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How do distinct firm characteristics affect behavioural additionalities of public R&D subsidies? Empirical evidence from a binary regression analysis

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Empirical evidence from a binary regression analysis

Abstract. Interest of STI policies to influence the innovation behaviour of firms has been increased considerably. This gives rise to the notion of behavioural additionality, broadening traditional evaluation concepts of input and output additionality. Though there is empirical work measuring behavioural additionalities, we know little about what role distinct firm characteristics play for their occurrence. The objective is to estimate how distinct firm characteristics influence the realisation of behavioural additionalities. We use survey data on 155 firms, considering the behavioural additionalities stimulated by the Austrian R&D funding scheme in the field of intelligent transport systems in 2006. We focus on three different forms of behavioural additionality – project additionality, scale additionality and cooperation additionality – and employ binary regression models to address this question. Results indicate that R&D related firm characteristics significantly affect the realisation of behavioural additionality. Firms with a high level of R&D resources are less likely to substantiate behavioural additionalities, while small, young and technologically specialised firms more likely realise behavioural additionalities. From a policy perspective, this indicates that direct R&D promotion of firms with high R&D resources may be misallocated, while attention of public support should be shifted to smaller, technologically specialised firms with lower R&D experience.

JEL Classification: C25, C42, H50, O31

Keywords: Behavioural additionality, public R&D subsidies, STI policy evaluation

1 Introduction

Theoretical considerations for the evaluation of Science Technology and Innovation (STI) policy programmes have regained great interest in the recent past (see, for instance, OECD 2006). Though government support for R&D has been offered for several decades in most industrialized countries, the evaluation of such STI policies has lagged behind. Impact assessment of policy measures remains challenging as it is difficult to isolate the impact of a specific policy programme from the general economic firm-internal background as well as external conditions influencing a firms´ innovation performance (see, for instance, Georghiou and Clarysee 2006). Thus, modern policy evaluations often take an *additionality* perspective to overcome the problem of attributing particular effects at the firm level to specific policy contributions or firm endeavours (see, for instance, Hsu 2009). The additionality concept aims to measure the extent to which public policy support stimulates new R&D activities as opposed to subsidising what would have taken place anyway (see Buisseret 1995). Next to the traditional additionality concepts, *input additionality* and *output additionality*, used by policy makers, particular attention has been recently given to the concept of *behavioural additionality* (see Buisseret 1995, Luukkonen 2000, Autio et al. 2008). The latter emphasises the importance of measuring how policy programmes influence the innovation behaviour of firms, referring to changes in the firm´s innovation behaviour directly attributable to the participation of that firm in a specific STI policy programme. This is related to the fact that modern STI policies – mainly based on the system failure rather than the market failure perspective (see Falk 2007) – shift emphasis to the acquisition of learning capabilities and problem-solving skills, including the ability to know where complementary expertise can be found.

Following these conceptual considerations, various empirical studies use the behavioural additionality concept for the evaluation of specific STI policy programmes. One notable recent example is the evaluation study of OECD (2006) providing a compilation of twelve evaluation studies of behavioural additionality effects in R&D policy programmes implemented in different OECD countries. Most studies focused on direct government funding of business R&D, but others examined public-private partnership programmes and tax incentives for R&D, using mainly survey based data analysed by descriptive statistics and exploratory data analysis techniques. In general, the studies provide important empirical insight into behavioural effects of

governmental R&D funding and, thus, underline the significance of the behavioural additionality concept as an expansion to traditional evaluation approaches.

However, from previous empirical work on behavioural additionality we know only little about how distinct firm characteristics influence the realisation of such additionalities. This is an important question for the future design of STI policy programmes that explicitly address the realisation of behavioural additionalities. Some few recent exceptions of empirical work that – at least to some extent – focuses on this question are the studies by Clarysee et al. (2009), Hsu et al. (2009) and Falk (2007). The study by Clarysee et al. (2009) identifies determinants of the behavioural additionality of R&D grants to explain the mechanism through which behavioural additionality is obtained using data on R&D grants provided in the region of Flanders in Belgium between 2001 and 2004. The results provide evidence that a higher number of external partners in funded R&D projects leads to increased behavioural additionality effects. However, these effects decrease with the number of subsidized projects that are undertaken by the firm. Hsu et al. (2009) investigate the behavioural additionality of government subsidies on strategic changes in the R&D behaviour of 127 firms in Taiwan. The results show that firms in different industry sectors and innovation categories emphasize different types and intensities of behavioural additionality. Falk (2007) relates observed additionalities of 1200 Austrian firms to different firm characteristics and their perceived barriers to innovation. The results show that start-up firms on average realize more behavioural effects than mature firms while at the same time additionalities slightly increase with firm size.

The study at hand follows this research stream by focusing drivers of behavioural additionalities in the light of different firm characteristics, including structural and R&D related characteristics. The objective is to estimate how distinct firm characteristics influence the realisation of behavioural additionalities. We use survey data on 155 firms and consider the behavioural effects stimulated by the policy programme IV2S that granted R&D subsidies in the year 2006 in the field of intelligent transport systems in Austria. The focus is on three different forms of behavioural additionality as captured by the survey – project additionality, scale additionality and cooperation additionality. Project additionality refers to the situation in which a project would have been cancelled or not started, if public support had been rejected. Scale additionality describes the case in which the funded project is conducted on a larger scale than previously

intended, while cooperation additionality denotes the impact of public R&D support on the collaboration and networking behaviour of firms. We employ a binary regression approach to address these research questions.

By this, the study departs from existing empirical literature in at least three major respects. *First*, we introduce a conceptual framework for analysing firm-specific drivers of behavioural additionality, putting special emphasis on firm-internal R&D related characteristics that may influence the realisation of specific types of additionalities. *Second*, we employ logistic binary regression models to identify firm specific characteristics influencing the realisation of behavioural additionalities. *Third*, we combine data on behavioural additionality with other relevant databases covering R&D related firm characteristics, in particular with the patent database of the European patent office (EPO) and the internal database of the Austrian Research Promotion Agency (FFG). By this, the study produces novel empirical insight on how behavioural effects of public R&D subsidies differ across specific firm characteristics, and, thus, add significant value to the scarce empirical literature in this research field.

The rest of the paper is organised as follows: Section 2 discusses the concept of behavioural additionality in some detail, focusing on different dimensions and peculiarities of this specific evaluation approach. Section 3 elaborates on the conceptual framework that is used for the empirical analysis and introduces the main hypotheses to be tested, before Section 4 describes the binary logistic regression modelling approach, the data used and the construction of the dependent and independent variables. Section 5 presents the estimation results for the three types of behavioural additionality under consideration by means of the logistic regression models estimated using Maximum Likelihood estimation procedures, while Section 6 closes with a summary of the main results, some concluding remarks and ideas for a future research agenda.

2 The concept of behavioural additionality

The classical theoretical rationale for governmental R&D subsidies is mainly based on the well-known market failure argument (Arrow 1962, Nelson 1959). This approach refers to leakages and spill-overs that reduce the propensity of firms to innovate as they cannot fully capture the benefits of their R&D investments. Thus, public intervention from this background is needed to

compensate for underinvestment in R&D in the private sector (see David et al. 2000). Taking this traditional market failure perspective in the context of R&D policy programme evaluations, policy makers are looking for empirical evidence of the leverage effect of the policy programmes, i.e. they are interested to estimate multiplier effects of their R&D subsidies on the total amount of firms´ R&D investments. This gives rise to the notion of *input additionality* in traditional evaluation approaches of R&D policy programmes (see OECD 2006). Its focus is on estimating to what extent a specific policy programme contributes to additional investments in R&D by the receiving firm. If this is not the case, these public funds just introduce inefficiencies or serve as substitutes for R&D that would have taken place also without funding (often referred to as crowding out effect) (see Clarysee et al. 2009). Next to leverage effects on private R&D investments, policy makers became increasingly interested in the impact of R&D subsidies on innovative output of firms, giving rise to evaluation concept of *output additionality* (see Klette et al. 2000). As defined by Luukonnen (1998), output additionality refers to the extent of additional outputs of the firms´ innovation efforts as a result of public R&D subsidies, often measured in terms of sales or patents.

Over the recent past, it has been criticized, both by policy makers and the scientific community (see, for instance, Georghiou 2002), that these traditional evaluation concepts are too narrow in light of new insights on the role of the public hand for supporting innovation processes. The traditional perspective relies – as mentioned above – mainly on the market failure argument, and thus, is based on outdated models of the innovation process, namely models that describe the generation of innovations as a linear process (see, for instance, Edquist 2005). When considering the nowadays widely accepted systemic view on innovation processes, where innovations are created within a complex web of interactions between different actors of the innovation system (see, for instance, Fischer 2001), it seems obvious that the traditional evaluation concepts are unsatisfactory in this context. They overlook important elements that, however, need to be considered when evaluating modern STI policy programmes; modern STI policies shift emphasis to systemic failures and the acquisition of additional learning capabilities and problem-solving skills as a result of public intervention. This lack in the evaluation concepts of input and output additionality has led to the implementation of an additional evaluation dimension focusing on changes in the firm´s innovation behaviour. This gives rise to the notion of *behavioural additionality* that can be assessed in the short term, but may also lead to additional innovation

inputs and outputs in the long term. The concept of behavioural additionality aims to measure changes in the firm´s innovation behaviour directly attributable to the participation of that firm in a specific STI policy programme (see Buisseret 1995). It is one way to face the changing requirements of R&D policy programmes, and to detect related effects of governmental policy interventions from a systemic point of view (Falk 2007, OECD 2006).

Behavioural additionalities are expected to result from any R&D policy instrument (Georghiou 2002), and can therefore be applied in several evaluation studies. The concept attempts to capture the impact of public intervention on the innovation process itself and focuses not only on direct effects, but also on indirect impacts on the firm's behaviour and its strategy. Although behavioural changes can be interpreted as intermediate results of public funding, their impacts are expected to persist beyond the period of the supported activity (OECD 2006). Long-term learning effects may be integrated into the firm's capabilities and may additionally have structural and institutional impacts on the entire system (Georghiou 2002). Behavioural additionality is therefore positioned between input additionality and output additionality, trying to open the black box and to recognise the underlying forces related to firm innovation processes (OECD 2006, Larosse 2004). By this, it tries to address the questions of how public support interacts with the capabilities and strategies of firms, including issues of competence building, skills in managing R&D processes as well as strategic alliances with other actors (e.g. suppliers, competitors, science organisations) involved in the R&D process.

Behavioural changes caused by public funding are expected to be ambiguous and manifold[1]. In the current study we focus on three specific dimensions of behavioural additionality that are captured by our survey based data (see Section 4):

i) *Project additionality* refers to the project launch and corresponds to the situation in which a project would have been cancelled or not started, if public support had been rejected. It can be distinguished between "pure" project additionality (project

[1] For this reason, until recently a number of different categorisations of behavioural changes emerged in the literature. As behavioural effects are very fuzzy and difficult to identify, the types are diffuse and may overlap in parts. An overview on different types of behavioural additionalities is given by Falk (2007).

continuation without any changes) and "partial" project additionality (adaptations in size, scope or timing of the project).

ii) *Scale additionality* describes the case in which a specific R&D project is conducted on a larger scale after public R&D funding has been provided than previously intended by the conducting firm(s).

iii) *Cooperation additionality* is in place when public support influences the collaboration behaviour of firms receiving R&D subsidies. This may be the case when public R&D support helps to create cooperations with new or diversified partners in the public and private sector, or where collaboration and joint R&D activities are continued even if the project has expired.

From this perspective, behavioural additionality is a multidimensional concept and refers to effects on different levels and aspects of the innovation process. Thus, an appropriate conceptual framework for the empirical analysis of the determinants of behavioural additionality at the firm level needs to be defined in the section that follows.

3 Behavioural additionality and firm-specific characteristics

The concept of behavioural additionality has come into wide-spread use in evaluation studies of policy programmes in various countries (see OECD 2006). However, the relationship of distinct firm characteristics – such as firm size, firm age or the firm´s R&D capacity – and the realisation of different types of behavioural additionalities remain unclear from previous evaluation studies. In this section we present a conceptual framework for our empirical analysis that is intended to indentify such firm-specific drivers of behavioural additionalities. The framework relies on previous empirical work in this direction (see Clarysee et al. 2009, Hsu 2009, Falk 2007), but expands the analytical scope of these studies by focusing on R&D relevant firm characteristics that may influence innovation behaviour, and, thus, also the realisation of behavioural additionalities at the firm level.

Theoretical and empirical literature discusses different aspects of firm-internal determinants of innovation behaviour. The main dimensions that have been taken into account in previous

empirical work are structural and organisational characteristics of the firm, while R&D relevant factors, such as R&D expenditures, were often – possibly due to data limitations – neglected (see, for instance, Falk 2007). The conceptual framework of the current study takes into account firm-internal characteristics that may be distinguished into resource-based factors, and factors related to the strategic orientation of the firm (see, for example, Galende J and De la Fuente JM 2003, Teece et al. 1997, Teece 2010, Barney 1991). Concerning resource-based factors, we include structural and organisational resources of the firm. As a proxy for structural resources we make use of the firm size, while firm age is used as a proxy for organisational resources (see Falk 2007 for a discussion on how firm size and firm age may influence the realisation of behavioural additionalities). Further, we use information on *R&D related resources and competences* as captured by the firm´s R&D intensity as an important resource-based factor. Concerning characteristics related to the firm´s strategy, we include the firm´s internationalisation strategy that may be an important determinant for the realisation of different behavioural additionalities. Also in the context of the firm´s strategic orientation R&D related factors may be relevant. Thus, our analytical framework comprises the *technological specialization* and the *R&D collaboration strategy*. In what follows, we focus on the derivation of the R&D related factors mentioned above and their role for the realisation of behavioural additionalities, and formulate our guiding hypotheses to be tested in the empirical analysis. We refrain from a more detailed elaboration on the general firm characteristics, such as firm size and firm age, as they are sufficiently discussed in the literature (see, for instance, Cohen 2010).

R&D-related resources and competences

Measures of R&D-related resources and competences are, for instance, the firm's R&D intensity, R&D expenditures, R&D personnel, the existence of a formal R&D department in the company, or the regularity of their R&D activities (see, for instance, Galende J and De la Fuente JM 2003). In the current study, R&D resources and competences are captured by the experience in the particular research field, and the R&D intensity of the firm. These factors are strongly correlated and appear jointly in most firms. R&D intensive firms invest comparatively large amounts in their R&D activities; R&D is incorporated in the firms' strategy and formalised at a high level. Experience and domain expertise indicate specific competences, which have been evolved in prior research activities. Hence, firms are able to benefit from their elaborated knowledge base

and their enhanced absorptive capacity (Cohen and Levinthal 1990). These aspects lead to the assumption that firms with higher R&D-related resources and competences are less dependent on public support, as they would carry out their "priority projects" anyway. Therefore the likelihood to modify or cancel major projects is lower. They rather adapt size, time horizon or scope of their projects and investments. On the contrary, a higher absorptive capacity allows them to better exploit external knowledge and to achieve valuable outcomes. Considering the high internal R&D resources and competencies, they are less dependent on collaboration partners providing them with lacking R&D capacities. This leads to the following hypotheses:

Hypothesis (*i*): Project additionality decreases with a higher level of R&D resources and competences, i.e. the probability of realising project additionality is higher in non-R&D intensive and unexperienced firms.

Hypothesis (*ii*): Scale additionality increases with a higher level of R&D resources and competences, i.e. the probability of realising scale additionality is higher in R&D intensive and experienced firms.

Hypothesis (*iii*): Cooperation additionality decreases with a higher level of R&D resources and competences, i.e. the probability of realising cooperation additionality is higher in non-R&D intensive and unexperienced firms.

Technological specialisation

Technological diversification or specialisation determines the firm's R&D and innovation behaviour (Breschi et al. 2003). In conducting R&D and innovation, a firm has to take the decision whether to operate in diversified fields or to focus on just a small number of technological fields. Through specialisation of research activities, a firm may benefit from a more efficient learning process and knowledge transfer. They have a more sophisticated knowledge base and, thus, achieve a higher degree of expertise. Further, specialised firms may easier gain comparative advantages in a specific technology field (Garcia-Vega 2006). Nevertheless, there are also theoretical considerations that assume a positive relationship between technological diversification and R&D or rather innovation activities. Large, diversified firms may benefit from complementaries among various activities occurring together (Teece 2010; Breschi et al. 2003).

Advantages arise from knowledge and learning spill-overs in related technology fields sharing a common knowledge base, but also from combining the expertise in unrelated technologies. This may lead to new and creative insights in a specific field.

This study takes into account the effects of the degree of diversification of the firms' technological knowledge base on behavioural additionality. The opportunity to spread costs and risk of R&D across several fields is rather limited in technologically specialised firms. Hence, it is assumed that specialised firms are more dependent on public R&D funds in realising their projects. They are more risk averse and investigate a more accurate prior impact assessment of their activities. Due to their high degree of specialisation they rely on external collaboration partners in conducting their R&D activities. They seek for new partners with supplemental resources and capabilities. Further it is assumed that specialised firms focus their activities on only a small number of projects. If public support is denied, an adjustment of the project size or scope would be more difficult for highly specialised firms. In this context, the following hypotheses are to be tested in the empirical analysis:

Hypothesis (*iv*): Project additionality increases with the degree of specialisation of the firm, i.e. the probability of realising project additionality is higher in technologically specialised firms.

Hypothesis (*v*): Scale additionality decreases with the degree of specialisation of the firm, i.e. the probability of realising scale additionality is higher in technologically diversified firms.

Hypothesis (*vi*): Cooperation additionality increases with the degree of specialisation of the firm, i.e. the probability of realising cooperation additionality is higher in technologically specialised firms.

Collaboration strategy

The collaboration strategy refers to the firm's strategy of how to organise R&D activities. It is another specific aspect determining the firm's R&D and innovation behaviour. Firms decide whether to engage in R&D cooperation, with how many partners and with which type of partners (customer, supplier, competitor, scientific research organisation). The choice of partners depends

on firm-specific characteristics (structure, industry, and organisation of the firm), on the type, strategy and target of its own R&D and innovation efforts (product or process innovation, basic or applied research or technological development), as well as on the costs involved in cooperating with others (Paier and Scherngell 2011).

In this study, it is assumed that both, a firm's collaboration strategy as well as its prior and existing network relations, influence behavioural effects of public R&D funding. Firms that have already organised their R&D within partnerships have gained experience in collaborations and developed a significant level of trust in cooperating with partners. Moreover, they are already experienced with sharing knowledge and have developed specific modes of managing appropriability and intellectual property aspects. They have developed a positive attitude towards cooperation, and, thus, may already have access to sufficient collaboration partners. In contrast, their likelihood of changing their behaviour as a result of public funding, especially in terms of cooperating with new partners, may be higher. The hypotheses derived in the context of the firm´s collaboration strategy are the following:

Hypothesis (*vii*): Project additionality decreases with the involvement in prior R&D collaborations, i.e. the probability of realising project additionality is higher in non-collaboration intensive firms.

Hypothesis (*viii*): Scale additionality decreases with the involvement in prior R&D collaborations, i.e. the probability of realising scale additionality is higher in non-collaboration intensive firms.

Hypothesis (*ix*): Cooperation additionality increases with the involvement in prior R&D collaborations, i.e. the probability of realising cooperation additionality is higher in collaboration intensive firms.

4 Empirical model, data and variables

This section sheds some light on the empirical setting of the current study. We introduce the binary regression modelling approach that is used to estimate how behavioural additionalities differ across distinct firm-specific characteristics, and discuss in some detail the construction of

the dependent and the independent variables. The core data for our empirical analysis comprise survey based data on behavioural additionalities resulting from the Austrian STI policy programme *Intelligent Transport Systems and Services – IV2S*, carried out by the Austrian Ministry for Transport, Innovation and Technology (BMVIT)[2]. The survey on behavioural changes was conducted in the year 2006 among 155 firms that were funded by the Programme (see Geyer 2006 for further details on the programme and results of the survey). To address our research question, we match the survey data with other databases that contain systematic information on the firm characteristics mentioned in the previous section. In this context we rely on the Aurelia database that contains general characteristics of firms located in Austria, the internal database of the Austrian Research Promotion Agency (FFG) that comprises data on R&D related resources of firms that have been funded by Austrian funding schemes, the EUPRO database of the Austrian Institute of Technology featuring data on international project collaborations within the European Framework Programmes (FP), and the PATSTAT database of the European Patent Office (EPO) containing systematic information on EPO patent applications. In what follows, we initially introduce the empirical model used to describe the relationship between behavioural additionalities and distinct firm characteristics, before we describe the dependent and independent variables in some detail.

The empirical model

In this study we aim to estimate how distinct firm characteristics influence the realisation of behavioural additionalities at the firm level. Thus, we seek to model the realisation of a specific type of behavioural additionality at the firm level dependent on various firm characteristics according to our analytical framework introduced in the previous section. As behavioural additionality is measured by binary dependent variables (see the detailed description of the variables below), we employ a binary probability modelling approach. Probability models have come into fairly wide use to explain the probability of an event occurring dependent on various exogenous factors (see, for instance, Long and Freese 2001). Among the different conceptual

[2] The programme was running from 2002 to 2006 and focused on the promotion of research and development in the transport and mobility sector. One of the main objectives of the programme was to pool several public R&D and innovation funding initiatives in the transport sector. The overall objective of the programme referred to technological development and environmental issues by means of innovative transport solutions and applications (Geyer 2006).

approaches to derive a binary probability model (see Greene 2003), we rely on the latent variable model that is based on a latent or unobservable endogenous variable, which is captured by a measurable and observable response with a binary outcome. In our case, the latent variable corresponds to change processes in a firm´s innovation behaviour that is unobservable, but the outcome of this change process may be captured by an observable response variable.

We assume that our firms i ($i = 1, ..., n = 155$) participating in the IV2S may change their innovation behaviour due to their participation in the programme in a distinct way. A change in behaviour stimulated by the programme may be formulated by the following latent regression

$$\boldsymbol{Y}^* = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \tag{1}$$

where $\boldsymbol{Y}^* = (Y_i^*;\ i = 1, ..., n)$ is the n-by-1 vector of latent responses, $\boldsymbol{X}$ is an n-by-K matrix of explanatory variables (including the constant), with X_{ik} denoting the measurement of the k-th characteristic (indexed $k = 1, ..., K$-1) on firm i, $\boldsymbol{\beta}$ is the associated K-by-1 parameter vector, and $\boldsymbol{\varepsilon}$ an n-by-1 random error term. Since the responses Y_i^* are unobservable, we follow common practice and define a link between the latent change in behaviour Y_i^* and the binary response variable $Y_i = (Y_i;\ i = 1, ..., n)$ as defined by

$$Y_i = \begin{cases} 1 & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \leq 0. \end{cases} \tag{2}$$

In this study the Y_i (indexed $i = 1, ..., n$) are observed by surveying respondents, whether they have realised behavioural effects due to public R&D funding within the IV2S programme, which would not have occurred otherwise. $Y_i = 1$ if firm i realises behavioural additionality, while $Y_i = 0$ otherwise. The study distinguishes – as mentioned in the previous section – between three different types of behavioural additionality that will be specified formally in the next section. The probability of $Y_i = 1$ depends on a set of firm-specific characteristics gathered in the i-th row of $\boldsymbol{X}$, that is $\boldsymbol{X}_i$, leading to the probability model $\Pr(Y_i = 1 \mid \boldsymbol{X}_i) = 1 - F(-\boldsymbol{X}_i\boldsymbol{\beta})$ (see Greene 2003 for details), where $F(.)$ denotes the cumulative distribution function (CDF) of $\boldsymbol{\varepsilon}_i$.

To get a measurable we need to specify $F(.)$. As is common practice, we assume $\boldsymbol{\varepsilon}_i$ to be logistically distributed, leading to the well known logit model, in our case given by

$$\Pr(Y_i = 1 | \boldsymbol{X}_i) = \frac{\exp(\boldsymbol{X}_i \boldsymbol{\beta})}{1 + \exp(\boldsymbol{X}_i \boldsymbol{\beta})} = \Lambda(\boldsymbol{X}_i \boldsymbol{\beta}) \tag{3}$$

where $\Lambda(.)$ indicates the logistic cumulative distribution function[3]. $\boldsymbol{\beta}$ is derived from maximum likelihood (ML) estimation procedures[4].

The dependent variables

Data on behavioural additionality of the strategic research and development initiative "Intelligent Transport Systems and Services" – IV2S come from a survey among programme participants carried out in 2006 (see Geyer 2006 for details on the survey). Three specific questions of the survey cover – as mentioned above – three different types of behavioural additionality that are used as dependent variables:

Project additionalities appear, if the research project would have been cancelled, unless it has been supported by public funds. Project additionality refers to the counterfactual situation. It is captured by the response option of a multiple-choice question "*We would not have continued the project*". The dependent variable is defined by

$$Y_{1i} = \begin{cases} 1 & \text{if project additionality occurs for firm } i \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

3 Note that the probit model using the standard normal cumulative distribution function is often used as alternative specification. Given the similarities between the logit and the probit model, it does usually not make much difference which model specification is applied (see, for example, Greene 2003). In the context of this study, we prefer the logit version as the estimates can be more intuitively interpreted in terms of odds-ratios (see Long and Freese 2001).

4 For details on maximum likelihood see, for example, Greene (2003, pp. 670-673).

Scale additionality refers to the situation in which the project is conducted on a larger scale than without public funding. The response option "*We would have run the project on a smaller scale*" is associated with the dimension of scale additionality, which is defined by

$$Y_{2i} = \begin{cases} 1 & \text{if scale additionality occurs for firm } i \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

Concerning *cooperation additionality*, respondents were questioned for collaborations with new partners ("*Did you run the project with new partners*?"). This means, if public funding helps to create new types of collaborations, cooperation additionality is apparent. The response for cooperation additionality is specified by

$$Y_{3i} = \begin{cases} 1 & \text{if cooperation additionality occurs for firm } i \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

The independent variables

The independent variables are chosen on the basis of the conceptual framework described in the previous section. Let the *k*-th columns of $\boldsymbol{X}$ be a set of firm-specific characteristics $\tilde{\boldsymbol{X}}_k$ (k = 1, ..., K–1), which may influence the existence of behavioural additionality. Concerning general firm characteristics, we use the *firm size*, $\tilde{\boldsymbol{X}}_1$, measured in terms of the number of employees and used in logarithmic form. The *age* variable, $\tilde{\boldsymbol{X}}_2$, is defined as the difference between the year of project launch within the firm *i* and the founding year of *i*. The age of the firm is a proxy variable for established organisational resources and competences as well as experience in business, R&D and public support. *Export activity*, $\tilde{\boldsymbol{X}}_3$, is defined by $\tilde{X}_{i3}$ = 1 if the firm records exports, and $\tilde{X}_{i3}$ = 0 otherwise. A firm's export activity is one possible measure for the firm's orientation on foreign markets and its degree of internationalisation.

The emphasis of this study is on R&D related characteristics: R&D intensity, $\tilde{\boldsymbol{X}}_4$, is, following common practice, defined by the R&D expenditures of *i* divided by total sales. This variable indicates whether the firm holds a formal in-house R&D department or promotes R&D activities

on a continuous basis. *Experience in research field*, $\tilde{X}_5$, is defined as a dummy variable which is taken from the online survey[5]. It serves as a proxy variable for the firm's learning and absorptive capability determining its R&D resources and competences in a specific field. Specific competences may determine the existing knowledge stock, the direction of R&D activities and facilitates the assessment of expected results. Further, we take the firm's patent portfolio as a proxy variable for *technological specialisation* or diversification, denoted by $\tilde{X}_6$. For this purpose, an index of specialisation of patent applications at the EPO is used[6]. The variable *FP cooperation*, $\tilde{X}_7$, measures the number of cooperative projects in EU-Framework programmes in which a firm *i* has participated. In order to ensure unbiased results due to firm age, only projects within the 5th (1998 – 2002) and 6th (2002 – 2007) EU FP are included.

In our model we have to control for idiosyncrasies related to different organisational types, as the core sample consists of organisations in the industry and the service sector, as well as public and private research organisations. For this purpose, dummy variables for each organisational type are defined. By convention, $\tilde{X}_{i8}$ = 1 if the firm *i* relates to the *service sector*, $\tilde{X}_{i8}$ = 0 otherwise. *Research organisations* are captured by $\tilde{X}_{i9}$ = 1; $\tilde{X}_{i9}$ takes the value zero otherwise. Table A in the Appendix gives details on the independent variables used in the different estimation models, their specification and the underlying data source.

5 Estimation results and discussion

Table 1 presents the Maximum likelihood (ML) estimates for the behavioural additionality models as specified in the previous section, asymptotic standard errors are given in brackets. For each type of behavioural additionality under consideration two different model versions are considered: The *basic* versions of the model contain general profile characteristics that are – according to our analytical framework – *firm size*, *firm age* and *export activity*. The *extended* model versions are of central interest in the context of the research questions of this study. In

5 The underlying survey question is: "Is your project thematically based on previous work?"

6 The index is defined by $\tilde{X}_{i6} = \frac{1}{2}\sum_Q |s_{iq} - \bar{s}_q|$ where s_{iq} is the firm's *i* share of patents in a specific IPC class *q* (indexed *q* = 1, …., 129) and $\bar{s}_q$ is the mean of IPC class *q*. In order to control for the time lag between R&D performance and patent application, patent applications with a priority date between 1997 and 2007 are considered. Patents were taken into account at a two-digit level (class level) corresponding to the International Patent Classification (IPC).

these models we add R&D related characteristics to the basic versions, involving *R&D intensity*, *technological specialisation*, *FP cooperation* and *experience in research field*. The extended model versions further feature control variables, namely the *service sector dummy* and the *research organisation dummy*. Note that the basic model is nested in the extended model version.

The bottom of Table 1 provides various model fit measures for comparison purposes. The Likelihood Ratio statistic comparing the estimated model with the constant-only null model increases from the basic to the corresponding extended model for all behavioural additionality models. This points to the first important, general result: the inclusion of R&D related firm characteristics is of crucial importance for improving model fit, i.e. when analysing the realisation of behavioural additionalities for distinct firm types from the perspective of policy makers, R&D relevant characteristics provide an important clue of why additionalities may appear in some firms, but not in other firms.

In general, the estimation results are promising in the context of relevant empirical and theoretical literature. Concerning the basic project additionality model as given by column (1) of Table 1, it can be seen that all parameter estimates are statistically significant. The negative coefficient for *firm size* suggests that the likelihood of project additionality decreases with the level of size. The same is true for the *firm age*; this means that the probability for cancelling the whole project in case of rejection increases for smaller and younger firms. In contrast, *export activity* positively influences the realisation of project additionality. Results suggest that export active firms ceteris paribus have a higher probability to abandon the project if they do not receive public support for their initiated projects. The results of the basic project additionality model in general confirm earlier results from scarce previous empirical work (see, for instance, Falk 2007).

However, the focus of interest is on the extended model versions including R&D relevant characteristics. For the extended project additionality model (column (2) of Table 1), the results show that a higher *R&D intensity* and a higher *experience in research field* decrease the probability that project additionality appears, i.e. we can confirm hypothesis (*i*) from our empirical results. R&D intensive firms have a 31% lower probability to realise project additionalities due to public R&D funding than non-R&D intensive firms, holding all other variables at their mean. One can assume that R&D intensive firms with a large knowledge stock

have a higher capability to select their projects from the outset. Hence, they probably conduct their major projects irrespective of the provision of public support. Concerning *experience in research field*, results show that prior thematic orientation and competences increase the average probability to continue their research activities within a project, even if public support is refused, by 17%. Considering the results for *technological specialisation*, hypothesis (*iv*) can be confirmed. Technologically diversified firms are less likely to change their behaviour due to the rejection of public funding, other things being equal. More specialised firms have a 25% higher average probability to realise project additionality than their diversified counterparts. As technological diversification empirically often goes in line with the level of maturity, this additionally supports prior findings. The parameter estimates for *FP cooperation* is statistically not significant, i.e. hypothesis (*vii*) has to be rejected. Therefore, one may conclude that prior FP cooperation experience has no significant effect on the decision of continuing or cancelling a project.

The scale additionality model (see column (3) and column (4) of Table 1) produces mixed results. For the basic model, we get – as expected – almost contrary results than for the project additionality model. Behavioural additionality decreases with *firm age*, but increases with a firm´s *export activity*. The *firm size* does not influence the realisation of scale additionalities. The results of the extended model versions show that only *technological specialisation* has a statistically significant effect on the probability of scale additionality. Technologically specialised firms have a 27% lower probability to re-adapt their project scale due to public funding, holding all other variables at their mean. Thus, hypothesis (*v*) is confirmed. They are more likely to continue their activities as originally intended. Technologically specialised firms may create projects at their core fields of activity. Research and development in a specific field may therefore be substantial for the whole strategy. In contrast, more diversified firms may run various projects and research activities simultaneously. A refusal of public financial support for a specific project may more often result in downgrading the scale of projects, as developments in a specific field are of minor importance and may be postponed.

Table 1: *ML estimations for the behavioural additionality models 2006* (n = 155)

	Project additionality		Scale additionality		Cooperation additionality	
	basic (1)	extended (2)	basic (3)	extended (4)	basic (5)	extended (6)
Constant	0.900 ** (0.433)	-0.379 (1.312)	-2.281 *** (0.520)	1.945 (1.693)	-0.899 * (0.486)	-1.371 ** (1.499)
General characteristics						
Firm size (β_1)	-0.118 * (0.070)	-0.069 (0.078)	0.135 (0.083)	0.063 (0.088)	-0.043 (0.079)	-0.028 (0.091)
Firm age (β_2)	-0.387 * (0.207)	-0.459 ** (0.233)	0.383 * (0.205)	0.482 * (0.249)	-0.155 (0.236)	-0.439 (0.301)
Export activity (β_3)	0.973 ** (0.417)	0.919 * (0.498)	-1.192 ** (0.530)	-1.616 ** (0.807)	0.389 (0.455)	1.509 ** (0.623)
R&D related characteristics						
R&D intensity (β_4)	–	-1.368 ** (0.600)	–	-0.785 (0.826)	–	0.318 (0.614)
Experience in research field (β_5)	–	-0.701 * (0.384)	–	0.209 (0.460)	–	-1.230 *** (0.437)
Technological specialisation (β_6)	–	1.067 ** (0.533)	–	-1.983 *** (0.755)	–	-0.153 (0.593)
FP cooperation (β_7)	–	0.000 (0.001)	–	-0.002 (0.001)	–	0.002 ** (0.001)
Controls						
Service sector (β_8)	–	-0.489 (0.483)	–	0.510 (0.591)	–	1.977 *** (0.683)
Research organisation (β_9)	–	1.108 * (0.668)	–	-0.289 (0.931)	–	1.070 (0.771)
Model fit						
Log-likelihood	-98.83	-90.26	-75.73	-70.64	-82.19	-72.94
AIC	205.66	200.52	159.47	161.49	172.38	165.88
Likelihood ratio test	10.28 **	27.42 ***	10.62 **	20.81 **	1.21	19.71 **

Notes: Breusch-Pagan Tests confirm the null hypothesis of no heteroscedasticity for all model versions; asymptotic standard errors given in brackets; ***significant at the 0.01 significance level, **significant at the 0.05 significance level, * significant at the 0.1 significance level

No statistically significant evidence is found for the remaining R&D relevant variables in the extended scale additionality model. Thus, hypothesis (*ii*) and hypothesis (*viii*) have to be rejected. One may conclude that the realisation of scale additionality is primarily influenced by general firm characteristics, with the exception of the firm´s technological specialisation. Adapting the size of the project due to public funding appears to be rather a matter of organisational and structural resources and not of R&D-related resources and competences.

The cooperation additionality model is given by columns (5) and (6) of Table 1. Regarding general firm characteristics, only *export activity* significantly affects cooperation additionality. It increases the average probability to initiate new collaborations by about 27%, holding other variables at their mean, while *firm size* and *firm age* play no statistically significant role. Concerning R&D relevant characteristics, two variables significantly influence the realisation of cooperation additionalities, namely *experience in research field* and *FP cooperation*. *Experience in research field* lowers the probability of cooperation additionality by about 19%, holding other variables at their mean. The odds for cooperating with new partners are 3.43 times higher for firms, which are still at the initial stage in a specific field. Firms that are acquainted with the peculiarities and risks of researching in a technological field are, ceteris paribus, less likely to look for new partners. They have already developed a critical knowledge stock and are less dependent on external knowledge flows. Thus, hypothesis (*iii*) can be partly confirmed (note that the estimate for *R&D intensity* is statistically not significant). The parameter estimate for *FP cooperation* shows a significant positive sign. Experience in cooperating and knowledge transfer increases – other things being equal – the likelihood of including new partners in the project consortium. Hypothesis (*ix*) can thus be confirmed, though the effect is rather small. Engaging in an additional FP cooperation increases the odds of cooperation additionality only marginally. Since we find no significant influence of a firm´s technological specialisation on the realisation of cooperation additionalities, hypothesis (*vi*) has to be rejected.

6 Closing comments

The concept of behavioural additionality has come into fairly wide use in evaluation of R&D policy programmes in recent years. The notion of behavioural additionality refers to changes in the way a firm performs its R&D activities induced by public policy support (Buisseret et al. 1995). Up to now, we know only little about the relationship of the realisation of behavioural additionalities and distinct firm characteristics at the firm level. Thus, the objective of the study at hand was to estimate the influence of distinct firm characteristics on the realisation of different types of behavioural additionalities, namely project additionality, scale additionality and cooperation additionality, at the firm level.

In our analytical framework we focused – in contrast to scarce previous empirical work (see, for instance, Falk 2007) – on different R&D relevant characteristics, such as R&D intensity or experience in a specific research field that may influence the occurrence of behavioural additionalities. In our study, we employed a binary regression modelling perspective to disclose the link between the realisation of behavioural additionalities and distinct firm characteristics. We estimated logistic binary probability models for each type of behavioural additionality under consideration, using data from a survey among 155 firms that were funded by the Austrian STI policy programme *Intelligent Transport Systems and Services – IV2S* in the year 2006. We combined observed behavioural additionalities – as captured by the survey – with distinct firm characteristics by matching the survey based information with other databases such as the Aurelia database, the internal database of the Austrian Research Promotion Agency (FFG), the EUPRO database of the Austrian Institute of Technology, and the PATSTAT database of the European Patent Office (EPO).

The results of the empirical analysis provide interesting insights, in particular for policy makers, on the relationship between distinct firm characteristics and the realisation of different types of behavioural additionalities. *First*, when analysing why certain firms realize behavioural additionalities as a result of public R&D subsidies, it is of crucial importance to take R&D relevant characteristics into account. Model fit significantly increases when such characteristics are added to standard model specifications featuring general firm characteristics such as firm size or firm age only. *Second*, the influence of R&D related firm characteristics differs across specific types of behavioural additionality under consideration. While R&D related resources and competencies play an important role for the realisation of project additionalities, they do not affect scale additionalities, and only partly influence cooperation additionalities. R&D intensity and previous experience in the research field significantly lowers the probability for project additionalities. A higher experience in the research field, moreover, decreases the likelihood of cooperation additionality. One may conclude that firms familiar with the peculiarities of a very specific technological field are acquainted with relevant partners, and, thus, are less likely to look for new partners in the field. In contrast, scale additionalities such as size adaptations of projects resulting from public R&D subsidies are not affected by R&D resources and competences, but are mainly related to general firm characteristics such as firm size and firm age. *Third*, the technological specialisation of the firm plays a crucial role for behavioural additionalities, in

particular concerning project additionality and scale additionality. Technologically specialised firms have a higher probability to realise project additionalities, but they show a lower probability to re-adapt their project scale due to public funding, i.e. to realize scale additionalities. *Fourth*, previous international cooperation shows no or rather small effects on behavioural additionalities. Only for cooperation additionalities the empirical results point to a positive – but rather small – effect of previous international collaboration behaviour.

These empirical results point to significant implications for STI policy makers: *First*, R&D relevant characteristic are to be taken into account when analysing the realisation of behavioural additionalities at the firm level. *Second*, direct R&D promotion of firms with very high R&D resources and competences may be misallocated regarding the stimulation of behavioural additionalities. *Third*, future policy programmes that support collaborative R&D should especially address firms with lower experience in a specific research field, since highly experienced firms realise lower cooperation additionalities. *Fourth*, since technologically specialised firms are more likely to realise project additionalities, i.e. to cancel the project without public funding, such firms should be particularly considered in the design of future policy measures.

Furthermore, the study confirms that econometric firm-level analyses of survey data merged with additional databases are an appropriate instrument for policy evaluation. In the context of STI policy, this delivers new insights into specific impacts and influences of public R&D funding which might in turn be valuable for future policy designs. However, the study is afflicted with some limitations raising issues for further research: Underlying data is spatially and technologically limited to the Austrian transport and mobility area. This may control for intervening environmental factors, but limit to a certain extent the general validity of results. Differences between particular sectors and regions are conceivable. Supranational analyses with an extended set of data might further provide significant findings on the interactions of public R&D assistance and firm-specific characteristics.

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Appendix

Table A: *List of independent variables*

Variable name	Type	Description	Source
General characteristics			
Firm size	Numeric	No. of total employees in logarithmic form	Aurelia
Firm age	Categorical	Period of existence from founding year until project launch; five categories* based on natural breaks (Jenks 1967)**	Aurelia
Export activity	Dummy variable	1 if exports are recorded; 0 otherwise	Aurelia
R&D relevant characteristics			
R&D Intensity	Dummy variable	1 if R&D intensity is higher than 50%; 0 otherwise; based on natural breaks (Jenks 1967)**	internal FFG data
Experience in research field	Dummy variable	1 if project is based on preliminary work; 0 otherwise	IV2S survey data
Technological specialisation	Dummy variable	1 if index of specialisation is higher than 0.69; 0 otherwise; based on natural breaks (Jenks 1967) **	EPO Patstat
FP cooperation	Numeric	No. of projects in 5th and 6th EU-FPs	EUPRO
Controls			
Service sector	Dummy variable	1 if respective sector; 0 otherwise	IV2S survey data
Research organisation	Dummy variable	1 if respective sector; 0 otherwise	IV2S survey data
Industry	Dummy variable	Reference category	IV2S survey data

Notes: * (less than 20; 21-48; 49-69; 70-82; higher than 82). ** The natural breaks classification method according to Jenks (1967) is a data classification method that seeks to minimise the average deviation within a class from the respective mean, while maximising the deviation from the means of the other classes.

Research Highlights

- We study changes in firms' innovation behaviour resulting from public R&D funding
- We estimate how firm characteristics affect the realisation of such additionalities
- Large and R&D intensive firms less likely substantiate behavioural additionality
- Small, young and specialised firms more likely realise behavioural additionalities
- In a policy context, R&D support of R&D intensive firms may be misallocated