriction is imposed and all firms exhibiting extreme values and therefore complicating the matching process are removed. Second, optimal matching is obtained when the control sample to select twin companies from, is as large as possible. Therefore, one can opt for matching with replacement. In the current work, we employ the conditional difference-in-differences approach with nearest neighbour propensity score matching and match with replacement. The average treatment effect θ is calculated as follows:

$$\theta_{CDiD} = \left(E(Y_{t_1}^1 \middle| D=1, X=x) - E(Y_{t_0}^1 \middle| D=1, X=x) \right) - \left(E(Y_{t_1}^0 \middle| D=0, X=x) - E(Y_{t_0}^0 \middle| D=0, X=x) \right). \tag{44}$$

We employ two variations of the CDiD method. In the first approach, we match firms which introduced profit-sharing between period t_0 and t_1 to firms which have never shared profits, using their respective vectors of exogenous characteristics X in period t_0. Then, we evaluate how the outcome Y of both groups (treated versus non-treated subjects) has evolved over time, comparing static (assessing Y in period t_1) and dynamic (comparing Y in the periods t_0 and t_1) variables for the treated and non-treated firms in t-tests on mean equality. We will refer to this technique as CDiD without control variables.

In our second variation on the CDiD technique, we control for unobserved heterogeneity in a more explicit way and additionally include the evolution in the control variables. The results of the CDiD analysis are presented as OLS and probit models; like in a normal DiD set-up (see also e.g. Aerts and Schmidt, 2008). As Wooldridge (2002) suggests, when the treatment effect is equal for each subject and constant over time, a fixed effects regression model is more appropriate than the random effects model. However, as Halaby (2004) shows, both models are frequently used in treatment analyses, so both estimators are employed and the Hausman test is conducted to test which model is more appropriate. Following

Albrecht et al. (2005) we also point out that a disadvantage of employing probit models in this context is that "*they do not enable the estimation of the quantitative effect of treatment on the employment outcomes. This effect is non-linear and depends on the unknown fixed effects. This means that we can only make a qualitative evaluation, in the sense that we can only determine the sign and significance of the treatment effect.*"

4. The data

This section describes the data which will be used to empirically investigate the interaction between profit-sharing and innovative performance in Germany. Bellman and Möller (2006) quantify profit-sharing in Germany: in 2005 about 9% of the total population of German firms employed this incentive system in addition to the normal wages. The percentage of companies sharing profits with employees heavily fluctuates according to size and industry affiliation, though. This percentage puts Germany on a mediocre rank, after France (57%), the UK (40%) and Sweden (20%). Van Den Bulcke (1999) identifies factors yielding a less favourable environment with respect to financial participation (which is more general than mere profit-sharing) of German employees: the German tax situation and social security, the complex legislation and the lack of a share ownership culture and tradition.

We constructed our database using various waves of the so-called IAB panel. Since 1993 (1996 for East Germany) the Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung: IAB) yearly surveys a panel of about 16,000 German companies. Based on size and industry affiliation, the sample of surveyed companies is randomly drawn from the employment statistics register of the German Federal Employment Agency (Bundesagentur für Arbeit). Because companies drop out due to non-response or market exit and new companies are continuously established, new companies are added to the sample every year, which results in an unbalanced panel structure. The survey gathers general company information on its establishment, turnover, staffing, investments, etc. but also leaves room for very specific questions, e.g. on public funding, innovation, technical equipment, etc. which are covered on an irregular basis, though.

Our key issue of interest is whether or not companies allow their employees to share in the profit. This information is reflected by the dummy variable PROF. In 2000, about 10% of the companies in the total IAB-sample used profit-sharing in addition to a fixed wage to remunerate their employees. In 2005 about 16% of the companies in the sample employed a system of profit-sharing[66]. Based on the theoretical arguments presented above, we advance the hypothesis that profit-sharing exerts a positive impact on the innovative capabilities of a company. To test our hypotheses, we select all companies from the IAB-sample which introduced profit-sharing between 2000 and 2005 and compare them to a control group of companies which indicated that they did not employ profit-sharing in their remuneration system, neither in 2000 nor in 2005. We eliminate all the differences in exogenous variables to counter the selectivity issue, employing the matching method. The selected sample of twin companies is then further analysed in a conditional difference-in-differences framework. This will enable us to evaluate the impact of the introduction of a profit-sharing system on a company's innovativeness.

The outcome to be evaluated is twofold: we test whether profit-sharing fosters process and/or product innovation. In the first CDiD variation we proceed as follows. First, we evaluate the company's innovative strength with respect to technological capabilities. TECH measures the condition of a company's technical equipment on a five-point Likert scale, going from fully up-to-date (score = 4) to fully outdated (score = 0). As the IAB-survey does not provide any explicit information on the process innovation capabilities of a company, we believe that this variable is a good proxy. ADVNAR (ADV = advanced; NAR = narrow) and ADV indicate whether the company's technical equipment is fully up-to-date (TECH = 4 and TECH = 4 or 3, respectively). As TECH is measured in the 2005 and 2000 waves of the IAB-panel, we use dynamic variables, reflecting the evolution of the condition of the technical equipment. The first dynamic variable is TECHch, measuring the difference in the condition of the technological equipment between 2005 and 2000 (= TECH05 - TECH00). However, we deliberate about the trade off between the econometric inaccurateness of using the difference in an index

[66] Pendleton et al. (2005) report a percentage of 18% for Germany. However, their study differs in many respects from the data available in the IAB-panel, e.g. in sampling, unit of observation, definition of the incentive schemes, etc. Therefore, the numbers are not comparable. Bellman and Möller (2006) extrapolate data on profit-sharing from the IAB-panel to estimate the share of companies with profit-sharing in the total population of German companies, which is then estimated at about 9%.

value on the one hand and the full use of the available information on the other hand. That is why we additionally include dummy variables reflecting the evolution of the company's technological equipment. We compute a variable indicating whether the company improved its technological strength and became a highly advanced technology user (ADVNARch = 1 if TECH00 ≤ 3 and TECH05 = 4). We expect all process innovation measures to be affected in a significantly positive way by the introduction of a profit-sharing system.

Second, product innovation is evaluated. This information was taken from the 2004 wave of the IAB panel, as product innovation was not covered in the 2005 wave. We assume that the innovative capability of 2004 is a good approximation for the innovativeness in 2005. INPDT indicates whether the company improved or further developed a product which was already comprised in the company's portfolio, within the two preceding years. NEWFRM measures whether the company adopted a product which was new to the firm, within the two preceding years. NEWFRMint measures the share of these new-to-the-firm products in the turnover. NEWMKT measures whether the company adopted a product which was new to the market, within the two preceding years. Parallel to the measures of new-to-the-firm products, NEWMKTint measures the share of new-to-the-market products in the turnover. INNO equals 1 when at least one of the variables INPDT, NEWFRM or NEWMKT is 1 and hence labels companies as innovative or non-innovative in a very broad sense. INNONAR is computed similarly, but narrows down the definition of innovativeness, as only NEWFRM and NEWMKT are included. As information on product innovations was also covered in the 2001 wave, we can again include dynamic product innovation variables, computed as the difference between 2004 and 2001: INPDTch (INPDT04-INPDT01), NEWFRMch (NEWFRM04-NEWFRM01), NEWMKTch (NEWMKT04-NEWMKT01), INNOch (INNO04-INNO01) and INNONARch (INNONAR04-INNONAR01). To recapitulate our evaluation set-up in this first CDiD variation, the static variables measure the outcome in period t_1, while the dynamic variables measure the evolution of the outcome between the periods t_0 and t_1. As argued in section 2, we expect to find indications that profit-sharing affects a company's product innovation capabilities, in addition to the effect on the technical equipment. The impact on improvements or the introduction of new-to-the-firm products is expected to be stronger than the impact on the development of totally new (new-to-the-market) products.

We use several control variables which may affect both the probability to employ a profit-sharing remuneration system in addition to a fixed wage and innovative capability of a company, respectively. To avoid endogeneity we measure the value of these covariates in 2000. Including the number of employees (EMP) allows controlling for size effects, which are empirically often found to explain innovativeness (see e.g. Veugelers and Cassiman, 1999). Moreover, size may be related to the company's choice for a specific incentive scheme. For example, as smaller firms may be better aware of employees' individual performance, they may opt for other financial rewards than a profit-sharing scheme. The logarithmic transformation (lnEMP) is used to smooth this variable. In addition, we removed the 1 and 99 percentile of EMP, to control for extreme size outliers in the dataset. Next, we introduce a number of control variables related to the organizational structure of the firm: the ratio of qualified employees (QUAL) and dummies indicating a shift in responsibilities (SHIFT), the introduction of team work (TEAM) and independent work groups (INDEP) as well as positive investments in ICT infrastructure (ICT) reflect how a company responds to requirements of its environment. Complex and interdependent workflows imply more difficulties in measuring individual output. Moreover, information asymmetries and monitoring problems may be more pronounced. Also a range of variables characterizing how the company interacts with its direct stakeholders is important. First, a high level of trust between employees and managers facilitates consultation and fine-tunes cooperation engagements. The presence of a works council (COUNCIL) is a good proxy for this relationship. Second, the relationship between the company and the unions may be important. As we will explain in the following paragraph, Germany is a special case and the works council tends to substitute for the strength of the union, so the variable COUNCIL also reflects the union's power to some extent. In addition, we include a dummy variable (CAO) indicating whether a collective labour agreement is in place. Limited liability may foster the introduction of profit-sharing; LTD has value 1 for joint stock companies (AG) and non-public limited liability companies (GmbH). Last, some final company characteristics are added. After1990 is a dummy indicating whether the company was established after 1990, as profit-sharing and age may interact. Also, firms located in East Germany (EAST = 1) may be less likely to introduce profit-sharing (Möller, 2002 as well as Bellman and Möller, 2006). Finally, industry affiliation may matter. We limit our sample to manufacturing firms, excluding agriculture, mining and construction and include 15 industry dummies (BR) in the analysis.

Our total sample consists of 1348 companies, of which 206 firms are treated (profit-sharing). The first empirical step is the selection of a non-profit-sharing twin company for each profit-sharing firm. To this end, a propensity score is estimated in a probit model, using the whole dataset and the control variables introduced above. The summary statistics of these variables (in period t_0) as well as the outcome variables (in period t_1 or the change (ch) between the two periods t_0 and t_1) are presented in Table 35. We also report the p-value statistics of two-sided t-tests, indicating the differences between the profit-sharing firms and the potential control group of all non-profit-sharing firms. In the database we constructed, companies introducing profit-sharing are typically the larger firms (lnEMP***). The work environment seems to be more complex in profit-sharing firms: the share of qualified employees (QUAL***) is higher and the firms are more likely to have introduced a shift in responsibilities (SHIFT***), team work organisation (TEAM***) or independent work groups (INDEP***). Moreover, the introduction of profit-sharing is positively correlated with investments in the ICT infrastructure (ICT***). Furthermore, profit-sharing firms tend to have a higher level of trust between employees and managers, as they are more likely to have a works council (COUNCIL***). Also the union is more powerful (CAO***) when the system of profit-sharing is employed. The ownership structure (LTD*** and EAST***) as well as industry affiliation (not reported here) are relevant, too. The age of the company does not seem to matter.

Table 35: Summary statistics before the matching

Variable	period	Profit-sharing firms Mean	Profit-sharing firms Std. Err.	Potential control group Mean	Potential control group Std. Err.	p-value two-sided t-test
OUTCOME VARIABLES						
Process innovation						
TECH	t_1	2.8398	0.0528	2.6445	0.0227	0.0008
ADVNAR	t_1	0.1845	0.0271	0.1200	0.0096	0.0257
ADV	t_1	0.6893	0.0323	0.5814	0.0146	0.0026
TECHch	$t_1 - t_0$	0.0390	0.0488	0.1060	0.0207	0.2081
ADVNARch	$t_1 - t_0$	0.1122	0.0221	0.0630	0.0072	0.0354
Product innovation						
INPDT	t_1	0.7805	0.0290	0.4416	0.0147	0.0000
NEWFRM	t_1	0.3140	0.0323	0.2051	0.0120	0.0018
NEWFRMint	t_1	2.6439	0.4835	1.7008	0.1524	0.0640
NEWMKT	t_1	0.1546	0.0252	0.0867	0.0083	0.0111
NEWMKTint	t_1	1.1520	0.4682	0.7489	0.1457	0.4119
INNO	t_1	0.7971	0.0280	0.4939	0.0148	0.0000
INNONAR	t_1	0.3865	0.0339	0.2546	0.0129	0.0003
INPDTch	$t_1 - t_0$	0.0000	0.0318	-0.0388	0.0156	0.2743
NEWFRMch	$t_1 - t_0$	-0.0531	0.0412	-0.0616	0.0153	0.8481
NEWMKTch	$t_1 - t_0$	-0.0386	0.0355	-0.0229	0.0119	0.6728
INNOch	$t_1 - t_0$	0.0000	0.0306	-0.0446	0.0155	0.1947
INNONARch	$t_1 - t_0$	-0.0483	0.0410	-0.0719	0.0158	0.5920
CONTROL VARIABLES						
lnEMP	t_0	4.7344	0.1109	3.2784	0.0482	0.0000
QUAL	t_0	0.3149	0.0176	0.1936	0.0065	0.0000
SHIFT	t_0	0.2754	0.0311	0.1598	0.0108	0.0005
TEAM	t_0	0.2367	0.0296	0.1039	0.0090	0.0000
INDEP	t_0	0.1353	0.0238	0.0550	0.0067	0.0014
ICT	t_0	0.8213	0.0267	0.5677	0.0146	0.0000
COUNCIL	t_0	0.7053	0.0318	0.3031	0.0136	0.0000
CAO	t_0	0.6329	0.0336	0.4655	0.0147	0.0000
LTD	t_0	0.8309	0.0261	0.5991	0.0145	0.0000
AFTER1990		0.3865	0.0339	0.4227	0.0146	0.3274
EAST		0.5990	0.0341	0.4297	0.0146	0.0000
Number of obs.:		206		1142		

Note: the details of BR are not presented here.

A large body of literature addresses the correlation between a strong union presence on the one hand and R&D and innovative activity on the other hand. This is highly relevant in the current chapter, as the presence of a strong union may be correlated with our treatment as well as outcome variables. Menezes-Filho and Van Reenen (2003) survey the literature in this domain and conclude that North American studies consistently reveal a strongly negative correlation, while European studies cannot substantiate any significant impact of the union on R&D and innovation. The studies investigating this issue in Germany are Addison and Wagner (1994), Schnabel and Wagner (1992a and b, 1994) as well as Fitzroy and Kraft (1990). Schnabel and Wagner (1992b) ascribe the neutral relationship to the more cooperative nature of industrial relations in Germany.

The relevant labour institutions on the plant and firm level are the unions and also the works councils (see the Works Constitution Act[67]). Addison et al. (1996)

[67] This Works Constitution Act (Betriebsverfassungsgesetz) was issued in 1972.

point out that the German situation is highly specific, because the workplace representation occurs rather through the mechanism of the works council than through the union. As the ties between the union and the works council are very close, they suggest that the works council substitutes for the union institution in the German case. So, we feel confident here to assume that the presence of a works council and the union's bargaining power (variables COUNCIL and CAO) have no impact on the innovative activity in German firms. Adversely, these variables are expected to have an impact on the propensity to introduce profit-sharing, i.e. our treatment variable.

After the matching, the evolution in the outcome variables (both static and dynamic) is evaluated for the subsample of matched pairs. This approach eliminates a considerable share of observed as well as unobserved heterogeneity in the treated and non-treated firms in the population and mitigates the potential selectivity bias. The first CDiD variation conducts two-sided t-tests to compare the means of the two groups after the matching. In the second CDiD approach, we also start off with the results obtained from the matching analysis, but then regress the outcome variables in a common DiD set-up on the treatment and exogenous variables. In this way, we also control for the change over time in the control variables. The variables which will be used to assess companies' innovative capabilities in the second CDiD variation are similar to the variables described above. Process innovation will be assessed with the variables TECH, ADVNAR and ADV. Product innovation will be evaluated on the variables INPDT, NEWFRM and NEWMKT. So, the difference in innovative capabilities is regressed on the treatment variable (PROF = introduction of profit-sharing between t_0 and t_1), the evolution of the exogenous characteristics (lnEMP, QUAL, SHIFT, TEAM, INDEP, ICT, COUNCIL, CAO and LTD) as well as dummy variable YEAR, indicating the year of the observation. By definition, this dataset consists of a balanced panel, with information on 404 companies (resulting in 808 observations, as two periods of data are available).

5. Estimates

The potential presence of selectivity in this evaluation exercise was introduced in the methodological section. Because of this potential endogeneity, a simple comparison of the outcome variables between companies with and without profit-sharing (as presented in Table 35) does not provide an adequate answer in this evaluation research; the introduction of profit-sharing may be induced by innovativeness. We observe significant differences in the innovative strength between profit-sharing companies and the potential control group. However, the control variables differ significantly as well and these differences may also explain differences in innovativeness. We address this potential selection bias empirically starting from nearest neighbour propensity score matching with replacement. Then we take two variations on the CDiD approach to assess the evolution of the outcome variables over time. This technique ensures that both observable and unobservable differences between treated and non-treated companies are taken into account, as well as any macro-economic change over time. We believe that the data at hand is sufficiently rich and that the matching procedure significantly curtails the selection bias. As a result, any potentially remaining difference in the outcome variables can be attributed to the introduction of profit-sharing.

To select a non-profit-sharing twin company for each profit-sharing company, we first estimate the propensity score, which reflects the probability that a company remunerates its employees with a system of profit-sharing in addition to a fixed wage. This model is presented in Table 36. In the probit model, size (lnEMP**), the share of qualified employees (QUAL***) and the presence of a works council (COUNCIL***) are significant. Also industry affiliation (BR**) matters. These estimates confirm expectations formulated in the section on selectivity. Smaller companies rather opt for other incentive schemes than profit-sharing. Companies employing large shares of qualified people are more likely to adopt profit-sharing. The presence of a works council, reflecting a high level of trust between company owners and employees as well as the bargaining power of the union, also create a favourable setting for a profit-sharing incentive scheme.

Table 36: Propensity to employ profit-sharing

	Probit estimates			Marginal effects		
	Coef.		Std. Err.	dy/dx		Std. Err.
lnEMP	0.1059	**	0.0461	0.0196	**	0.0085
QUAL	0.6677	***	0.1999	0.1235	***	0.0369
SHIFT°	0.0403		0.1195	0.0076		0.0228
TEAM°	0.0721		0.1321	0.0138		0.0261
INDEP°	0.1656		0.1647	0.0334		0.0361
ICT°	0.1545		0.117	0.0280		0.0207
COUNCIL°	0.5412	***	0.1413	0.1098	***	0.0312
CAO°	-0.0917		0.1134	-0.0170		0.0209
LTD°	0.1933		0.1191	0.0346		0.0205
AFTER1990°	0.1762		0.1252	0.0332		0.0239
EAST°	0.1507		0.1266	0.0281		0.0238
constant	-2.4041	***	0.2332			
BR	$\chi^2(14) = 28.39$**					
Log-Likelihood	-475					
Pseudo R²	0.1790					
# obs.	1352					

*** (**, *) indicate a significance level of 1% (5, 10%). The marginal effects on subsidies are calculated at the sample means for continuous variables and for a discrete change of dummy variables (indicated by °) from 0 to 1. Their standard errors are obtained by the delta method.

The probit model provides estimated propensity scores and enables us to select[68] similar companies. After the matching process, any difference in the control variables is eliminated and the remaining differences in outcome variables can be attributed to the introduction of a profit-sharing system. In the first analysis, we evaluate how the outcome has evolved over time in the profit-sharing firms and their selected twin partners, respectively. Table 37 shows the difference in outcome variables, which reflect innovative capabilities. Profit-sharing companies are more likely to have a fully up-to-date technical equipment after the introduction of profit-sharing (TECHch**). Also in the same time period, profit-sharing companies are more innovative than their non-profit-sharing twin companies (TECH**). They are significantly more eager to use advanced technologies (ADV** and ADVNAR**) and companies introducing profit-sharing have become more advanced technology users (ADVNARch**). Our hypothesis on the impact of profit-sharing on a company's technological strength is confirmed.

Also the outcome variables measuring product innovation significantly differ after the matching. We notice that profit-sharing companies are more likely to have improved a product in the company's existing portfolio (INPDT***) or introduced a new-to-the-firm product (NEWFRM***). Also, profit-sharing enables companies to realize a higher share of their turnover based on new-to-the-firm products

[68] The selection process is based on a minimization of the Mahalanobis distance between companies. We match with replacement, to optimize the matching quality.

(NEWFRMint***). The general measures on product innovativeness show that they are more innovative in comparison with companies that did not introduce profit-sharing (INNO** and INNONAR**). However, as expected as well, this increased performance in product innovation is limited to the improvement of existing products and the introduction of products which are new to the company, but not to the market (NEWMKT and NEWMKTint do not differ significantly between the two matched samples). As profit-sharing increases employee involvement in the innovation process, they are more likely to disclose relevant and valuable information. This information is important, but the knowledge captured in the company's human resources, is relatively 'straightforward'. The information does not contribute to the development of radical innovations, or, as measured here, innovations which are new to the market. Another expectation was that the impact of profit-sharing is larger with respect to process than product innovation. The dynamic variables reflecting the change in companies' product innovation capabilities are not significantly different after the matching (INPDTch, NEWFRMch, NEWMKTch, INNOch and INNONARch). This result seems to indicate that the companies which introduced profit-sharing already were more innovative before the introduction. Hence, companies which have higher product innovative capabilities are more likely to employ better remuneration systems. We will return to this issue when we discuss the results of our second approach.

Table 37: Outcome variables matched samples

	Profit-sharing firms		Selected control group		θ	
	Mean	Std. Err.	Mean	Std. Err.		
Process innovation						
TECH	2.8439	0.0529	2.6634	0.0503	0.1805	**
ADVNAR	0.1854	0.0272	0.1073	0.0217	0.0781	**
ADV	0.5854	0.0345	0.6927	0.0323	0.1073	**
TECHch	-0.0390	0.0488	-0.1902	0.0512	0.1512	**
ADVNARch	0.1122	0.0221	0.0537	0.0158	0.0585	**
Product innovation						
INPDT	0.7833	0.0290	0.6517	0.0337	0.1315	***
NEWFRM	0.3122	0.0324	0.1832	0.0273	0.1290	***
NEWFRMint	2.6650	0.4880	1.2165	0.2661	1.4485	***
NEWMKT	0.1512	0.0251	0.1188	0.0228	0.0324	
NEWMKTint	1.1485	0.4727	1.3366	0.5467	0.1881	
INNO	0.8000	0.0280	0.7129	0.0319	0.0871	**
INNONAR	0.3854	0.0341	0.2772	0.0316	0.1081	**
INPDTch	0.0322	0.4571	0.0371	0.5177	0.0491	
NEWFRMch	-0.0537	0.0416	-0.0896	0.0406	-0.0359	
NEWMKTch	-0.0439	0.0355	-0.0297	0.0336	0.0142	
INNOch	0.0000	0.0309	0.0347	0.0347	0.0347	
INNONARch	-0.0488	0.0414	-0.0792	0.0429	-0.0304	
# obs.	205		205			

Note: the control variables (lnEMP, QUAL, SHIFT, TEAM, INDEP, ICT, COUNCIL, CAO, LTD, AFTER1990, EAST and BR) as well as the propensity score are not significantly different after the matching and therefore not reported here. The common support restriction was imposed, but no treated firms had to be removed; some observations were lost because of missing values, though. *** (**,*) 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. θ is the average treatment effect of profit-sharing.

To complete the first CDiD variation, we now conduct a second variation: in the matched panel, constructed with the matching procedure, we regress the outcome variables on our treatment variable (PROF), a year dummy (YEAR) and the exogenous time-varying characteristics (lnEMP, QUAL, SHIFT, TEAM, INDEP, ICT, COUNCIL, CAO, LTD). In this set-up, both observed and unobserved differences in exogenous characteristics are explicitly controlled for, as well as different reactions to macro-economic changes over time from firms which do and do not share profits with their employees. The reader is reminded here that the probit models only allow a qualitative evaluation, as only the sign and significance of the treatment effect can be determined. The results are presented in Table 38. Compared to the first approach, the conclusions are less strong, but by and large still hold. The panel regression on the variable TECH is significant in the random effects model, but not in the fixed effects model, which is most appropriate in treatment analysis according to Wooldridge (2002) and the Hausman test. The sign of the coefficient is negative, which is in line with our expectations. The estimates for the dummy variables ADVNAR and ADV are significantly positive and confirm our previous findings. With respect to process innovations, we therefore conclude that profit-sharing firms seem to hold a technologically stronger position than firms without profit-sharing. Turning to the measures for product innovation, a positive effect can be found on the likelihood to introduce new-to-the-firm products (NEWFRM***), which are however not new-to-the-market (NEWMKT). The estimate for INPDT is not significant (the p-value of the estimated coefficient is 0.120). The first CDiD variation (see Table 37) did not provide evidence to support our hypothesis that companies improve their product innovative capabilities after the introduction of profit-sharing; it seemed that mainly the better performing companies introduce profit-sharing, explaining the insignificance of changes in product innovativeness over time. However, our estimate for NEWFRM*** now suggests that profit-sharing firms outperform non-profit-sharing firms, but that profit-sharing firms also enhance their performance with respect to product innovation once they introduce this remuneration scheme. To conclude, our analyses provide substantial support in favour of the hypotheses we built based on theoretical arguments. We conclude that profit-sharing enhances companies' innovative capabilities, both on the level of product and process innovations.

Table 38: CDiD regressions

	Process innovation				Product innovation		
	TECH[a] FE	TECH[a] RE	ADVNAR[b]	ADV[b]	INPDT[b]	NEWFRM[b]	NEWMKT[b]
PROF	0.1328	0.1583 **	0.3770 **	0.4449 **	0.3060	0.5182 ***	-0.0366
	(0.0860)	(0,0707)	(0.1911)	(0.1844)	(0.1969)	(0.1759)	(0.1765)
YEAR	-0.2457 ***	-0.2239 ***	-2.0709 ***	-0.5066 ***	-0.0177	-0.5325 ***	-0.0965
	(0.0650)	(0.0576)	(0.2127)	(0.1529)	(0.1597)	(0.1551)	(0.1537)
lnEMP	-0.1294	0.0326	0.0795	0.1078	0.2346 ***	-0.0965	0.0018
	(0.1039)	(0.0281)	(0.0608)	(0.0728)	(0.0760)	(0.0612)	(0.0589)
QUAL	0.1389	0.2805 **	0.7190 ***	0.4732	0.1885	0.1952	0.5643 **
	(0.2036)	(0.1161)	(0.2620)	(0.3107)	(0.3046)	(0.2582)	(0.2435)
SHIFT	0.1266	0.0768	0.0994	0.3211 *	0.4052 **	-0.1009	-0.0307
	(0.0891)	(0.0645)	(0.1536)	(0.1737)	(0.1899)	(0.1478)	(0.1438)
TEAM	0.0848	0.0069	0.3155 *	0.1859	0.4647 **	0.1190	-0.1595
	(0.0938)	(0.0674)	(0.1638)	(0.1829)	(0.2024)	(0.1528)	(0.1599)
INDEP	-0.0550	0.0787	-0.0604	0.0150	0.1544	0.5197 ***	0.3991 **
	(0.0936)	(0.0746)	(0.1810)	(0.2013)	(0.2318)	(0.1683)	(0.1629)
ICT	-0.1182	-0.0562	-0.2221	-0.3665 **	0.3770 **	0.2503	0.3599 **
	(0.0832)	(0.0657)	(0.1635)	(0.1797)	(0.1705)	(0.1620)	(0.1735)
COUNCIL	0.0432	-0.1479 *	-0.3853 **	-0.3173	-0.0911	0.0118	0.0670
	(0.1622)	(0.0867)	(0.1959)	(0.2223)	(0.2219)	(0.1894)	(0.1855)
CAO	0.1689	0.1180 *	0.2603 *	0.2453	0.3782 **	-0.1583	0.0887
	(0.1142)	(0.0679)	(0.1546)	(0.1770)	(0.1823)	(0.1513)	(0.1494)
LTD	0.3683 ***	0.1768 **	0.1917	0.1299	-0.0028	0.3667 *	0.1627
	(0.1309)	(0.0869)	(0.1885)	(0.2227)	(0.2271)	(0.1976)	(0.1982)
Constant	3.0670 ***	2.5368 ***	0.0473	0.2104	-0.9863 ***	-0.7769 ***	-1.7741
	(0.5168)	(0.1163)	(0.2534)	(0.2943)	(0.2978)	(0.2549)	(0.2853)
R^2							
within	0.0656	0.0426					
between	0.0014	0.0438					
overall	0.0027	0.0433					
Log-likelihood			-376.419	-452.132	-379.566	-407.860	-301.625
# obs.	808	808	754	754	754	754	754
# companies	404	404	386	386	386	386	386

*** (**, *) indicate a significance level of 1% (5, 10%). The standard errors (between brackets) are heteroskedasticly consistent.

[a] OLS regression with RE: random effects and FE: fixed effects. The Hausman test rejects the Null Hypothesis, i.e. that RE is consistent and efficient, at the 10% level. This is a weak indication that the fixed effects model is more appropriate than the random effects model. Therefore, we include both models.

[b] These probit models were estimated with random effects. The population-averaged models yielded similar results.

6. Conclusion

We empirically investigated the impact of profit-sharing on the innovative capabilities of German manufacturing companies. Since the introduction of a profit-sharing system may be endogenous, we employ two variations of the CDiD approach. Once the potential selection bias is eliminated, companies with and without a profit-sharing system still differ significantly in their innovativeness. Profit-sharing companies outperform non-profit-sharing companies on both process and product innovativeness. The introduction of profit-sharing increases the strength of a company's technological equipment.

In Bellman and Möller (2006) two profiles of companies introducing profit-sharing emerge. On the one hand profit-sharing companies are the larger companies with a complex working environment, introducing profit-sharing to motivate the workforce. On the other hand also small and young, technology-oriented firms introduce profit-sharing as they do not have substantial resources to attract and keep highly qualified employees; the profit premium is treated as a bonus to the regular pay slip. The firms in our sample, introducing profit-sharing, are mainly the larger firms, with a more complex work environment, a high level of trust between employees and managers and a powerful union. The ownership structure as well as industry affiliation is relevant, too. The age of the company does not seem to matter. Therefore, the firms in our sample seem to belong mainly to the first profile. Hence, the impact of profit-sharing on innovativeness may be different in smaller high-tech firms.

The results presented in this chapter establish valid proof supporting the hypotheses developed on the impact of profit-sharing on a company's innovative activity. However, as new survey waves will become available and existing datasets may be extended, robustness checks, e.g. with different specifications of the moment when the economic return becomes apparent, different measures of innovativeness, etc. will provide valuable additional insights into this domain. An interesting point of view was advanced by Lerner and Wulf (2007), who link different incentive schemes to reward R&D managers to patenting activity. Also the size of the profit premium, instead of mere stochastic information on the application of this remuneration scheme, could yield an interesting path for further research, as the impact of profit-sharing may be heterogeneous in size.

Although our results suggest that profit-sharing adds to companies' innovative capacity, the share of German companies actually employing this system is rather limited in comparison with other countries (especially France and the UK). Research on the obstacles hampering German employers to let employees share in the profit indicates an unfavourable taxation system, the complex legislation system as well as a bad fit with the cultural background as key problems (Van Den Bulcke, 1999). Therefore, German policy makers may consider designing a more profit-sharing friendly environment for German companies. Besides the potential positive productivity and employment gains, also the national innovative capacity may benefit from this remuneration system.

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Epilogue

This dissertation attempts to advance the literature on the economics of evaluation on the level of both methodology and content. Public as well as private measures to foster private R&D activity are evaluated in a bundle of essays. The first part (chapters two to five) entails an assessment of public R&D funding of companies; in the second part (chapter six) the impact of a particular private remuneration system, i.e. profit-sharing, is evaluated. In this epilogue, the main results are briefly summarized and their contributions to the existing literature are highlighted. To finish, some limitations are mentioned, which at the same time give rise to new and promising research questions. We also devote attention to some policy implications.

Public innovation policy

Public R&D funding in Flanders is subjected to an evaluation exercise in the first part of this dissertation. We thoroughly investigate its impact on private R&D activity in Flanders. Different indicators are evaluated using different techniques and careful attention is paid to heterogeneity in the population of funded firms, potentially inducing heterogeneity in additionality effects. Extensive data sources are exploited to this end. Key information on the funding status and on companies' R&D and innovative activity was obtained from the biannual R&D and CIS (Community Innovation Survey) surveys. These surveys are embedded in a large harmonization effort in European and some other countries, managed by Eurostat and the OECD. The Steunpunt O&O Indicatoren (formerly the Steunpunt O&O Statistieken) holds responsibility for the data collection in Flanders. The CIS collects mainly qualitative information on the innovative effort and performance in a sample of firms which is randomly drawn, according to size and sector, from the total population of Flemish firms with more than ten employees. The R&D survey gathers more quantitative data on the inputs of companies' R&D process. In contrast to the CIS, the set-up of the R&D survey is inventory-based: all potentially R&D active companies are identified and surveyed. In terms of R&D expenditure, the collected data cover a sample of companies which are, in total, responsible for about 80% of the total R&D expenditure in Flanders. Hence, the R&D sample is close to the population of all R&D active companies in Flanders. These surveys are the starting point of the empirical analyses presented in this work. To optimize the quality of our results, the survey data were supplemented with data stemming from other sources. First, information on the amount of funding and on companies' subsidy history was obtained from IWT (the Institute for the Promotion of Innovation through Science and Technology in Flanders and the main funding agency for private R&D activities). Next, in collaboration with the Steunpunt O&O Indicatoren, information on patent applications at the European Patent Office (EPO) was linked to our dataset. Last, financial data from companies' balance sheets, collected by the National Bank of Belgium (Belfirst) were added. The combination of several rich data sources added a substantial surplus value to the empirical results. Similar data are available in Germany. Different methodologies, assessing both discrete and continuous treatment, could be employed and different additionality issues were investigated. A concise summary is given in the following paragraphs.

Chapter 1 introduces the reader in the domain of treatment effects research and more specifically the issue of selectivity. **Chapter 2** provides an introduction on additionality research and sketches a concise image of the Flemish public R&D funding system.

Chapter 3 rejects full crowding-out effects in Flanders and Germany: R&D subsidies induce additional private R&D investment, measured in absolute terms and in R&D intensity. We use pooled cross-sectional data from the Community Innovation Survey, supplemented with patent and balance sheet data as well as the company's subsidy history. The traditional matching approach is extended in a conditional difference-in-differences framework for repeated cross-sections, to control for observed and unobserved heterogeneity. It is concluded that public subsidies induce increased private R&D spending.

However, increased R&D budgets may still hide crowding-out effects, as the actual R&D effort may not be increased, e.g. because the subsidy and induced R&D investments are allocated to mere wage increases. Hence, in **Chapter 4**, I introduce labour market dynamics into the traditional additionality research and analyze the effect of public R&D subsidies on private R&D investment, employment and wages in Flanders. The main data source is the Flemish R&D Survey. Financial data were added, as well as information on companies' patenting behaviour and subsidy history. Parametric treatment effects models and IV regression methods show that R&D subsidies increase private R&D activity: funded companies allocate larger budgets to R&D activities and employ more R&D personnel. Partial crowding-out cannot be rejected, though. The impact on the wage structure is found to be significant: in addition to an increase in R&D expenditure and staffing, R&D wages are higher in companies receiving a subsidy. Further analysis learns that the main explanation seems to lie in an upskilling process: the subsidy allows companies to recruit more qualified personnel.

Chapter 5 digs into the potential presence of heterogeneity in additionality effects with respect to the funding recipient. The matching procedure is employed, pooling two cross-sectional datasets from the Community Innovation Survey, supplemented with patenting, financial and subsidy information. It appears that foreign firms are less likely to receive public R&D funding in Flanders, but if they do, the amount of funding typically is larger than what domestic firms receive. It is found that foreign ownership does not induce any difference in the impact of public R&D funding on private R&D budgets: both domestic and foreign-owned companies increase their R&D budgets to the same extent when an R&D subsidy is granted. However, when turning to the output side, the estimates show that foreign-owned companies outperform domestic companies when it comes to innovativeness and the creation of economic value, realized with the publicly induced, additional R&D expenditure.

Each of these chapters has its merit and advances the literature on additionality effects of R&D subsidies. This advancement is a mixture of methodological and content-wise extensions. In the third chapter, the conditional difference-in-differences methodology for repeated cross-sections is applied for the first time in this domain. Also, the availability of identical datasets for Flanders and Germany enabled us to take some first steps towards an internationally harmonized evaluation of public R&D subsidies. The fourth chapter extends the set of outcome variables in additionality research (traditionally mainly R&D expenditure) towards labour economics and assesses the impact on R&D employment and the wage structure. Moreover, this chapter draws attention to the importance of evaluating the effectiveness of an R&D policy measure in terms of both the funding status and the grant size. The treatment effects and IV regression estimates indicate that full crowding-out is rejected, but that partial crowding-out cannot be ruled out. The fifth chapter addresses potential heterogeneity in the treatment effects of public R&D subsidies. Moreover, the link with innovative and economic output is established, relating the counterfactual and induced private R&D spending to the output side of the R&D process.

Different data and research questions give rise to different methodological approaches. By and large, the overlapping findings tend to point in the same direction. An actual assessment of this convergence would require constructing confidence intervals for the treatment effects. This goes beyond the set-up of this dissertation, though. It is rather suggested to bring all conclusions together and to build a broad, coherent, rich and nuanced view on the assessment of public R&D policy.

I want to put forward some caveats here, which at the same time give occasion to more profound and refining research. First, public R&D funding is provided by many governmental institutions, at the regional, national and European level. The research presented in this dissertation evaluates the general impact of public funding, irrespective of the provider. Different governments could demonstrate different preferences, though, which may result in heterogeneous additionality effects. Therefore, it would be interesting to distinguish between different funding schemes (see e.g. Aschhoff, 2008, and Wallsten, 2000, for an evaluation of the German DPF scheme and the US SBIR program, respectively) and their mutual interaction. For example, in 2000, the Flemish government introduced a new SME program, uniting the complicated structure of different funding schemes under one single denominator. Detailed information about this single funding scheme recently became available and will be employed in future research to evaluate the effectiveness of this specific SME program. Also, the way in which public funding is provided yields an interesting research topic. For example, the US SBIR program is two-phased. In a first phase, the concept is assessed. Only projects which prove they may offer significant added value (on average 30% of the proposed projects) can then proceed to the second phase, in which the project is actually implemented. The funding amount is significantly larger in the second phase. A comparison of the effectiveness of the US and Flemish system in terms of additionality is definitely meaningful and could raise important policy implications.

Second, in this dissertation, the application and granting process have been regarded as a black box. However, an analysis from the perspective of, on the one hand, (non) applying companies and on the other hand, the government, providing subsidies, may give interesting insights. Blanes and Busom (2004), Takalo et al. (2005), Tanayama (2007) and Aschhoff (2008), investigate this aspect of the public R&D funding process. For Flanders, very recently a rich dataset has become available, which is well suited to dig into the selection process of public R&D funding. Through government mediation, Flemish companies can appeal to an external advisor, who assists them in the subsidy application. Also, the Flemish government recently started assessing the scientific added value and the valorisation potential of submitted projects. This information can be linked to details on the subsidy project as well as company information. This dataset can then provide evidence on e.g. whether the advisor generates added value for the company.

Third, heterogeneous additionality effects could stem from different types of research. Little research has been undertaken to disentangle the components of R&D budgets, and to address the crowding-out hypothesis on research versus development activities. Notable exceptions are Clausen (2007) as well as Aerts and Thorwarth (2008). They distinguish between the impact of public funding on research on the one hand and development activities on the other hand. The crowding-out hypothesis tends to be rejected only for the latter.

Fourth, the funding system is based on projects, while here the impact is evaluated at the company level. It is not unlikely that one 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 activity, irrespective of how this increase is generated.

Fifth, this dissertation also illustrates the value of international R&D activity for public funding agencies. Including more detailed information on MNE affiliates may unravel why these companies outperform domestic companies in the creation of R&D output and economic value. Moreover, also within the population of foreign-owned companies, heterogeneous effects may be found. For example, strongly locally embedded foreign affiliates may realize more (social) value to the host country and more knowledge may spill over to local companies. This would have important policy implications. A profound analysis of local embeddedness and knowledge flows within MNEs and between foreign-owned and domestic companies seems to be worthwhile. Aerts and Sofka (2008) provide a first study in this respect: they assess whether publicly funded R&D intensifies or relaxes a firm's knowledge protection strategy. Conversely, simple economic logic in MNEs' accounting procedures may provide an additional explanation as to why MNE affiliates realize more economic value. This deserves further investigation.

Last, this dissertation addresses the direct, short term effect of public R&D funding. However, also the long term effect is an important evaluation criterion to policy makers. Time-series data on public funding, R&D activity, innovative performance and economic value would provide deeper insights and would allow testing different lag specifications. In recent years, special attention has been devoted to the careful construction of a panel structure in the Flemish Community Innovation and R&D Surveys. As more survey waves will become available, the long term impact of public R&D funding will develop into a challenging, but valuable and promising research issue.

In the first part of this dissertation, the effectiveness of a public intervention tool in the market for R&D was investigated. More specifically, I focussed on the impact of public R&D funding in Flanders. In the following paragraphs I proceed with some policy implications of this research. IWT acts as the single counter in Flanders where companies can submit a dossier and apply for a subsidy and therefore manages all corporate R&D subsidies, at the Flemish and Belgian level, as well as certain EU-funded projects[69]. Vital policy issues for IWT are the significance of the additionality of the public money they redistribute and the valorisation of the outcome of the research effort which is induced by their R&D grants.

[69] The Framework Program projects are not managed through IWT. However, typically the scale of these projects is very large because these projects are often managed in international company consortia. As a result, the number of Flemish firms engaging in these programs is very limited.

The research bundled here rejects the full crowding-out hypothesis; it is however also found that R&D grants crowd-out private R&D activity to some extent. Nevertheless, this is a positive result for the Flemish R&D policy: funded firms spend more on R&D activities, employ more R&D personnel and realize innovative output with subsidised R&D budgets. Our findings show that the public money which IWT provides for R&D activities indeed induces additional private R&D activity, both at the input and output side. However, IWT judges the fear for a leakage of the valorisation value and brain drain as highly relevant, especially with respect to MNEs. Ideally, IWT wishes to see that the innovative and economic value which is generated through funded research is kept and valorised in Flanders. However, foreign multinationals signal that they come to Flanders because of the strong pool of knowledge, which is embedded in the Flemish research institutions like IMEC, VITO, VIB and IBBT. The financial support from the government is of minor importance (typically only up to 5% or 10% of their total R&D budget). Although our research tends to point out that the foreign-owned subsidiaries generate innovative and economic value in Flanders, even more than the domestic firms do, the answer to the question whether the knowledge they generate is sufficiently appropriated by the Flemish economy, remains unclear to a large extent. Knowledge is volatile and extremely hard to retain in a world of increasing globalisation.

Furthermore, from interviews with IWT officials, it became apparent that the government is still puzzled by another essential question: are all potentially interested companies covered by the subsidy system? Innovation is a top priority of the Flemish government and the budget to support and stimulate innovative activity in the private sector is substantial. However, IWT finds itself faced with the 'luxury problem' that many companies, especially SMEs and start-ups, are not familiar with IWT nor with the measures they qualify for, despite numerous initiatives like specific promotion actions, advisors assisting in the application process, collaboration with polytechnic schools, etc. This may entail implications for the assessment of the Flemish public R&D policy.

It was found that R&D subsidies induce additional R&D expenditure and the employment of more R&D personnel (Chapter 4). At the same time, an increase of the R&D wages was observed, which can mainly be ascribed to an upskilling process: funded companies are able to attract and to employ higher-skilled personnel. However, an often heard complaint uttered by R&D active companies is that they experience heavy difficulties in finding adequate personnel. This seems to constitute a severe bottleneck for innovative activity (also in many other countries; see e.g. Mohnen et al., 2008). Therefore, it is called for a general policy framework, in which all public measures (a strong education system, adequate knowledge protection measures, stimulating measures, a good balance between basic and more applied research, an efficient transfer of knowledge between the public and private sectors, etc.) are fine-tuned and geared to each other and jointly create an innovator-friendly environment for the business sector. Moreover, current statistics indicate that the decrease and subsequent stagnation in R&D expenditure in Flanders (and in many other EU-countries) mainly result from the evolution of the private R&D spending (see e.g. Debackere and Veugelers, 2007). Public R&D expenditure remained at the same level or even increased a little bit. This has not been investigated in the framework of this dissertation, but especially in times of decreasing private R&D expenditure, additionality effects could be high. The counter-cyclical support of private R&D activity could help companies standing up to this evolution.

This dissertation mainly looks into the impact of direct R&D funding on private R&D activity. Fiscal measures were only limitedly popular until recently. However, in 2007 the fiscal support system has been redesigned and first evaluation exercises reveal that the new system seems to be very popular, especially due to tax reduction measures for R&D employees. In this work these fiscal measures were not yet relevant; they are expected to become so in the near future, though. IWT officials expect that the fiscal measures predominantly provide additional incentives to conduct R&D and they do not expect to see a decline in the number of applications for R&D subsidies. However, as raised before, fiscal measures carry an implicit relabeling danger: to maximise the benefit from these tax credits, companies may relabel activities as being an R&D activity, while before the same activity was not accounted for in the company's R&D budget. This implies an artificial increase in R&D expenditure which actually did not take place. Then obviously this evolution becomes highly relevant in evaluation exercises, also of direct R&D support, as it may seriously bias the evaluation exercises. The interaction of direct and indirect support measures for private R&D activity provides an interesting path for further research.

Corporate strategies in innovation

In **Chapter 6** we employ evaluation econometrics to assess the impact of profit-sharing on a company's innovative performance. Profit-sharing aligns the mutual interests of company employees and owners. As a result, potential obstacles, impeding employees to share their information advantage with the company, may be alleviated. Therefore, we advanced the hypotheses that profit-sharing companies employ better and more up-to-date technological equipment and also realise more product innovations. The application of conditional difference-in-differences methods on a rich dataset on German manufacturing companies reveals that indeed, profit-sharing strengthens the company's product and process innovative capabilities.

To the best of our knowledge, this research provides the first empirical testing of the relationship between profit-sharing and innovativeness. More recent survey waves will become available and existing datasets may be extended. This may yield new possibilities to test different time lags, different measures of innovativeness, etc. For example, Lerner and Wulf (2007) link different remuneration schemes of R&D managers to a company's patenting activity. An extension of the measure of profit-sharing is possible: one could not only take the mere presence of profit-sharing into account, but use information on the size of the profit premium; heterogeneous additionality effects may become apparent.

Innovation has become the driving force in the current increasingly knowledge-based society. Private as well as public efforts are vital to maintain a significant degree of competitiveness. This is reflected for example in the so-called Lisbon agenda: in 2000, the European Union designed an ambitious strategy to strengthen the EU's innovativeness. It was postulated that by 2010, 3% of the GDP should be allocated to R&D activities. One third should be financed publicly; the remaining two thirds should be financed privately. However, intermediate evaluations show that this goal is far from being reached: in 2005 only 1.77% of the EU25 GDP was spent on R&D. Conversely, the EU's main competitors performed significantly better in this respect: the US R&D expenditure amounted to 2.62% of the GDP and in Japan this number rose to 3.33% (OECD, 2007). As a consequence, very recently an integrated innovation/research action plan was initiated, which calls for a major upgrade of the research and innovation conditions in Europe. Mobilizing EU funds and further development of instruments to support research and innovation are key objectives formulated in this plan.

This dissertation illustrates that both public and private measures aiming at stimulating private innovative capabilities have their merit. Further research, as outlined above, will allow digging further in the specificities of how these measures affect innovativeness. However, already now it is clear that public R&D funding and private incentive measures unmistakably have a noteworthy potential to contribute in reaching the 3% target. To conclude, I urge for a fine-tuning effort with respect to these measures in order to optimize consistency in public and private incentives.

لا غد في الأمس فلنتقدم إذا

طباق, محمود درويش (١٩٤١ - ٢٠٠٨)

No future behind us, so let us move forward!
*Counterpoint, **Mahmoud Darwish** (1941 - 2008)*

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