UNIVERSITY OF LINCOLN

L INCOLN E CONOMICS A ND F INANCE

LEAF Working Paper Series

No. 19-05

National and international R&D support programmes and technology scouting in European small and medium enterprises (SMEs)

Dragana Radicic

Lincoln International Business School, University of Lincoln,
Brayford Pool, Lincoln, LN6 7TS
Tel: +44 (0)1522 882 000

National and international R&D support programmes and technology scouting in European small and medium enterprises (SMEs)

Dragana Radicic[1]

October 2019

Abstract

This paper evaluates the effectiveness of national and international R&D support programmes on firms' technology scouting, defined as firms' use of external knowledge sources. Drawing on a unique dataset on R&D support programmes for small and medium-sized enterprises (SMEs) operating in both manufacturing and service sectors across 28 European countries, this study reports treatment effects estimated by the copula-based endogenous switching model, which takes into account unobserved firm heterogeneity. Empirical results indicate that R&D support programmes have heterogenous effects on technology scouting, whereby a crowding out effect arises in the case of a short-run scouting, while additional effect are mostly reported for strategic external knowledge sourcing. Moreover, our results suggest that unfavourable, crowding out, effects could be reduced, if not eliminated, by a random distribution of public funding.

Keywords: Technology scouting, External knowledge search, European SMEs, copula-based endogenous switching model

[1] Lincoln International Business School, Dradicic@lincoln.ac.uk

1. Introduction

Innovation policy has taken centre stage among policy makers in the European Union (EU) (Edler et al., 2012). One of three priorities put forward in a new EU strategy for economic growth and employment - Europe 2020, is achieving and sustaining smart growth by developing an economy based on knowledge and innovation (European Commission, 2010). To achieve a common strategy of Europe 2020, the European Commission designed Horizon 2020, the 2014-2020 Framework Programmes for Research and Technological Development, with a generous budget of nearly 80 billion Euros to be invested in creating innovation-led growth and fostering research (CLORA, 2013). A key feature of Horizon 2020 is the emphasis given to innovation that encompasses a broad perspective. It acknowledges not only R&D and research, but also demand-driven innovation through public procurement and setting up of standards and regulations, for non-technological innovation and areas relevant for this type of innovation, such as design, service innovation and creativity (European Commission, 2013a).

Another relevant feature of Horizon 2020 is attention dedicated to small and medium-sized enterprises (SMEs), through policy instruments that will aim to support development, growth and internationalization of SMEs (European Commission, 2013b). Small and medium-sized enterprises are the engine of growth in the European economy, contributing to employment with 66.5 per cent of all European jobs in 2012 and gross value added at 57.6 per cent (European Commission, 2013b). Innovation is among the most important means through which small and medium sized enterprises contribute to increased employment, economic growth and development.

Policy makers not only recognize the importance of innovation and its public support, but increasingly recognize the relevance of evaluating the impact of support measures (Edler et al., 2012). Therefore, the central question within the evaluation debate is related to the effectiveness of public subsidies, i.e. whether firms indeed increase their innovative efforts as a result of public intervention. Evaluation of public innovation support attempts to answer this question through qualitative evaluation (including case studies and interviews) and through quantitative evaluation using *inter alia* econometric evaluation models and techniques. Referring to this latter approach, key research questions pertain as to whether public support measures induce larger investment in R&D, relative to firms' private funding (input additionality); larger innovation output, such as the introduction of technological and non-technological innovations (output additionality); and, whether policy instruments establish changes in firms' innovative behaviour (behavioural additionality) (Busom and Fernández-

Ribas, 2008; Cerulli, 2010; Falk, 2007). In general, if public support measures have a positive impact on the above innovation indicators, it is interpreted as additionality effect, i.e. public funding is a complement to firms' private innovation activities. On the contrary, if public support measures are ineffective, public funding crowds out (substitutes) firms' innovation activities (Busom 2000; David et al., 2000). It is worth noting that the effectiveness of public support is an econometric issue, as theoretically, either effect is plausible (David et al., 2000).

Our study evaluates the effectiveness of R&D support programmes on firms' technology scouting (i.e. the use of external knowledge sources), thus fitting into the category of behavioural additionality studies. Furthermore, very few evaluation studies examine the effectiveness of public innovation programmes across countries. This study aims to contribute to filling this gap by examining the impact of national and international R&D support programmes on European SMEs. In addition, our key contribution is associated with the empirical strategy employed in this study. This is among first study to explore the policy effects on technology scouting applying a copula-based endogenous switching model. Most cross-sectional empirical studies employ matching estimators, although their main disadvantage is the selection on observables, i.e. unobserved firm characteristics cannot be taken into account, thus raising an issue of robustness of empirical findings to unobserved heterogeneity. Unlike matching estimators, an endogenous switching model (also known as a Roy model or tobit 5 type model, Hasebe, 2013) controls for both observed and unobserved firm characteristics.

Additionally, another contribution of our study is related to the estimated treatment parameters. Namely, most evaluation studies report the average treatment effect on the treated (ATT) effects, without considering an issue of potential misallocation of public funding. That is, by estimating the average treatment effect (ATE), and by comparing it to the ATT effect, we can conclude whether public support could be more effective if randomly distributed among firms (in which case, the ATE would be larger than the ATT, as the ATE, by definition, represents the treatment effect had public support been distributed among random population of firms).

The reminder of the paper is structured as follows. Section 2 provides a brief literature review of empirical studies exploring behavioural additionality. Section 3 describes the data and the empirical strategy. Section 4 discusses the empirical results, while Section 5 present main conclusions and policy implications drawn from the empirical analysis.

2. Literature review

The traditional or neo-classical approach to public support of technology and innovation is based on the theory of market failures. Other approaches are those of evolutionary economics and systems of innovation, which focus on systemic failures. Systemic failure and market failure approaches are not mutually exclusive, but rather complement each other (Smits, 2002). Market failures refer to inefficient allocation of goods and services in a market due to externalities, asymmetric information, non-competitive markets, uncertainty and risk, appropriability issues, indivisibility of knowledge generation, imperfect capital markets and missing markets for high-risk investments (Arrow, 1962). From the late 1950s onwards, the market failure rationale has provided a basis for public innovation policies (Schröter, 2009).

The evolutionary approach of systemic failures has been developed since the 1990s as a corollary of the development of evolutionary economics and of a resource-based, evolutionary theory of the firm (Smits, 2002). The systems approach to public innovation policy emphasizes the role of institutions and innovation infrastructure. Innovation policy should enhance firms' access to knowledge by developing an institutional structure that is aimed at supporting innovation processes, i.e. an innovation system. The policy incorporates not just innovation-related activities, but also the domains of education and training, science, technology, the labour market and regulated industries (Hauknes and Nordgren, 1999). The market is just one constitutive element in the process of technological advances and innovation processes. The other element pertains to institutions and networks in the broad context of innovation systems. Therefore, the systems approach does not exclude the policy instruments designed to address market failures, but introduces additional instruments aimed at changing the institutional set-up under which innovation processes occur.

With respect to different types of additionality effects, input additionality and output additionality arise from the traditional or neo-classical market failure rationale, while a broader concept of behavioural additionality has emerged from the evolutionary, system failure rationale. Compared to a large number of empirical studies on input additionality and to a lesser extent on output additionality, behavioural additionality has been the subject of only a few studies. An interesting feature of the empirical analysis of behavioural additionality is that matching estimators are the only estimation methods that have been employed. The reason for this is associated with impediments imposed by the data at hand. Innovation studies, in general, mostly report empirical findings from the Community Innovation Survey (CIS) datasets. The main issues with this large-scale survey are twofold: first, the survey is not longitudinal by design, which typically precludes panel analysis; and, second, other evaluation methods, such as selection models and Instrumental Variable (IV) approaches require a valid instrument, which is hard if not impossible to find in the CIS surveys (Busom and Fernández -Ribas, 2008).

Among the first studies to investigate behavioural additionality is the one by Fier et al. (2006), who assessed the impact of public support on innovative behaviour of German firms in manufacturing sectors. Behavioural additionality is measured by three types of cooperation: with other businesses; with scientific institutions; and a combination of both. The results from matching estimation on the third and fourth CIS datasets are positive for all three types of cooperation. Moreover, the results indicate the heterogeneity of the impact; the largest effect of public support is on combined cooperation, and the smallest on cooperation with other businesses.

Busom and Fernández-Ribas (2008) used a subsample of Spanish manufacturing firms participating in the CIS survey in 1999 to explore the impact of national support programmes on vertical cooperation (with suppliers and customers) and with private-public partnerships (cooperation with universities or public laboratories). National programmes have a positive effect on both types of cooperation, but the effect on private-public partnership is more prominent; the average treatment effect of the treated (ATT) on this type of partnership is twice the effect on vertical cooperation.

Fernández - Ribas and Shapira (2009) investigate how local and national support programmes affect cooperation with international partners among manufacturing firms in Catalonia. The authors use the third CIS survey covering the period 1998 -2000. The estimated ATT effect is positive, but fairly small (8 percentage points). Afcha- Chàvez (2011) explores behavioural additionality using the Spanish ESEE survey of business strategy for the period 1998-2005. The treatment effects are estimated for vertical cooperation and private-public partnerships while separating regional from national programmes. Estimated programme effects are significantly positive only for private-public cooperation for both sources of funding, but not significant for vertical cooperation.

Antonioli et al. (2014) investigate the impact of a specific regional innovation policy (PRRITT) in the Italian region of Emilia-Romagna. The results are contrary to previous studies – the authors report no effect of public support on regional cooperation. Furthermore, regional policy shows a negative effect on horizontal cooperation. In summary, most studies report behavioural additionality, i.e. a positive impact of public support on firms' cooperation. However, the magnitude and significance vary depending on sources of funding and types of cooperative partners.

3. Methodology

3.1 Data

The dataset used in the analysis was gathered in 2010 within the MAPEER project commissioned by the European Commission's DG-Research.[2] The survey questionnaire covered the period 2005-2010. The sample includes 763 SMEs from 28 European countries. The survey was targeted at the population of SMEs with less than 250 employees and an annual turnover of less than 50 million Euros (EU definition of SMEs - Article 2 of the Annex of Recommendation 2003/361/EC) (European Commission, 2005). Within the group, micro-sized firms are defined as those with less than 10 employees, small firms with 10 or more and less than 50 employees and medium-sized firms with 50 or more and less than 250 employees. The sample consists of 376 micro firms, 242 small firms and 145 medium-sized firms. Given the small number of firms from individual countries, we grouped them into four categories following the European Innovation Scoreboard (European Commission, 2011). The categories are as follows (for variable construction and descriptive statistics see Table A.1):

- *'Innovation leaders'*, countries whose innovation performance is well above the EU27 average. Our sample consists of 146 SMEs operating in countries from this category.
- *'Innovation followers'*, countries with performance close to the EU27 average (219 firms in our sample; this is the base or reference category);
- *'Moderate innovators'*, countries whose performance is below that of the EU27 average (284 firms in the sample); and
- *'Modest innovators'*, representing countries whose performance is well below that of the EU27 average (114 firms in the sample).

Grimpe and Sofka (2008) control for heterogeneity in national innovation systems by grouping 13 EU countries on the basis of their total national R&D expenditure (GERD) as a share of each countries' GPD. For a robustness check, they grouped countries based on the share of firms performing R&D on a continuous basis. We opted to control for distinct national innovation systems based on both innovation inputs and outputs, and not just on innovation inputs (such as R&D expenditure).

[2] The description of and information about the project are given on https://cordis.europa.eu/project/rcn/93511/factsheet/en and https://www.strast.cz/en/projects/projects-list/mapeer-sme.

Table A1 in the appendix shows the variable description and summary statistics for the treatment and outcome variables, as well as for control variables. Half of the surveyed SMEs (53.2 per cent) participated in national/regional R&D programmes in the period covered by the survey, while less than a third of firms (30.3 per cent) received public support from international sources. Regarding the use of external knowledge sources, the largest number of firms (62.5 per cent) utilizes informal networks with other firms as a source of external knowledge, followed by customer involvement (59 per cent of firms), informal networks with research organizations (52.6 per cent) and strategic alliances with other firms (44.9 per cent). The least practiced networking activity is non-equity alliances with other firms (24.9 per cent). With regards to firm characteristics, the modal group of SMEs' reported total R&D expenditures as a percentage of total expenditure is the range of 11 to 20 per cent, two-thirds of firms are exporters (67.9 per cent), and a similar proportion of SMEs reports a highly competitive intensity (61.3 per cent). Moreover, 41.4 per cent of firms have a separate R&D department, while half of the sample firms have a defined R&D and innovation strategy for the period 2010-2015. Less than a third of firms are located in technology parks/areas and have integrated a technology platform (23.6 and 24.5 per cent respectively). Finally, concerning firms' innovative capacity, 44.4 per cent of firms reported to have devoted fewer resources to innovation five years prior to the survey, while 23.5 per cent of firms reported to have had a leading innovation capacity relative to their competitors.

3.2 Empirical strategy

Measuring the impact of a treatment includes economic agents (firms, households, and individuals), potential outcomes and treatment. We will refer to firms in our further discussion. If we denote T_i to be treatment (T_i =1 if a firm i received a treatment and T_i=0 if not) and $Y_i(T_i)$ for outcomes of firms i = 1,..., N, where N is the total population of firms, $Y_i(1)$ is the outcome of treated firms, $Y_i(0)$ is the outcome of treated firms without a treatment, and Δ_i is a treatment effect for a firm i, then

$$\Delta_i = Y_i(1) - Y_i(0) \qquad (1)$$

Equation 1 points to the fundamental evaluation problem. To evaluate the impact of a treatment, both outcomes with and without treatment should be simultaneously observed. Therefore, the outcome for treated firms had it not been treated (counterfactual outcome - $Y_i(0)$)

cannot be observed and has to be estimated, which implies that the treatment effect itself cannot be observed and must be estimated (Aakvik et al., 2005).

Further, two effects are usually estimated in the evaluation literature. The average treatment effect (ATE) indicates the difference in outcome between two counterfactuals: the outcomes for all firms if they were to be treated, Y(1) (e.g. by programme participation); and the outcomes for all firms if they were not to be treated, Y(0). As not all firms are treated and not all firms are untreated, both Y(1) and Y(0) are counterfactuals that have to be estimated.

$$ATE = E[Y(1) - Y(0)] \quad (2)$$

The average treatment effect on the treated (ATT) indicates the difference in outcomes of the treated firms with and without treatment and can be written as:

$$ATT = E[Y(1)|T = 1] - E[Y(0)|T = 1] \quad (3)$$

The second term $E[Y(0)|T = 1]$ in Equation 3 is the expected outcome had treated firms not receive a treatment. This is a counterfactual outcome that is not observed. If the unconditional outcome of non-treated firms is taken to estimate the counterfactual outcome, then that would lead to selection bias, as treated and non-treated firms may differ even before a treatment assignment (Aakvik et al., 2005). The problem of selection bias can be solved by imposing certain identifying assumptions, which will be further discussed in Section 3.3. Thus, evaluation methods are designed to take into account the estimation of counterfactual outcomes as well as to control for selection bias. David et al. (2000) in their review of the evaluation innovation studies, pointed out that public support in a domain of R&D and innovation should be treated as endogenous, given two sources of selection bias usually pertinent to the selection process: first, firms self-select themselves into public support programmes, and second, managers in public agencies adopt a 'picking the winner' strategy (see e.g. Antonelli and Crespi, 2013), that is, select those firms that are more likely to succeed in their innovation activities.

3.3 Model Specification

Our main hypothesis is that SMEs participating in R&D support programmes would show on average a significantly higher propensity to use specific approaches to external knowledge than non-participating firms. Our treatment variables are constructed as binary variables equal to 1 if a firm participated in national R&D programmes, and zero otherwise (variable *National participation*) and equal to 1 if a firm participated in international R&D programmes and zero otherwise (variable *International participation*). Regarding outcome variables, the dataset contains information on the six different approaches to acquiring external knowledge:

- Informal networking with other firms;
- Informal networking with research organizations;
- Strategic alliances with other firms;
- Non-equity alliances with other firms (a type of alliance that is not based on formal economic return for either party);
- Participation in innovation networks, S&T parks, clusters, etc.; and
- Customer involvement (i.e. close involvement of customers in idea generation/concept development).

Each approach to acquiring external knowledge is measured on a five-point scale (from 'Don't apply at all' to 'Apply expensively'). Based on the scale, binary indicators were created for each source, where the indicator is equal to 0 if the firm reports either of three categories ('Do not apply at all'; 'Do not apply'; or 'Neutral') and is equal to 1 if the firm reports either 'Apply' or 'Apply extensively' for a particular source of external knowledge.

Following Van de Vrande et al. (2009), SMEs often engage in informal networking, because this type of networking relationships does not require substantial financial resources, which are, besides limited human resources, major constraints in SME innovation activities. Our dataset contains information on two types of informal networking (with other firms and with research organization) as sources of external knowledge. To avoid cooperation failure in networking with other economic agents, firms require strong appropriation mechanisms. Another way of avoiding cooperation failure is the use of knowledge and innovation brokers (Lee et al, 2010). These intermediary organisations can facilitate SMEs in finding appropriate collaborative partners and creating a climate of trust between partners and, at the same time, preventing involuntary information leakage among partners. Huizingh (2011) argues that both large and small firms can benefit from intermediaries, particularly for outbound open innovation. The questionnaire used in our study contains questions on the extent of use of online technology and knowledge brokers/intermediaries as sources of external knowledge. We utilize this question to measure the openness of innovation processes and the use of knowledge brokers.

A further source of external knowledge included in the analysed survey is that of strategic alliances. Narula and Hagedoorn (1999) refer to strategic alliances as cooperative agreements aimed at long-term profit optimisation. They argue that the form of cooperative agreement depends on the underlying motives: establishing and maintaining vertical cooperation with customers and suppliers is mainly motivated by cost reduction and short-term profit increase; whereas firms enter strategic alliances to increase the value of the firm and it long-term market position. However, SMEs are less likely to form strategic alliances than are large firms, due to a higher level of physical resources needed for this type of networking (Narula, 2004; Narula and Hagedoorn, 1999). We extend this argument by pointing out that partnerships, through strategic alliances, would require certain entrepreneurial/managerial resources and competences, identified as the major constraint in the resource-based view of the firm (Barney, 1991; Peteraf, 1993). Furthermore, the high failure rate of strategic alliances is also associated with higher levels of investment and involvement required for this type of cooperation (Narula and Hagedoorn, 1999). But, if SMEs do cooperation through strategic alliances, their impact on SME performance and innovativeness is positive, suggesting that this form of networking is an important source of external knowledge (Lee et al., 2010).

In addition, our dataset contains information on non-equity alliances, defined as a type of alliance that is not based on formal economic return for either party. Following Hagedoorn (2002), non-equity alliances are more relevant for firms in high-tech and ICT sectors than for firms in medium and low-tech industries. Emden et al. (2006, p. 338) define co-development alliances as 'non-equity-based relationships in which each party contributes a significant portion of the end solution'. A unique feature of non-equity alliances is that partners maintain a certain level of competitiveness towards one another, while cooperating through this type of alliances.

The treatment parameters are obtained by estimating a copula-based endogenous switching model. The model has two equations: Equation 4 is the outcome equation, which estimates the probability of firms using external sources of knowledge conditional on both other influences on the usage of external knowledge and the probability of participating in a support programme; and Equation 5 is the selection equation, which models the participation decision, that is, the probability that a firm will participate in R&D programme.

$$Knowledge\_source_i = C_1 + \beta Participation_i + \gamma Z_i + u_i \quad (4)$$

$$Participation_i = C_2 + \lambda Z_i + \theta Obstacle_i + \varepsilon_i \quad (5)$$

Where subscript i indexes each firm in the sample 1…n, where n is the number of firms; C_1 and C_2 represent the intercept in equations 1 and 2 respectively; the β coefficient measures the effect of programme participation; the γ and λ coefficients measure the effects of control variables commonly identified in the literature (firm size, market power, exporting activities etc.) on the use of knowledge sources and the participation in R&D programmes, respectively; the k×1 θ vector contains coefficients that measure the participation effects of a 1×k vector of indicators of firms' views on factors promoting or impeding programme participation (*Obstacle*), which are the anticipated identifying variables; and u and ε are the error terms, which capture the unobserved influences on the respective dependent variables. Full definitions and descriptive statistics for each variable are presented in Table A1 in appendix.

The independent variables must include (for econometric reasons) all the control variables from the outcome equation 4 together with at least one variable to identify equation 5. This identifying variable (Obstacle) must influence the programme participation decision but not the probability of using external knowledge sourcing. For this purpose, the survey included a question related only to programme participation whereby firms were asked about SME needs in general: "Which would you say are the specific needs for SMEs in order to participate in R&D programmes??" In all 22 parts of this question, the corresponding indicator variable was defined as 1 if the response was "Very high importance" and 0 otherwise ("No importance", "Low importance", "Important" or "High importance"). However, only few of these variables were used as exclusion restrictions (see Table A1 for their description and summary statistics).

We constructed Equation 4 to test the hypothesis that whether or not a firm use a particular form of technology scouting depends on whether or not the firm participates in R&D programme. This makes *Participation* a switching variable: if the firm participated in R&D programme (*Participation* = 1), then it enters a state in which the use of knowledge source is hypothesised to be more likely (Regime 1); if the firm did not participate in R&D programme

(*Participation* = 0) then the firm remains in a state less conducive to using a particular knowledge source (Regime 0).[3]

Because the outcome variable, *Knowledge_source*, can exist in one of two regimes, Equation 4 should be estimated over both regimes 1 and 0, in which case *Participation* disappears as a separately estimated variable. Instead of the single Equation 4, we now have two equations, 4a and 4b, differentiated by an additional subscript: 1 for Regime 1 (for which *Participation* = 1); and 0 for Regime 0 (for which *Participation* = 0).

Regime 1 (*Participation* =1)

$$Knowledge\_source_{i1} = C_{11} + \gamma_1 Z_{i1} + u_{i1} \qquad (4a)$$

Regime 0 (*Participation* =0)

$$Knowledge\_source_{i0} = C_{10} + \gamma_0 Z_{i0} + u_{i0} \qquad (4b)$$

This switching process is endogenous if unobserved influences on *Knowledge_source* (u_{i1} in equation 4a and u_{i0} in equation 4b) are correlated with unobserved influences on *Participation* (ε_i in equation 5). In this three-equation model (5, 4a and 4b), a bivariate outcome (*Knowledge_source*) is partitioned into two regimes by a potentially endogenous bivariate switching variable (*Participation*). The three equations are linked by both common observed variables and, potentially, by common unobserved variables.

The estimated switching probit model can be used to generate counterfactual probabilities of acquiring external knowledge for firms in different regimes of participation (Lokshin and Glinskaya, 2009). In turn, these probabilities are used for the calculation of the average treatment effects of the treated (ATTs) and the average treatment effects (ATEs). As our main focus is not the interpretation of the estimated coefficients, but rather the interpretation and a comparison of the estimated treatment effects, the results of the estimated switching probit models are presented in the appendix Tables A3 and A4 for national R&D programmes, and Tables A5 and A6 for international programmes.

[3] Firms responded to the questions: "Did you participate in national / regional R&D programmes in the last 5 years? and "Did you participate in international R&D programmes in the last 5 years?". The limitation of the corresponding *Participation* variable is that we lack information on the level of support. This limitation is shared with the EU's Community Innovation Survey (CIS).

The original implementation of the endogenous switching model relies on the strong assumption of joint normality of the error terms (Aakvik et al., 2005). Consequently, if the normality assumption does not hold, the estimates will be inconsistent. To relax the normality assumption in sample selection models, Smith (2003) applied the copula approach, which allows different types of joint distribution in error terms between the outcome and the selection equations (Hasebe, 2013). Moreover, another advantage is that the copula method allows the model to be estimated via the maximum likelihood method, which means that the estimates are efficient (Hasebe, 2013). A copula represents a joint distribution function that binds together marginal distributions of the error terms in the selection and the outcome equations, although the copula itself is independent of marginal distributions (Smith, 2003). In our analysis, we have considered a range of copulas: Gaussian, Frank, Plackett, Clayton, AMH, FGM, Joe, and Gumbel (for detailed discussion see Smith, 2003; Trivedi and Zimmer, 2005; Hasebe, 2013). In each of the estimated models reported below, the preferred copula was determined using the Vuong test together with the AIC and BIC information criteria. The former evaluates the contribution of each copula to the log likelihood, such that the copula with the highest contribution is preferred (Hasebe, 2013). In addition, the smallest AIC or BIC suggests the preferred copula (Smith, 2003; Hasebe, 2013).

Control variables are grouped into three categories: those measuring firms' absorptive capacity; those controlling for firm characteristics; and those controlling for external, environmental (external) influences. Firms' absorptive capacity is usually measured by internal R&D activities, proxied by several measures: internal (intramural) R&D expenditures; the share of R&D personnel; and the presence of a separate R&D department (Spithoven et al., 2010). Our dataset contains information on each measure, but the variable measuring R&D expenditures (*R&D expenditure*) represents total R&D expenditures, thus including the following categories: R&D staff salaries; contracts to outside R&D performers; acquisition of machinery, equipment and software; purchase of patents and know-how from other organizations; training in R&D; and, market introduction of innovations. Having a separate R&D department is measured as a binary variable (=1 if a firm has a separate R&D department; 0 otherwise; *R&D department*). However, the variable measuring R&D expenditures *(R&D expenditure)* is highly correlated with the variable measuring the share of R&D personnel (the correlation coefficient is 0.79), suggesting a potential problem with multicollinearity if both variables were to enter the model (Greene, 2008). Hence, the model specification includes only the former, because it is a broader measure of innovation input. We also included a binary variable *R&D strategy* equal to 1 if the firm has defined a R&D and innovation strategy for the next five years (zero otherwise).

Regarding firm characteristics, we control for a firm's degree of internationalization by including a binary indicator that is equal to 1 if a firm undertakes exporting activities (*Export*). Exporting firms tend to have more incentive to innovate as a result of competitive pressure on international markets (Busom and Fernández-Ribas, 2008; Parida et al., 2012). SMEs are a heterogeneous group of firms; correspondingly, we created three binary indicators for micro firms with less than 10 employees (*Micro firms*), small firms having between 10 and 49 employees (*Small firms*) and medium-sized firms having between 50 and 249 employees (*Medium firms*). Moreover, the model includes two variables to control for firm-level "quasi" fixed effects (or initial conditions). The first variable (*Relative capacity*) is equal to 1 if firms report that their research and innovation record was leading compared to other firms in the industry five years prior to the survey (zero otherwise). The second variable (*Resources for innovation*) is equal to 1 if firms report having devoted fewer resources to innovation five years prior to the survey (zero otherwise).

Our model also takes into account environmental factors, such as competitive pressure, industry characteristics, and whether firms operate in technology parks and integrate technology platforms. Competitive intensity is measured as a binary indicator, equal to 1 if a firm reported that the competition is strong in its main markets (zero otherwise) (*Competition*). Furthermore, the model includes two binary indicators for firms located in technology parks (*Tech. parks*), and for those that integrate a cluster/technology platform (*Tech. platform*). Finally, we control for sectoral heterogeneity by constructing six industry categories following NACE classification: high tech; medium high tech; medium low tech; low tech; Information and Communication Technology (ICT); and services (as the base category).

Finally, the selection equation (Equation 5) should include all independent variables from the outcome equation (Equation 4) together with at least one additional, identifying variable. Identification restrictions are imposed on the model by including variables that influence the participation decision, but do not directly affect the use of external knowledge sources. The survey questionnaire for the MAPEER project included questions related only to programme participation. Specifically, the question that served as an exclusion restriction in our model was in relation to SME needs in general: "Which would you say are the specific needs for SMEs in order to participate in R&D programmes?". In all 22 parts of this question, the corresponding indicator variable was defined as 1 if the response was 'Most important' and 0 otherwise ('Not important at all', 'Not important', 'Neutral' or 'Important'). For each estimated model, the selection equation included only those parts of the relevant question that were statistically significant in the selection equation and insignificant in the outcome equation.

4. Results

The correlation matrix shown in Table A2 in the appendix indicates no issues with multicollinearity between the independent variables. For evaluating the impact of programme participation on firms' innovative behaviour, we estimated two treatment parameters - the average treatment effect on the treated (ATT), and the average treatment effect (ATE). Estimated treatment effects for each model are presented in Table 1 (for national R&D programmes) and in Table 2 (for international R&D programmes). In all models, the likelihood-ratio (LR) tests reject the null hypothesis of the independence of the error terms in the outcome and the selection models (columns 3 in both tables) (Hasebe, 2013).

The estimated treatment effects shown in Table 1 are rather heterogeneous across different outcome variables. A participation in national R&D programmes reduces the probability of the use of informal networking with other firms by programme participants by 14.9 percentage points (p.p.) but would have increased this probability for firms randomly selected from the entire population by 17.3 p.p. Likewise, receiving national support decreases the probability of the use of informal networking with research organizations by 8.3 p.p. but would have increased the probability for firms randomly selected from the entire population by 12.7 p.p. In contrast, receiving national support increases the likelihood of using strategic and non-equity alliances as external knowledge sources by 2.2 p.p. and 22.7 p.p. respectively, while the estimated ATEs in both cases are smaller than the ATTs (and the difference is statistically significant at the 1% level). Concerning SMEs' participation in innovation networks, receiving national R&D programmes reduces its probability by 0.2 p.p., while a random distribution of the programmes would have increased the likelihood by 8.4 p.p. Finally, the treated firms are less likely to use customers as the knowledge sources by 15.3 p.p., while a random distribution of national R&D support would have not resulted in significant, additional, effects.

Table 1. National support - the average treatment effect on the treated (ATT) and the average treatment effect (ATE)

Outcome variable	Copula	LR test of independence	ATT (n=315)	ATE (n=592)	Relation between ATT & ATE
Informal networking with other firms	AMH	p = 0.000	-0.149*** (0.000)	0.173*** (0.007)	ATT<ATE ***
Informal networking with research organizations	Frank	p = 0.011	-0.083*** (0.000)	0.127*** (0.006)	ATT<ATE ***
Strategic alliances with other firms	Frank	p = 0.018	0.022*** (0.000)	-0.007 (0.007)	**ATT>ATE *** **
Non-equity alliances with other firms	Plackett	p = 0.000	0.227*** (0.000)	0.017** (0.008)	**ATT>ATE *** **
Participation in innovation networks, S&T parks, clusters etc.	Frank	p = 0.000	-0.002*** (0.000)	0.084*** (0.007)	ATT<ATE ***
Close involvement of customers in idea generation and concept development	Frank	p = 0.002	-0.153*** (0.000)	0.011 (0.009)	ATT<ATE ***

Notes: *** *p<0.01*, ** *p<0.05*, * *p<0.10*. Bootstrapped standard errors, 1,000 replications.

Table 2. International support - the average treatment effect on the treated (ATT) and the average treatment effect (ATE)

Outcome variable	Copula	LR test of independence	ATT (n=178)	ATE (n=588)	Relation between ATT & ATE
Informal networking with other firms	AMH	p = 0.000	-0.077*** (0.000)	0.092*** (0.009)	ATT<ATE ***
Informal networking with research organizations	Joe	p = 0.001	0.104*** (0.003)	0.358*** (0.008)	ATT<ATE ***
Strategic alliances with other firms	AMH	p = 0.000	-0.041*** (0.007)	0.106*** (0.009)	ATT<ATE ***
Non-equity alliances with other firms	Frank	p = 0.000	0.136*** (0.000)	0.096*** (0.008)	**ATT>ATE *** **
Participation in innovation networks, S&T parks, clusters etc.	AMH	p = 0.000	0.006*** (0.000)	0.103*** (0.009)	ATT<ATE ***
Close involvement of customers in idea generation and concept development	Joe	p = 0.003	0.141*** (0.004)	0.166*** (0.010)	ATT<ATE

Notes: *** *p<0.01*, ** *p<0.05*, * *p<0.10*. Bootstrapped standard errors, 1,000 replications.

With regards to policy effects of international R&D programmes shown in Table 2, the first interesting finding is that this source of support produces more additional effects on technology scouting than national R&D programmes (four positive and significant ATTs compared to two in Table 1). More precisely, receiving international support increases the probability of using informal networking with research organizations (by 10.4 p.p.), the use of non-equity alliances (by 13.6 p.p.), participation in innovation networks (by 0.6 p.p.) and the use of customers (by 14.1 p.p.).

The second interesting finding is in relation to ATEs. Namely, although international support yields a larger number of additional effects than national support, a random distribution of this type of support would have results in larger effects on all external knowledge sources, except for the use of non-equity alliances. In other words, a random allocation of international R&D programmes would stimulate the use of external knowledge sources by SMEs to a larger degree than the current selection criteria.

5. Conclusions and policy implications

This study reports the impact of national and international R&D programmes on behavioural additionality in European SMEs, in particular, focusing on technology scouting. While receiving national R&D programmes increases the likelihood of using strategic and non-equity alliances as the knowledge source, receiving international R&D programmes also stimulates informal networking with research organizations and the use of customers.

Besides reporting the policy effects on treated firms, our analysis also provides the estimates of policy effects had R&D programmes been randomly allocated. Analysing each source of external knowledge separately, the results suggest that a random distribution of national R&D support measures would increase the probability of using informal networking, participation in innovation networks and customer involvement to a larger degree than the distribution using current selection criteria. This pattern is reinforced in the case of a random allocation of international R&D programmes, in which case, only a single ATT effect (on the use of non-equity alliances) is larger than the corresponding ATE. The largest potential effect of random distribution is implied by the results for informal networking with research organizations. Therefore, the overall results seem to indicate that, for most sources of external knowledge, a random distribution of R&D measures would have a substantially larger effect – even if only by reducing crowding out – rather than using current selection criteria.

This paper makes two contributions to the literature. First, it explores behavioural additionality applying the empirical strategy that takes into account both observed and unobserved heterogeneity. Our results suggest that public support measure might not have an additionality effect among surveyed firms. On the contrary, the overall findings suggest that public support measures crowd out SMEs use of networking as a source of external knowledge.

Second, it reports the ATE effects and compares it to the ATT effects to identify potential misallocation of public funding, and thus suggesting potential improvements with that respect. By randomly allocating public funding, public agencies could increase the effectiveness of public support measures on firms' acquisition of external knowledge. Current selection criteria should remain in place for the purpose of accounting for firms' observed characteristics, but in addition, they should be more inclusive to enable participation of other SMEs, that might increase their exploitation of external sources of knowledge to a larger extent than currently participating firms. In conclusion, a larger behavioural additionality among European SMEs might be achieved with a lottery system of public funding distribution (Authors, 2016).

Although our study provides new insights into behavioural additionality, future research might explore how public support measures affect firms' innovative behaviour in medium and long run, which would require the availability of longitudinal data. Furthermore, other types of behavioural additionality (such as cognitive capacity additionality, see e.g. Knockaert et al., 2014) could be explored. Finally, gathering and analysing information on the selection process could be a fruitful avenue for further exploration of the effectiveness of public funding (Antonelli and Crespi, 2013).

References

Aakvik, A., Heckman, J. and Vytlacil, E. (2005) ‘Estimating treatment effects for discrete outcomes when responses to treatment vary: an application to Norwegian vocational rehabilitation programs’, *Journal of Econometrics*, Vol. 125, No. (1-2), pp. 15–51.

Afcha Chàvez, S.M. (2011) ‘Bhavioural additionality in the context of regional innovation policy in Spain’, *Innovation: Management, Policy & Practice*, Vol. 13, No.1, pp. 95–110.

Antonelli, C. and Crespi, F. (2013) ‘The "Matthew effect" in R&D public subsidies: The Italian evidence’, *Technological Forecasting and Social Change*, Vol. 80, No. 8, pp. 1523–1534.

Antonioli, D., Marzucchi, A. and Montresor, S. (2014) ‘Regional Innovation Policy and Innovative Behaviour: Looking for Additional Effects’, *European Planning Studies*, Vol. 22, No. 1, pp. 64-83.

Arrow, K.J. (1962) ‘Economic welfare and the allocation of resources for invention’, in Nelson, R.R. (Eds.), *The Rate and Direction of Inventive Activity: Economic and Social*

Factors, pp. 609–625, Princeton University Press for N.B.E.R., Princeton.
Barney, J. (1991) 'Firm Resources and Sustained Competitive Advantage', *Journal of Management*, Vol. 17, No. 1, pp. 99–120.
Busom, I. (2000) 'An Empirical Evaluation of the Effects of R&D Subsidies', *Economics of Innovation and New Technology*, Vol. 9, No. 2, pp. 111–148.
Busom, I., and Fernández-Ribas, A. (2008) 'The impact of firm participation in R&D programmes on R&D partnerships', *Research Policy*, Vol. 37, No. 2, pp. 240–257.
Cerulli, G. (2010) 'Modelling and Measuring the Effect of Public Subsidies on Business R&D: A Critical Review of the Econometric Literature', *Economic Record*, Vol. 86, No. 274, pp. 421–449.
Club des Organismes de Recerche Associes (CLORA) (2013), www.clora.eu
David, P.A., Hall, B.H. and Toole, A.A. (2000) 'Is Public R&D a Complement or Substitute for Private R&D? A review of the Econometric Evidence', *Research Policy*, Vol. 29, No. 4–5, pp. 497–529.
Edler, J., Berger, M., Dinges, M. and Gök, A. (2012) 'The practice of evaluation in innovation policy in Europe', *Research Evaluation*, Vol. 21, No. 3, pp. 167–182.
Emden, Z., Calantone, R.J., and Droge, C. (2006) 'Collaborating for New Product Development: Selecting the Partner with Maximum Potential to Create Value', *Journal of Product Innovation Management*, Vol. 23, No. 4, pp. 330–341.
European Commission (2005) 'SME definition', available at: http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/sme-definition/index_en.htm
European Commission (2010) *European Innovation Scoreboard*, Brussels.
European Commission (2011) *European Innovation Scoreboard*, Brussels.
European Commission (2013a) *European Innovation Scoreboard*, Brussels.
European Commission (2013b) *A recovery on the horizon*, Annual Report on European SMEs 2012/2013.
Falk, R. (2007) 'Measuring the effects of public support schemes on firms' innovation activities: Survey evidence from Austria', *Research Policy*, Vol. 36, No. 5, pp. 665–679.
Fernández-Ribas, A. and Shapira, P. (2009) 'The role of national and regional-level innovation programs in stimulating international cooperation in innovation', *International Journal of Technology Management*, Vol. 48, No. 4, pp. 473–498.
Fier, A., Aschhoff, B. and Löhlein, H. (2006) 'Behavioural Additionality of Public R&D Funding in Germany', in OECD (Eds.), *Government R&D Funding and Company Behaviour: Measuring Behavioural Additionality*, pp. 127–149, OECD Publishing, Paris.
Grimpe, C. and Sofka, W. (2008) 'Search patterns and absorptive capacity: Low- and high-technology sectors in European countries', *Research Policy*, Vol. 38, No. 3, pp. 495–506.
Greene, W.H. (2008) *Econometric analysis*, 6th ed., Prentice Hall, Boston, MA.
Hagedoorn, J. (2002) 'Inter-firm R&D partnerships: an overview of major trends and patterns since 1960', *Research Policy*, Vol. 31, No. 4, pp. 477–492.
Hasebe, T. (2013) 'Copula-based maximum-likelihood estimation of sample selection models', *Stata Journal*, Vol. 13, No. 3, pp. 547–573.
Hauknes, J. and Nordgren, L. (1999) 'Economic rationales of government involvement in innovation and the supply of innovation-related service', STEP Working Paper 8/99.
Huizingh, E.K.R.E. (2011) 'Open innovation: State of the art and future perspectives', *Technovation*, Vol. 31, No. 1, pp. 2–9.

Knockaert, M., Spithoven, A. and Clarysse, B. (2014) ‘The impact of technology intermediaries on firm cognitive capacity additionality’, *Technological Forecasting and Social Change*, Vol. 81, No. 1, pp. 376–387.

Lee, S., Park, G., Yoon, B. and Park, J. (2010) ‘Open innovation in SMEs – An intermediated network model’, *Research Policy,* Vol. 39, No. 2, pp. 290–300.

Lokshin, M. and Glinskaya, E. (2009) ‘The Effect of Male Migration on Employment Patterns of Women in Nepal’, *World Bank Economic Review*, Vol. 23, No. 3, pp. 481–507.

Narula, R. (2004) ‘R&D collaboration by SMEs: new opportunities and limitations in the face of globalization’, *Technovation,* Vol. 24, No. 2, pp. 153–161.

Narula, R. and Hagedoorn, J. (1999) ‘Innovating thorough strategic alliances: moving towards international partnerships and contractual agreements’, *Technovation*, Vol. 19, No. 5, pp. 283–294.

Parida, V., Westerberg, M. and Frishammar, J. (2012) ‘Inbound Open Innovation Activities in High Tech SMEs: The Impact on Innovation Performance’, *Journal of Small Business Management*, Vol. 50, No. 2, pp. 283–309.

Peteraf, M.A. (1993) ‘The cornerstones of competitive advantage: A resource- based view’, *Strategic Management Journal*, Vol. 14, No. 3, pp. 179–191.

Schröter, A. (2009) ‘New Rationales for Innovation Policy? A Comparison of the Systems of Innovation Policy Approach and the Neoclassical Perspective’, Jena Max Planck Institute of Economics Economic Research Paper 2009–033.

Smits, R. (2002) ‘Innovation studies in the 21st century: Questions from a user's perspective’, *Technological Forecasting and Social Change*, Vol. 69, No. 9, pp. 861–883.

Spithoven, A., Frantzen, D. and Clarysse, B. (2010) ‘Heterogeneous Firm-Level Effects of Knowledge Exchanges on Product Innovation: Differences between Dynamic and Lagging Product Innovators’, *Journal of Product Innovation Management,* Vol. 27, No. 3, pp. 362–381.

Van de Vrande, V., de Jong, J.P.J., Vanhaverbeke, W. and de Rochemont, M. (2009) ‘Open innovation in SMEs: Trends, motives and management challenges’, *Technovation*, Vol. 29, No. 6-7, pp. 423–437.

Appendix

Table A1. Variable definition and descriptive statistics

Variables	Variable construction	Mean (standard deviation)
Treatment variables		
National participation	DV=1 if a firm participated in national/regional R&D programmes in the last five years; zero otherwise	0.532 (0.499)
International participation	DV=1 if a firm participated in international R&D programmes in the last five years; zero otherwise	0.303 (0.460)
Outcome variables – use of external knowledge		
Informal networking with other firms	DV=1 if the response was 'Apply' or 'Apply extensively'; =0 if 'Don't apply at all', 'Don't apply' or 'Neutral' to the question "Do you have a specific approach towards acquiring external knowledge - Informal networking with other firms"	0.625 (0.485)
Informal networking with research organizations	DV=1 if the response was 'Apply' or 'Apply extensively'; =0 if 'Don't apply at all', 'Don't apply' or 'Neutral' to the question "Do you have a specific approach towards acquiring external knowledge - Informal networking with research organizations"	0.526 (0.500)
Strategic alliances with other firms	DV=1 if the response was 'Apply' or 'Apply extensively'; =0 if 'Don't apply at all', 'Don't apply' or 'Neutral' to the question "Do you have a specific approach towards acquiring external knowledge - Strategic alliances with other firms"	0.449 (0.498)
Non-equity alliances with other firms	DV=1 if the response was 'Apply' or 'Apply extensively'; =0 if 'Don't apply at all', 'Don't apply' or 'Neutral' to the question "Do you have a specific approach towards acquiring external knowledge - Non-equity alliances with other firms"	0.249 (0.433)
Participation in innovation networks, S&T parks, clusters etc.	DV=1 if the response was 'Apply' or 'Apply extensively'; =0 if 'Don't apply at all', 'Don't apply' or 'Neutral' to the question "Do you have a specific approach towards acquiring external knowledge - Participation in innovation networks, S&T parks, clusters etc."	0.408 (0.492)
Close involvement of customers in idea generation and concept development	DV=1 if the response was 'Apply' or 'Apply extensively'; =0 if 'Don't apply at all', 'Don't apply' or 'Neutral' to the question "Do you have a specific approach towards acquiring external knowledge - Close involvement of end users/customers in idea generation/concept development"	0.590 (0.492)
Control variables		
R&D expenditure	Annual R&D expenditures as % of total expenditure (including both intramural and extramural R&D activities; purchase of patents and know-how; training in R&D; and market introduction of innovation) =1 if the share is 0-10 %; =2 if the share is 11-20%; =3 if the share is 21-50 %; =4 if the share is >50%	2.064 (1.132)

Export	Geographic markets where firms sell goods or services, DV=1 if a firm engages in exporting activities; zero otherwise	0.679 (0.467)
Competition	DV = 1 if a firm responded ‘Very strong’ to the question “How would you judge the competition in your main market(s)”; otherwise 0	0.613 (0.487)
R&D department	DV=1 if a firm has a separate R&D department; zero otherwise	0.414 (0.493)
R&D strategy	DV=1 if a firm has developed R&D and innovation strategy for the next five years; zero otherwise	0.505 (0.500)
Resources for innovation	DV = 1 if the response was 'Fewer' to the question “Resources devoted by the firm to innovation compared to the present”; = 0 if 'About the same' or 'More'	0.444 (0.497)
Relative capacity	DV = 1 the response was 'Leading' to the question “The firm’s research and innovation record relative to other firms in their industry in 2005”; = 0 if 'Average' and 'Lagging'	0.235 (0.424)
Tech. park	DV=1 if a firm is located in a technology park/area; zero otherwise	0.236 (0.425)
Tech. platform	DV=1 if a firm integrates a technology platform; zero otherwise	0.245 (0.430)
Transparent proposal evaluation procedures	DV=1 if a firm responded ‘Most important’ to the question “Which would you say are the specific needs for SMEs in order to participate in R&D programmes? – Transparent proposal evaluation procedures; zero otherwise	0.432 (0.496)
Simple reporting requirements	DV=1 if a firm responded ‘Most important’ to the question “Which would you say are the specific needs for SMEs in order to participate in R&D programmes? – Simple reporting requirements; zero otherwise	0.448 (0.498)
Adequate networks of potential partners	DV=1 if a firm responded ‘Most important’ to the question “Which would you say are the specific needs for SMEs in order to participate in R&D programmes? – Adequate networks of potential partners; zero otherwise	0.260 (0.439)
Adequate marketing of programmes	DV=1 if a firm responded ‘Most important’ to the question “Which would you say are the specific needs for SMEs in order to participate in R&D programmes? – Adequate marketing of programmes; zero otherwise	0.240 (0.427)
Micro firms	DV=1 if a firm has less than 10 employees; zero otherwise	0.478 (0.500)
Small firms	DV=1 if a firm has more than then 10 but less than 50 employees; zero otherwise	0.333 (0.472)
Medium-sized firms	DV=1 if a firm has more than then 50 but less than 250 employees; zero otherwise	0.189 (0.392)
Innovation leaders	DV=1 if countries are Denmark, Finland, Germany and Sweden; zero otherwise	0.172 (0.378)

Innovation followers	DV=1 if countries are Austria, Belgium, Cyprus, Estonia, France, Ireland, Luxembourg, Netherlands, Slovenia and the United Kingdom; zero otherwise (base category)	0.298 (0.457)
Moderate innovators	DV=1 if countries are Czech Republic, Greece, Hungary, Italy, Malta, Poland, Portugal, Slovakia and Spain; zero otherwise	0.407 (0.492)
Modest innovators	DV=1 if countries are Bulgaria, Latvia, Lithuania, Romania and Bosnia and Herzegovina; zero otherwise	0.123 (0.329)
High-technology industries	DV=1 if firms operate in high-technology intensive industries; zero otherwise (NACE classification rev 1.1)	0.198 (0.399)
Medium high-technology industries	DV=1 if firms operate in medium high-technology intensive industries; zero otherwise	0.130 (0.337)
Medium low-technology industries	DV=1 if firms operate in medium low-technology intensive industries; zero otherwise	0.128 (0.335)
Low-technology industries	DV=1 if firms operate in low-technology intensive industries; zero otherwise	0.142 (0.349)
Information and Communication Technology (ICT) industries	DV=1 if firms operate in ICT industries; zero otherwise	0.211 (0.408)
Service sectors	DV=1 if firms operate in service industries; zero otherwise (base category)	0.191 (0.393)

Table A.2. The correlation matrix

Independent variables	R&D expenditure	Export	Competition	Relative capacity	Resources for innovation	R& D strategy	R&D department	Tech. park
R&D expenditure	1							
Export	0.164***	1						
Competition	-0.108**	0.004	1					
Relative capacity	0.282***	0.116***	-0.092**	1				
Resources for innovation	0.030	-0.019	0.145***	-0.102**	1			
R&D strategy	0.328***	0.144***	-0.037	0.142***	0.124***	1		
R&D department	0.322***	0.203***	0.019	0.093**	0.112***	0.358***	1	
Tech, park	0.320***	0.093**	-0.121***	0.142***	-0.002	0.122***	0.097**	1
Tech. platform	0.193***	0.072*	0.065	0.018	0.202***	0.179***	0.143***	0.228***

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A3. Results from the copula approach for national R&D programmes – part 1

Independent variables	Selection equation	Outcome equation regime 0	Outcome equation regime 1	Selection equation	Outcome equation regime 0	Outcome equation regime 1	Selection equation	Outcome equation regime 0	Outcome equation regime 1
R&D expenditure	0.191***	0.021	-0.002	0.195***	0.059*	0.014	0.194***	0.065*	0.024
	(0.065)	(0.036)	(0.027)	(0.066)	(0.032)	(0.027)	(0.066)	(0.034)	(0.029)
Export	0.174	0.116*	0.076	0.182	0.124**	0.022	0.185	0.047	0.024
	(0.128)	(0.065)	(0.065)	(0.129)	(0.057)	(0.065)	(0.129)	(0.060)	(0.065)
Competition	-0.275**	-0.052	0.024	-0.260**	-0.079	0.044	-0.251**	-0.113*	0.009
	(0.119)	(0.062)	(0.053)	(0.120)	(0.059)	(0.053)	(0.120)	(0.060)	(0.055)
Resources for innovation	0.045	0.035	-0.025	0.017	0.145*	0.092	0.031	0.098	0.043
	(0.144)	(0.080)	(0.059)	(0.146)	(0.081)	(0.058)	(0.147)	(0.080)	(0.063)
Relative capacity	0.371***	0.112*	0.004	0.352***	0.082	0.040	0.361***	0.077	0.108*
	(0.122)	(0.066)	(0.052)	(0.121)	(0.060)	(0.052)	(0.121)	(0.063)	(0.055)
R&D strategy	0.419***	0.005	0.132**	0.418***	0.193***	0.229***	0.425***	0.220***	0.213***
	(0.122)	(0.072)	(0.056)	(0.124)	(0.067)	(0.057)	(0.122)	(0.068)	(0.059)
R&D department	0.309**	-0.106	0.034	0.313**	-0.112	0.055	0.314**	0.027	-0.048
	(0.134)	(0.071)	(0.057)	(0.136)	(0.070)	(0.057)	(0.136)	(0.074)	(0.061)
Small firms	0.467***	-0.019	-0.075	0.456***	0.070	0.005	0.460***	-0.146**	0.028
	(0.136)	(0.072)	(0.059)	(0.136)	(0.067)	(0.058)	(0.137)	(0.062)	(0.065)
Medium firms	0.327**	-0.065	0.002	0.332**	-0.054	0.008	0.337**	-0.105	-0.062
	(0.166)	(0.091)	(0.073)	(0.168)	(0.079)	(0.075)	(0.168)	(0.084)	(0.078)
Tech. park	0.042	-0.068	-0.017	0.050	0.004	-0.043	0.051	0.007	0.041
	(0.163)	(0.082)	(0.069)	(0.166)	(0.080)	(0.066)	(0.166)	(0.076)	(0.075)
Tech. platform	0.098	-0.112	0.072	0.108	0.171**	0.081	0.121	0.038	0.168***
	(0.148)	(0.083)	(0.060)	(0.148)	(0.078)	(0.057)	(0.147)	(0.080)	(0.062)
Simple reporting requirements	0.256**			0.273**			0.279**		
	(0.120)			(0.122)			(0.122)		
Adequate marketing of programmes	-0.330**			-0.329**			-0.367**		
	(0.141)			(0.143)			(0.144)		
Constant	-1.422***	0.454***	0.582***	-1.440***	0.199**	0.300***	-1.450***	0.331***	0.259**
	(0.223)	(0.102)	(0.112)	(0.230)	(0.093)	(0.115)	(0.230)	(0.095)	(0.118)

Notes: Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Industry and country dummies are included but not reported.

Table A4. Results from the copula approach for national R&D programmes – part 2

Independent variables	**Selection equation**	**Outcome equation regime 0**	**Outcome equation regime 1**	**Selection equation**	**Outcome equation regime 0**	**Outcome equation regime 1**
R&D expenditure	0.198***	-0.002	0.009	0.195***	0.021	0.018
	(0.065)	(0.028)	(0.024)	(0.066)	(0.033)	(0.029)
Export	0.184	0.009	0.022	0.181	0.088*	-0.096
	(0.129)	(0.050)	(0.053)	(0.129)	(0.051)	(0.070)
Competition	-0.253**	0.043	0.054	-0.258**	-0.019	-0.034
	(0.120)	(0.049)	(0.047)	(0.119)	(0.054)	(0.056)
Resources for innovation	0.027	0.091	-0.039	0.030	0.127*	-0.021
	(0.147)	(0.067)	(0.056)	(0.146)	(0.076)	(0.066)
Relative capacity	0.365***	0.132**	0.104**	0.356***	0.056	0.050
	(0.122)	(0.053)	(0.047)	(0.121)	(0.056)	(0.059)
R&D strategy	0.426***	0.129**	0.034	0.412***	0.149**	0.034
	(0.122)	(0.055)	(0.053)	(0.122)	(0.066)	(0.059)
R&D department	0.325**	-0.017	0.017	0.318**	-0.027	0.096
	(0.137)	(0.060)	(0.055)	(0.134)	(0.068)	(0.064)
Small firms	0.452***	-0.087	-0.150***	0.466***	-0.062	-0.002
	(0.139)	(0.053)	(0.055)	(0.136)	(0.062)	(0.063)
Medium firms	0.329*	-0.019	-0.113	0.345**	-0.101	-0.027
	(0.171)	(0.073)	(0.071)	(0.167)	(0.068)	(0.082)
Tech. park	0.039	0.049	-0.034	0.054	0.045	0.089
	(0.169)	(0.072)	(0.066)	(0.166)	(0.080)	(0.072)
Tech. platform	0.131	0.064	0.100*	0.102	0.238***	0.247***
	(0.149)	(0.065)	(0.055)	(0.147)	(0.081)	(0.064)
Simple reporting requirements	0.305**			0.309**		
	(0.123)			(0.125)		
Adequate marketing of programmes	-0.379***			-0.353**		
	(0.140)			(0.139)		
Constant	-1.421***	0.131*	0.389***	-1.458***	0.153*	0.525***
	(0.229)	(0.073)	(0.101)	(0.232)	(0.083)	(0.119)

Notes: Robust standard errors in parentheses; *** *p<0.01*, ** *p<0.05*, * *p<0.1*. Industry and country dummies are included but not reported.

Table A5. Results from the copula approach for international R&D programmes – part 1

Independent variables	Selection equation	Outcome equation regime 0	Outcome equation regime 1	Selection equation	Outcome equation regime 0	Outcome equation regime 1	Selection equation	Outcome equation regime 0	Outcome equation regime 1
R&D expenditure	0.329***	-0.015	0.052	0.343***	0.012	-0.010	0.341***	0.064**	-0.019
	(0.069)	(0.028)	(0.039)	(0.070)	(0.031)	(0.038)	(0.070)	(0.027)	(0.039)
Export	0.370***	0.062	0.174*	0.372***	0.082	-0.016	0.392***	0.052	0.013
	(0.140)	(0.053)	(0.090)	(0.144)	(0.055)	(0.086)	(0.144)	(0.048)	(0.087)
Competition	0.087	-0.046	0.017	0.092	-0.027	-0.053	0.109	-0.061	-0.027
	(0.129)	(0.048)	(0.074)	(0.132)	(0.047)	(0.078)	(0.130)	(0.047)	(0.078)
Resources for innovation	0.369**	-0.023	-0.078	0.405***	0.094	0.021	0.368**	0.043	0.104
	(0.149)	(0.060)	(0.072)	(0.150)	(0.067)	(0.074)	(0.144)	(0.063)	(0.076)
Relative capacity	0.156	0.076	-0.064	0.158	0.065	0.011	0.130	0.102**	0.048
	(0.128)	(0.049)	(0.072)	(0.128)	(0.047)	(0.069)	(0.128)	(0.047)	(0.075)
R&D strategy	0.301**	0.114**	-0.007	0.277*	0.258***	0.032	0.280**	0.209***	0.153*
	(0.136)	(0.053)	(0.070)	(0.144)	(0.071)	(0.070)	(0.136)	(0.051)	(0.082)
R&D department	-0.185	-0.005	0.053	-0.221	0.010	0.032	-0.202	-0.062	0.107
	(0.138)	(0.058)	(0.072)	(0.139)	(0.058)	(0.068)	(0.139)	(0.058)	(0.076)
Small firms	0.548***	-0.110*	0.135*	0.624***	-0.010	0.047	0.627***	-0.091*	0.064
	(0.154)	(0.059)	(0.076)	(0.148)	(0.061)	(0.072)	(0.148)	(0.053)	(0.087)
Medium firms	0.717***	-0.055	-0.028	0.788***	-0.080	-0.046	0.762***	-0.039	-0.260**
	(0.188)	(0.073)	(0.102)	(0.190)	(0.069)	(0.093)	(0.190)	(0.071)	(0.101)
Tech. park	-0.186	-0.017	-0.051	-0.151	0.018	-0.046	-0.152	-0.013	0.107
	(0.171)	(0.065)	(0.092)	(0.176)	(0.065)	(0.086)	(0.173)	(0.063)	(0.095)
Tech. platform	0.055	-0.036	0.135*	0.088	0.102*	0.139**	0.023	0.107*	0.180**
	(0.150)	(0.062)	(0.072)	(0.152)	(0.062)	(0.064)	(0.152)	(0.064)	(0.077)
Transparent evaluation procedures	0.301**			0.333**			0.341***		
	(0.130)			(0.135)			(0.127)		
Adequate networks of potential partners	0.524***			0.454***			0.419***		
	(0.142)			(0.147)			(0.141)		
Adequate marketing of programmes	-0.580***			-0.653***			-0.614***		
	(0.159)			(0.157)			(0.154)		
Constant	-2.039***	0.541***	0.372**	-2.179***	0.190**	0.715***	-2.111***	0.304***	0.284*
	(0.276)	(0.090)	(0.162)	(0.278)	(0.079)	(0.145)	(0.279)	(0.087)	(0.152)

Notes: Robust standard errors in parentheses; *** *p<0.01*, ** *p<0.05*, * *p<0.1*. Industry and country dummies are included but not reported.

Table A6. Results from the copula approach for international R&D programmes – part 2

Independent variables	Selection equation	Outcome equation regime 0	Outcome equation regime 1	Selection equation	Outcome equation regime 0	Outcome equation regime 1
R&D expenditure	0.338***	0.033	-0.026	0.332***	0.062**	-0.031
	(0.069)	(0.022)	(0.034)	(0.069)	(0.027)	(0.042)
Export	0.387***	0.031	0.007	0.376***	0.053	-0.107
	(0.142)	(0.042)	(0.076)	(0.142)	(0.048)	(0.096)
Competition	0.100	0.084**	-0.010	0.108	-0.044	-0.023
	(0.128)	(0.039)	(0.071)	(0.128)	(0.045)	(0.079)
Resources for innovation	0.367**	0.041	-0.034	0.372**	0.068	0.033
	(0.143)	(0.056)	(0.073)	(0.145)	(0.060)	(0.084)
Relative capacity	0.127	0.134***	0.096	0.132	0.096**	0.019
	(0.129)	(0.042)	(0.069)	(0.129)	(0.045)	(0.077)
R&D strategy	0.284**	0.138***	-0.030	0.295**	0.061	0.059
	(0.135)	(0.045)	(0.075)	(0.135)	(0.052)	(0.080)
R&D department	-0.199	-0.044	0.091	-0.202	0.008	0.164**
	(0.139)	(0.050)	(0.071)	(0.139)	(0.058)	(0.080)
Small firms	0.642***	-0.116***	-0.044	0.615***	-0.067	0.063
	(0.145)	(0.044)	(0.079)	(0.146)	(0.050)	(0.089)
Medium firms	0.756***	-0.036	-0.166**	0.742***	-0.037	-0.127
	(0.191)	(0.063)	(0.082)	(0.191)	(0.070)	(0.099)
Tech. park	-0.147	0.016	-0.033	-0.151	0.036	0.123
	(0.171)	(0.058)	(0.085)	(0.170)	(0.063)	(0.096)
Tech. platform	0.019	0.047	0.154**	0.017	0.272***	0.276***
	(0.152)	(0.052)	(0.076)	(0.152)	(0.064)	(0.075)
Transparent evaluation procedures	0.310**			0.377***		
	(0.131)			(0.126)		
Adequate networks of potential partners	0.385***			0.372**		
	(0.143)			(0.145)		
Adequate marketing of programmes	-0.585***			-0.643***		
	(0.157)			(0.153)		
Constant	-2.094***	0.109	0.320**	-2.099***	0.161**	0.594***
	(0.279)	(0.067)	(0.139)	(0.281)	(0.079)	(0.162)

Notes: Robust standard errors in parentheses; *** *p<0.01*, ** *p<0.05*, * *p<0.1*. Industry and country dummies are included but not reported.