DEM Discussion Papers

Department of Economics and Management

2015/01

The Role of Firm R&D Effort and Collaboration as Mediating Drivers of Innovation Policy Effectiveness

Giovanni Cerulli, Roberto Gabriele, Bianca Potì

ISSN 2282-2801 DEM discussion papers [online]

UNIVERSITÀ DEGLI STUDI
DI TRENTO

DEM Discussion Paper

ISSN 2282-2801 DEM Discussion Papers [online]
Università degli Studi di Trento

Department of Economics and Management, University of Trento, Italy.

Editors

Luciano ANDREOZZI luciano.andreozzi@unitn.it

Roberto GABRIELE roberto.gabriele@unitn.it

Technical officer

Marco TECILLA marco.tecilla@unitn.it

Guidelines for authors

Papers may be written in Italian or in English. Faculty members of the Department must submit to one of the editors in pdf format. Management papers should be submitted to R. Gabriele. Economics Papers should be submitted to L. Andreozzi. External members should indicate an internal faculty member that acts as a referee of the paper.

Typesetting rules:

1. papers must contain a first page with title, authors, abstract, keywords and codes. Page numbering starts from the following page;
2. a template is available upon request from the managing editors.

The Role of Firm R&D Effort and Collaboration as Mediating Drivers of Innovation Policy Effectiveness

Giovanni Cerulli
Ceris-CNR, g.cerulli@ceris.cnr.it

Roberto Gabriele
University of Trento, roberto.gabriele@unitn.it

Bianca Potì
Ceris-CNR, b.poti@ceris.cnr.it

Abstract. This paper investigates the impact of firm R&D policies sustaining R&D investment and collaboration on company innovation performance. Individual and cooperative R&D investments are considered as intermediate outcomes ("input" and "behavioral" additionality, respectively) contributing to the final outcome (presence of product innovation). We use a treatment random coefficient model to estimate the policy additionality on a panel dataset merging the third and the fourth wave of the Italian Community Innovation Survey (CIS). Results show a significant and positive policy impact on company propensity to product innovation only for the input additionality and for the interaction between the input and the cooperative additionality. This occurs when company cooperation scores overcome a certain threshold, in accordance with the theory which states that cooperation outcomes tend to increase when higher spillovers are .pursued by the firms.

Keywords: R&D collaborations, R&D policy, additionality; average treatment effect

JEL code: O31; O38

1. Introduction

Public policies can follow two different (although linked) ways to increase company innovative performance: (i) financial subsidies, aimed at contrasting firms' insufficient investment in R&D; and (ii) incentives to increase R&D cooperation, usually implemented by funding R&D cooperative programs or agreements.

A large number of papers have been trying to estimate the effect of R&D subsidies and fiscal incentives on company R&D activity, while a smaller amount has evaluated the effect on both input and R&D cooperation and on the output they produce (firms' R&D and/or innovation performance).

One important limit of previous studies is that of considering the two evaluation analyses as separated, while they are in fact strictly interdependent. The aim of this paper is thus that of assessing the impact of policies sustaining "R&D investment" and, at the same time, "R&D collaboration" on company innovation output, when individual and cooperative R&D investments are taken as intermediate outcomes ("input" and "behavioral" additionality, respectively) contributing to the final innovative result ("output" additionality).

As such, this study has a twofold goal: (i) evaluating the effect of an R&D supporting policy, not exclusively directed to R&D cooperation, on firms' R&D cooperation ("behavioral" additionality), meant as a behavioral change in terms of higher quantitative/qualitative degree of cooperation, besides a change in the R&D input additionality; (ii) comparing the effect of the two intermediate results (additional R&D effort and additional R&D cooperation), both in a separated and combined manner, on companies' innovation performance.

An extensive body of empirical literature studied the impact of R&D policies on input additionality. Among them, several studies rejected full crowding-out effects (Aerts and Czarnitzki, 2004, 2006; Almus and Czarnitzki, 2003; Aerts and Schimdt, 2008; Czarnitzki and Fier, 2002; Duguet, 2004; Gonzalez and Pazo, 2006; Gonzalez et al., 2005; Gorg and Strobl, 2007; Hussinger, 2008 and Lööf and Heshmati, 2005). Others found support for partial crowding-out of private investments (Busom, 2000; Heijs and Herrera, 2004; Kaiser, 2004; Lach, 2002; Suetens, 2002 and Wallsten, 2000).

Some authors have studied the effect of an R&D policy on technological output (*output-additionality*) by assuming a "direct" impact of public policy on company innovation (Merito, Giannangeli and Bonaccorsi, 2007, Corsino et al., 2014, and Bronzini and Piselli, 2013). Other scholars (Czarnitzki and Hussinger, 2004; Cerulli and Potì, 2012) have provided some improvement by adopting a two-step method which assesses the policy capacity to foster innovation *via* its ability to firstly promote companies' R&D additionality.

Some authors have studied the effect of an R&D subsidy policy on cooperation additionality (Busom and Fernandez-Ribas 2008), and found out an increasing rate of cooperation mostly with public research institutes, lesser with other firms, and mainly when firms have protected their research with international patents.

Closer to this paper, some further research have focused on the effect of R&D subsidy policy and of voluntary (or supported) firms' collaborations (along with their combination), on innovation outcome. Hinloopen (1997; 2000; 2001), for instance, compared three different policies: (i) providing R&D subsidies, (ii) sustaining the formation of R&D cooperatives, and (iii) subsidizing R&D cooperatives. Czarnitzki et al. (2007) studied the impact of R&D subsidy policy and of voluntary R&D collaboration on firm R&D investment and patenting performance.

The present paper aims at deepening the analysis looking at the "transmission mechanisms" in between the policy implementation and firm innovation output. In this direction, we propose a framework which incorporates the existence of two *mediating effects* laying between policy and innovation: one related to the effect of the policy on firm R&D investment (*input-additionality*); the other related to the impact of the policy on firm collaborative R&D strategy (*behavioral-additionality*). In other words, we consider the level of the additional private investments in R&D and that of the additional R&D cooperation effort induced by the policy as endogenous, i.e. as two intermediate outcomes of a technology program. Such model allows us to jointly consider and analyze the role played by the input, the behavioral and the output additionality in determining the success of a given R&D and innovation policy (Antonioli and Marzucchi, 2012).

One novelty of our approach stands in focusing on identifying possible *synergy* or *weakening mechanisms* between the firms' R&D and the collaboration additionalities on the innovation output. This may returns relevant policymaking implications: it is possible to know whether the two mediating drivers are positively or negatively inter-dependent and whether there exists a statistically significant magnitude of this dependence.

In this paper we refer to a general subsidy based innovation policy, which includes policies explicitly encouraging the formation of cooperative arrangements in R&D and innovation projects. We are firstly interested in finding out the degree of "collaboration additionality" promoted by the policy, i.e. the different "quality" of cooperation between supported (or treated) and unsupported (or untreated) companies. In this direction, we also offer a novel measure of the "collaboration effort" of a firm, as given by the number of different cooperating partners "weighted" by the relevance that the single innovating firm attributes to each type of cooperation.

The dataset of this study is based on a panel data structure merging the third and fourth wave of the Italian Community Innovation Survey (CIS 3 and 4) referring respectively to the three-

year window 1998-2000 and 2002-2004.

The rest of the paper is organized as follows: Section 2 presents the literature review. Section 3 introduces the research design and the methodology. Section 4 presents and discusses the data. Section 5 describes the results. Finally, in Section 6, we discuss and put forward the conclusions of the paper.

2. Literature review

In order to give our model proper theoretical and evidence-based underpinnings, we organize the review of the literature around three main subjects: (i) the R&D subsidization effect on input and output additionality; (ii) the behavioral additionality of firms and its relation with input and output additionality; (iii) the relationship between R&D subsidization, R&D cooperation (either subsidized or not) and firm innovation performance.

2.1 The effect of R&D subsidization on input and output additionality

Additionality can be defined as the change in firm financed R&D spending, company behaviour or performance that would not have occurred without the public program (Georghiou and Clarysse, 2006). Evaluations of technology programs and subsidy schemes have to determine whether public resources generate "additional activities" by the recipient firms. Typically, the additionality concept rests on the market failure argument: left to themselves, firms will under-invest in innovative activities (Metcalfe et al., 1997). Public subsidies are then needed to overcome the reluctance firms have when they come to invest in innovation (Luukkonen, 1998). Hence, by subsidizing innovative activities, technology programs can increase the private rate of innovation thus making it closer to the socially optimal one.

Policymakers and academics are interested in evaluating whether government R&D expenditures and company financed R&D behave like substitutes or complements (David et al., 2000; Georghiou & Roessner, 2000). If subsidized firms increase their level of R&D investments, then public resources complement private funds, and the technology program under evaluation has input additionality effects.

Input additionality occurs when public subsidies lead to a higher R&D activity of companies which received them; alternatively, when public funds introduce inefficiencies or are substitutes for R&D that would have anyhow taken place, a crowding-out effect occurs.

An increase in private R&D due to a public subsidy does not necessarily translate into technological progress (Aerts et al., 2006), therefore there is the need to also look at the R&D output. Output additionality may be defined as the proportion of firm "outputs" that would not have

been achieved without public support. According to a literature review, what emerges is that both input and output additionality have been the preferred performance measures in the evaluation of technology programs. While input additionality is however quite straightforward to measure in relation to specific R&D projects, output additionality raises a number of problems concerning in particular the presence of many unobserved determinants that might have impacted on the output generated by a given R&D project.

Some authors have studied the effect of an R&D policy on technological output (*output-additionality*) by assuming a "direct" impact of public policy on company innovation (Merito et al., 2007 and Bronzini and Piselli, 2013). Other scholars (Czarnitzki and Hussinger, 2004; Cerulli and Potì, 2012) have provided an improvement by adopting a two-step method assessing the effectiveness of a policy in fostering innovation *via* its capacity in firstly promoting companies' input additionality.

Georghiou (2002) suggests however that the focus on input or output additionality overlooks a third fundamental effect component, the "learning" effect activated by the technology program: it takes place within the company in the short term, but it is also a fundamental driver of the input and output additionality in the long term. Such learning effect translates into an adjustment of companies' internal R&D processes, routines, competences and strategies, leading to changes in entrepreneurial behavior ("behavioral additionality").

2.2. Behavioural additionalilty and its relation with input and output additionality

The behavioural additionality deals with "the change in a company's way of undertaking R&D, which can be attributed to policy action" (Buisseret et al., 1995). It gives more detailed information on firms' R&D strategies or management. The concept aims to complement and not to replace the traditional input and output additionality concepts and its theoretical foundations stem from the behavioural and resource based theory of the firm (Barney, 1991; Teece et al. 1997).

Within firms' R&D behaviour, R&D collaborations represent a relevant aspect, that can be potentially influenced by public funding, "which may encourage firms to extend their existing collaborations or enter in new ones with new (types of) partners" (OECD, 2006, p. 132). The OECD (2006) study investigated the behavioural effect of public funded R&D cooperation in Germany, thus assessing whether public R&D funding stimulated firms cooperative behaviour change (through new partners or new type of partnerships), and the duration of joint R&D projects. The results show that only a few percentage of firms would choose a business-to-business collaboration strategy if granted a public subsidy, while newly initiated R&D cooperation with universities and research centers are more diffused. In this sense, the public support can help to

overcome risks and costs of establishing collaborations with partners having different objectives and incentives.

Although there is a large body of empirical studies on the determinants of research partnerships, evidence on the capacity of public support to have an effect on them is still limited (Busom and Fernandez-Ribas, 2008). Evaluation studies of the R&D cooperation policy look mostly at the impact on private R&D expenditure and less at the effect on firm behaviour, which is related to how R&D cooperation is organised.

Looking at the determinants of voluntary R&D cooperation, some studies show that firm size and innovation cost sharing increase the likelihood of partnership, but especially that of cooperation with public research organizations (Cassiman and Veugelers , 2002). The possibility of benefiting from incoming spillovers increases the likelihood of cooperation with public research organizations, but not with private partners (Lopez, 2008), and the effectiveness of strategic protection methods is the most important determinant for cooperation with competitors.

The most of the papers analyzing the impact of public R&D programs on partnership formation and partner choice often do not control for the endogeneity of program participation due to the presence of unobservable factors influencing firms' decisions to participate to the program. The paper by Belderbos et al. (2004) is however an exception, as it takes into account the bias associated with the firms' choice to participate to the policy; unfortunately, the results on the effect of receiving R&D subsidies are highly sensitive to the econometric strategy chosen for reducing the endogeneity bias: when lagged subsidies are used, a positive effect on R&D vertical cooperation (suppliers and customers) is found besides that on private-public collaborations; no effect on cooperation with competitors (horizontal cooperation) is however observed. When only firms new-to-cooperation are included in the sample, no policy effect seems emerge.

Busom and Fernandez-Ribas (2008, p.246) study the effect of public support on firm's propensity to cooperate with other firms or with public research organizations (PROs). These scholars aim to assess whether "general" R&D public subsidies, i.e. measures not specifically devoted to R&D cooperation, are able to trigger a behavioural cooperative additionality. They do not include policies explicitly directed to support R&D cooperation, such as EU programmes, because participation and cooperation in that case is an identical event and such inclusion could produce a "perfect predictor" problem. This paper includes only national R&D policy, which includes both R&D cooperation incentives and public subsidy not conditional on cooperating. Their results show that national subsidies increase the rate of cooperation mostly with PROs, lesser with other firms, and basically when firms have intangible knowledge assets embodied in international patents. Using the Spanish Community Innovation (CIS) Survey, this study underlines CIS

limitations, mostly concerning the difficulty of using CIS for a longitudinal analysis, thus limiting the possibility of checking results' robustness under alternative procedure to address endogeneity and firm heterogeneity. Interestingly, the authors also conclude that "even if public funding increases the development of partnerships, output additionality generated by these partnerships has to be verified before concluding that public subsidies are the most efficient tool to reach the goal of increasing innovation" (Busom and Fernandez-Ribas, 2008, p. 253).

Clarysse et al. (2009) focused on the behavioral effect of subsidy policy and defined it as the changes in management practices of innovation process within the company. They showed that organizational learning is a useful theory to explain the mechanisms through which behavioral additionality emerges. These scholars found that input and behavioral additionality are strongly correlated and explain this result with the fact that companies which aim to change their R&D management methods are also those more oriented to spend on R&D and research personnel.

Clausen et al. (2008) examined the relationships between input, output and behavioral additionality using longitudinal data from a large-scale evaluation of a R&D tax-credit scheme in Norway. They found that these three concepts are strongly interrelated and that the behavioral additionality is a prerequisite to gain "indirect input" additionality (as, for instance, the ability to launch additional new R&D projects) and output additionality. These findings show that behavioral additionality may be of high relevance for understanding the overall effect of any R&D and innovation policy scheme.

Finally, Antonioli and Marzucchi (2012) analyzed the concept of behavioral additionality in the light of the evolutionary theory of "system failure", as opposed to the neo-classical "market failure" approach. They reviewed some recent econometric and quantitative studies dealing with the measurement of the behavioral additionality at firm level and supported the need to jointly analyze input, output and behavioral additionality as they are strictly interdependent, thus stressing at the same time the importance of a better understanding and measurement of agents' interrelations within a systemic approach.

2.3. The relation between R&D subsidies, R&D cooperation and innovation.

The debate on the effect of subsidies on R&D cooperation is still open, but the policy effect is generally found positive. Government R&D policy can be directed to correct the distortion created by R&D spillovers among firms and also to incentivate cooperation when its cost and risk are high. Geroski (1993) interestingly stated that, since there is no presumption that the benefit from R&D joint ventures is large or easy to reach, the design of the policy is of a critical stance. Within the literature we find a justification for a policy supporting R&D cooperation in the case of more

complex collaborative agreements (Lhuillery and Pfister, 2009), and it is also recognized that more heterogeneous cooperation, even if more risky, can produce a deeper innovation effect (Feldman and Kelley, 2006, Teece 1992).

The link between public funding and cooperative R&D have been examined by only a few empirical studies. Folster (1995) studied the effectiveness of subsidies on cooperation, by answering to two relevant research questions: (i) does support which require cooperation increase the probability of cooperation? (ii) do subsidies increase incentives to conduct R&D? The scholar adopts the analytical model of Katz and Ordover (1990), who expressed the joint venture as an agreement to share both costs and technology, but extends the analysis to other forms of R&D cooperative arrangements. In particular, the theory suggests that a subsidy not requiring a specific form of R&D collaboration could not affect the type of cooperation chosen by firms; the likelihood of cooperating in some form, however, can increase and R&D incentives can raise more than when a subsidy specifically requires a joint-venture.

The empirical implication of this model is derived from comparing profit maximization conditions under different cooperation types. The empirical results show that when a conditional-on-cooperation subsidy allows firms to choose how to cooperate, it does not increase the likelihood of cooperation more than that usually followed by firms; however, it increases firm R&D effort as subsidies supporting individual R&D. Moreover, when a cooperation support requires the sharing of R&D results, it increases the likelihood of cooperation, but decreases incentives to do R&D: this can be due to the reduction of R&D duplication or to firms' moral hazard behavior. Folster (1995) explanation of these empirical results is that voluntary R&D cooperation internalizes at best the externality effects taking place among firms (more precisely, the effect on other firms' profits), but with no positive effect on the consumers' surplus given by the additional R&D. Subsidized R&D cooperation, which does not require results' sharing (thus resembling to voluntary cooperation) can increase incentives to do R&D, but in the same way as subsidies devoid of any cooperation requirement.

D'Aspremont and Jacquemin (1988), in their two-stage "patent-race" model, assume that in the case of cooperation firms jointly choose the level of R&D to maximize the joint profits and the level of spillovers influences the outcome: when they are relatively large, both the investment and the output are greater within the R&D cooperation regime than within the R&D competition regime. The implication for policymakers is therefore that when some research activity is recognized ex-ante as source of large spillovers, it is worth to subsidize R&D cooperation agreements, although in the presence of high R&D spillovers the risk of free-riding can be significant. In contrast with D'Aspremont and Jacquemin (1988), Hinloopen (2001) argues that

R&D cooperation also has many drawbacks: for instance, R&D cooperation partners can collectively decide to reduce R&D if the increase in the innovating firm's profit does not compensate enough for the profit loss of the other firms (Katz, 1986; Geroski, 1993). By generalizing the D'Aspremont and Jacquemin model (1988), Hinloopen (2001) compares three policies: providing R&D subsidies, sustaining the formation of R&D cooperatives and, finally, subsidizing R&D cooperatives. The results show that subsidizing individual R&D is more effective in raising R&D effort than sustaining (by legal instruments) R&D cooperation and that subsiding cooperative R&D brings to the same amount of R&D investment as when subsidies are given to individual research activity.

Czarnitzki et al. (2007) study the impact of R&D subsidy policy and of voluntary R&D collaboration on R&D investment and on patents in two countries, Germany and Finland. They consider collaborations and subsidies as heterogeneous treatments and conduct a treatment effect analysis by distinguishing and simultaneously analyzing voluntary R&D collaborations, individual R&D subsidies and the interaction between subsidies and collaboration. Their results are slightly different between the two countries: in Germany the interaction of collaboration and subsidy leads to improved R&D intensity compared with only subsidy or only voluntary collaboration; in Finland, by contrast, R&D subsidy does better than voluntary collaboration. However, when the patent outcome is considered, the combination of collaboration and subsidy would give better results than only subsidy in both countries.

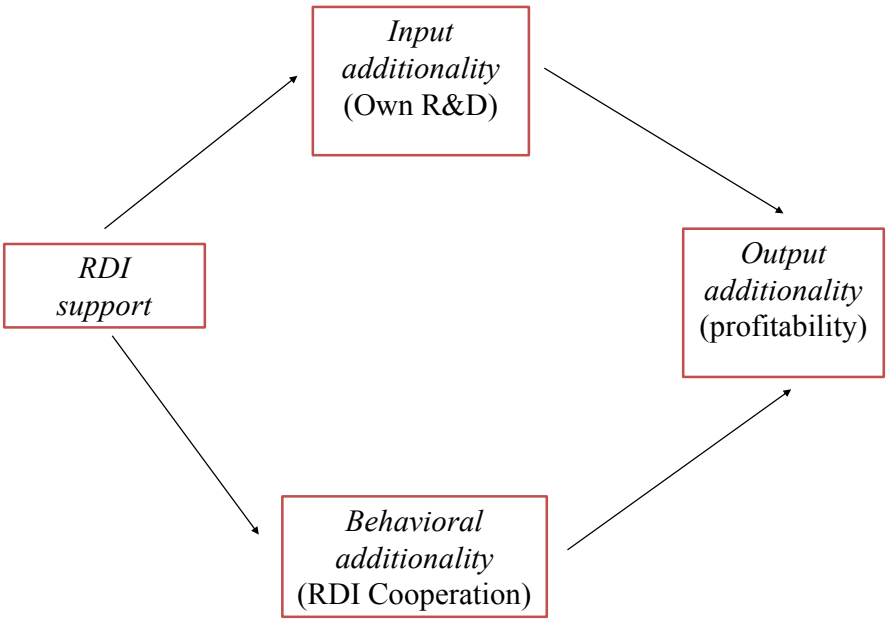
Firms benefit from R&D cooperation if the cooperation positively affects their economic success enough to outweigh the costs of cooperation – e.g., transaction and coordination costs. Thus, it is important to analyse the effects of cooperation on outcome measures in addition to its effects on inputs (Aschhoff and Schmidt, 2008). Lööf, and Broström (2008) find that the collaboration between universities and firms not only increases the probability that firms will apply for a patent in the future, but it also has a positive impact on the innovative sales per employee. Gemünden et al. (1997) investigate the relationship between sales due to product innovations and cost reductions through process innovations finding that cooperating firms have higher sales attributable to product innovations than non-cooperating firms.

3. Research design, methodology and data

Assuming the previous literature review as reference, our research goal is that of studying the ultimate effect of R&D and innovation (RDI) support on company propensity to innovate (*output additionality*) through the *mediating effect* the subsidy has had on company own R&D (*input*

additionality) and RDI cooperation strategy (*behavioral additionality*). The causal path-diagram of our model is represented in Fig. 1.

Figure 1. Path-diagram of the model.



This is a two-step model, where: (i) the first step defines how the subsidy impacts on private R&D investment and on the cooperation behavior of firms; here, we obtain two (generated) regressors $ATE_{\text{input}}(\mathbf{x}_i)$ and $ATE_{\text{behavioral}}(\mathbf{x}_i)$ representing the causal "counterfactual" effects of the policy considered on the R&D effort and on the R&D cooperation degree. (ii) The second step performs a regression of the output variable (i.e., the innovation propensity of firms) on the two regressors $ATE_{\text{input}}(\mathbf{x}_i)$, $ATE_{\text{behavioral}}(\mathbf{x}_i)$, plus their interaction and a group of control variables; from this regression we obtain an estimation of the sign and magnitude of the additional effect generated by the subsidy policy through the two mediating variables "cooperation" and "R&D effort" respectively.

As econometric counterpart of the previous diagram, we use a *treatment random coefficient model* (see Wooldridge, 2010, p. 945-951), implemented in Stata through the routine IVTREATREG by Cerulli (2014). This model allows to estimate, for each company, an idiosyncratic effect of the support on R&D and cooperation, formally defined as the Average Treatment Effect conditional on a vector of covariates **x**. In standard regression models these effects cannot be estimated individually, but only as a common (and thus singleton) parameter (typically, the *ATE*). This is the advantage of using a random coefficient approach.

This estimation strategy permits us to identify, for each company *i*, two distinct effects:

(1) $ATE_{\text{input}}(\mathbf{x}_i)$ = average treatment effect of RDI support on company *i* R&D (idiosyncratic *input additionality*)

(2) $ATE_{\text{behavioral}}(\mathbf{x}_i)$ = average treatment effect of RDI support on company *i* degree of cooperation (idiosyncratic *behavioral additionality*)

Once the previous two variables are calculated, we can exploit them as predictors (*mediating effects*) in an invention/innovation regression function of this type:

$$Y = a + \sum_{p=1}^{P} b_p \left[ATE_{input}\left(\mathbf{x}\right) \right]^p + \sum_{q=1}^{Q} c_q \left[ATE_{behavioral}\left(\mathbf{x}\right) \right]^q + d \cdot ATE_{input}\left(\mathbf{x}\right) \cdot ATE_{behavioral}\left(\mathbf{x}\right) + \mathbf{ew} + error \quad (1)$$

where the index *i* is omitted for the sake of simplicity. In Eq. (1): *Y* is a binary innovation outcome measuring the presence/absence of product innovation; **w** is a vector of covariates explaining invention/innovation performance; *a*, b_p, c_p *d* and **e** are regression parameters; and *P* and *Q* are the maximum polynomial order one can consider in the regression for the two types of additionality.

Observe that Eq. (1) also shows an interaction between $ATE_{input}(\mathbf{x})$ and $ATE_{behavioral}(\mathbf{x})$. Thus, in terms of derivatives, we obtain:

$$\frac{\partial \mathrm{E}(Y \mid \mathbf{x}, \mathbf{w})}{\partial ATE_{input}\left(\mathbf{x}\right)} = \sum_{p=1}^{P} p \cdot b_p \left[ATE_{input}\left(\mathbf{x}\right) \right]^{p-1} + d \cdot ATE_{behavioral}\left(\mathbf{x}\right) \quad (2)$$

$$\frac{\partial \mathrm{E}(Y \mid \mathbf{x}, \mathbf{w})}{\partial ATE_{behavioral}\left(\mathbf{x}\right)} = \sum_{q=1}^{Q} q \cdot c_q \left[ATE_{behavioral}\left(\mathbf{x}\right) \right]^{q-1} + d \cdot ATE_{input}\left(\mathbf{x}\right) \quad (3)$$

In the simple case in which *P*=1 and *Q*=1, we have:

$$\frac{\partial \mathrm{E}(Y \mid \mathbf{x}, \mathbf{w})}{\partial ATE_{input}\left(\mathbf{x}\right)} = b_1 + d \cdot ATE_{behavioral}\left(\mathbf{x}\right) \quad (4)$$

$$\frac{\partial \mathrm{E}(Y \mid \mathbf{x}, \mathbf{w})}{\partial ATE_{behavioral}(\mathbf{x})} = c_1 + d \cdot ATE_{input}(\mathbf{x}) \tag{5}$$

Equations (2) and (3) clearly show that the effect of the input additionality on product innovation depends on the behavioral additionality, and vice versa. Our approach will therefore allows us to take into account potential "synergistic" or "weakening" effects of combined input and behavioral additionality on output performance.

This treatment model can be used to calculate input and behavioral additionality on two sub-populations of interest: *supported* and *unsupported* companies. It would be possible, for instance, to know whether the input and behavioral additionality have been higher for supported than unsupported companies, thus providing interesting policy implications: for example, finding out that unsupported units have had a higher performance, would show that company self-selection and/or agency-selection into program have selected companies to support having lower additionality potential.

The dataset employed in this study is a panel dataset built by merging the third and fourth wave of the Italian Community Innovation Survey (CIS3 and 4) collecting a large set of innovation and R&D-related variables for the three-year window 1998-2000 and 2002-2004 for a sample of manufacturing and services companies. This dataset is then merged with company balance sheet data (AIDA dataset). All the fundamental target and control variables needed for applying our model are available in CIS3 and 4 plus AIDA, and the RDI subsidy takes the form of a binary variable (supported vs. non-supported) including all regional, national, and European support.

A particular attention should be devoted to the definition of our variable measuring the intensity of collaborations. We rely upon the CIS questions about the collaboration activities of firms, respectively, the 10.1 in CIS3 and 6.4 in CIS4. In these questions firms are asked to define the kind of collaboration they agreed upon according to the typology and geographical localization of the partner.

First, we built an indicator measuring the number of different types of collaborations carried out in the three years of each survey, which ranges from 0 – no collaborations at all – to 6 – the firm has collaborations covering all the types of partners. The different typologies are those defined by different kind of partners, namely: other firms of the same groups, suppliers, customers, competitor firms, consultants, public research institutes[1]. Secondly, we weighted this indicator by assigning more weight to the type of collaborations that a firm declares to be more important from the point

[1] We grouped in one category the two types of partners given by universities and public research institutes – modalities (f) and (g) of the this specific CIS question.

of view of its "relevance as a source of information for innovation". The weights range from "no important", "low degree of importance", "medium importance" and "high relevance", where the modalities are taken from question 11.1 in CIS3 and question 6.1 in CIS4.

We re-coded previous relevance statements into the numerical values w_k={0.25; 0.5; 0.75; 1} representing the relative intensity of the relevance of each source of information. Note that we decided to weight with 0.25 an existing collaboration of a firm even if it was judged by the firm as "not important" in order to keep into the indicator all the collaborations. In other words, this assumption is made to be as closer as possible to the literature that investigates the role played by collaborations, irrespectively of their importance and nature. More formally, we built for each firm the following weighted collaboration indicator as in Eq. (6):

$$\mathrm{Coop} = \sum_{k=1}^{6} \mathrm{I}(\mathrm{coop}_k = 1) \cdot w_k \qquad (6)$$

where the index k=1,...,6 spans over all the different typologies of collaboration; $\mathrm{I}(\mathrm{coop}_k = 1)$ is an indicator variable that assumes the value 1, if the typology of collaboration is present for the firm and 0 otherwise; w_k is the weight that a firm assigns to the k^{th} type of collaboration. This indicator ranges from 0 to 6, where the minimum is reached when a firm declares not to have any collaboration, i.e. $\mathrm{I}(\mathrm{coop}_k = 1)$=0 for k=1,…6. The maximum of this indicator is obtained when a firm declares to have all the types of collaborations, i.e. $\mathrm{I}(\mathrm{coop}_k = 1) = 1$, k=1,…,6 and declares that each collaboration was "highly relevant" as a source of information, i.e. w_k=1 for k=1,…6 (see the Appendix for an example of calculation of the indicator). Table 1 presents the summary statistics for this indicator calculated within the CIS3 and CIS4 in our sample of firms.

Table 1. Summary statistics of the weighted collaborations indicator for firms in CIS3 and CIS4.

	Obs	*Mean*	*Std. Dev.*	*Min*	*Max*
Coop(CIS3)	2372	.232	.656	0	5.250
Coop(CIS4)	2100	.337	.855	0	5.125

4. Results

Table 2 shows the results on the input and behavioral additionality using the RDI cooperation indicator presented above for the behavioral additionality, and the R&D intensity (total intra-muros R&D expenditure on turnover) for the input additionality. Due to an abundant presence of missing values the sample size drops to around 1,100 companies.

The Table sets out a positive and strong significant effect of receiving RDI support (our binary treatment variable) on cooperation. The level of ATE is – in this case – around 0.34. As said above, in order to get this result, we make use of a treatment random-coefficient model as proposed by Wooldridge (2010, p. 945-951) implemented in Stata by Cerulli (2014). Figure 2, plotting the distribution of ATE(**x**) for this regression, clearly shows that the average of that distribution coincides with ATE. The model specification considers a set of covariates ("observable confounding variables"), whose meaning is clearly evident: *size* – measured as the number of employees – identifies company scale economy in its collaborative performance; *cash-flow* – measured as revenues minus costs on turnover – catches the role played by liquidity in promoting collaborative projects; *debt* – measured as the sum of short and long-run indebtedness on turnover – gauges company reliance on overcome liquidity constrains through accessing bank loans and is a fundamental asset shaping the capital structure of the firm; *knowledge* – as measured by the stock of capitalized R&D and acquired intellectual property – is a variable approximating firm experience and capacity in doing R&D and innovation over time; *foreign* is a binary variable taking on value one for foreign companies and zero for home companies; finally, *size*, *sector* and *location* dummies are also considered in the regression estimation but not reported in the table.

Table 2. Input and behavioral additionality. Result for the Average Treatment Effect.

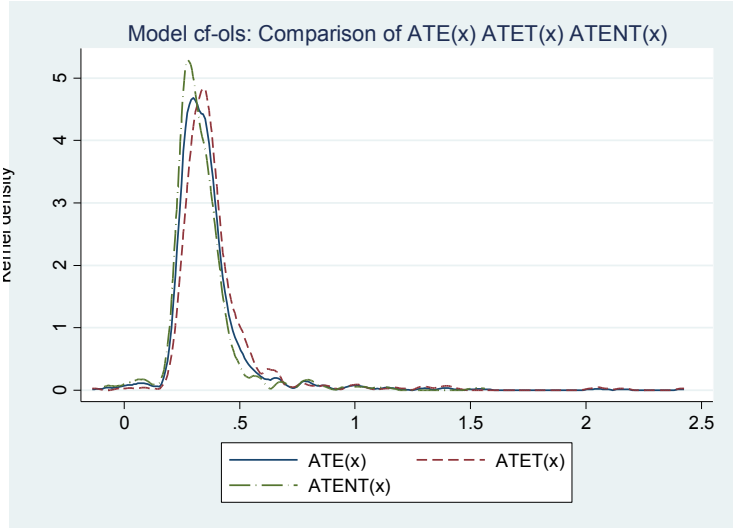
	(1) *Input*	(2) *Behavioral*
Treatment	0.01***	0.34***
	(0.00)	(0.07)
Size	0.00	0.00***
	(0.00)	(0.00)
Cash-flow	0.00	0.00
	(0.00)	(0.00)
Debt	0.01	0.19
	(0.01)	(0.17)
Knowledge	0.00	0.00
	(0.00)	(0.00)
Foreign	-0.00	-0.02
	(0.00)	(0.08)
Age	-0.00	-0.20
	(0.00)	(0.15)
N	1130	1130
R^2	0.45	0.21
F-test	n.a.	n.a.

Note: Dep. Var.: "R&D intensity" and "Cooperation". Size, sector and location dummies included, but not reported. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. n.a.= not available.

Table 2 shows that the significance of these control variables is poor. Observe, moreover, that they are measured at the outset on the two time windows selected, i.e. 1998 for CIS3 and 2002 for CIS4, to take them as pre-treatment (and thus exogenous) variables as much as possible.

The previous table also reports results for the R&D intensity (or input additionality), using the same control variables. Also in this case, results show a highly significant and positive effect of the RDI support on firm R&D performance, with a value of ATE around 0.016. As in the case of the behavioral additionality confounders are poorly significant.

Figure 2. Distribution of ATE(**x**) for the behavioral additionality.



Similarly to Figure 2, Figure 3 shows the distribution of ATE(**x**) when the R&D intensity is considered as target variable. The well bell-shaped form centered in 0.016 is clearly illustrated.

Table 3 sets out an estimation of Eq. (1) according to different polynomial orders. We regress the binary innovation variable *inno* (i.e., propensity to product innovation) – taking one for companies performing some product innovation in the period covered by CIS3 and CIS4 and zero otherwise – on behavioral additionality (ATE(**x**) for cooperation), input additionality (ATE(**x**) for R&D intensity), plus their multiplicative interaction (*interaction*) along with size, sector and location controls.

Figure 3. Distribution of ATE(**x**) for the input additionality.

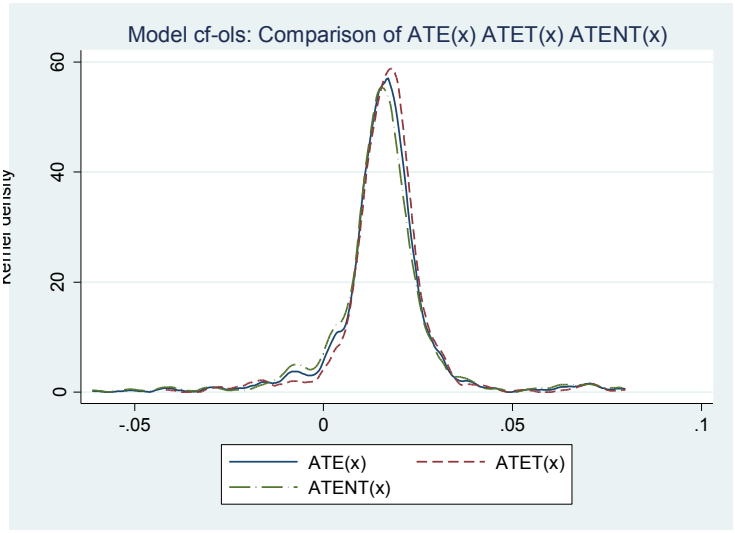


Table 3. Estimation of Eq. (1) according to different choices of P and Q.

	(1) REG_P3Q3	(2) REG_P2Q2	(3) REG_P2Q1	(4) REG_P1Q2	(5) REG_P1Q1
ATE_behavioural	-0.73 (0.59)	-0.38 (0.25)	-0.30 (0.24)	-0.11 (0.09)	-0.11 (0.09)
ATE_input	-1.42 (2.83)	-2.25 (2.05)	-3.58* (1.85)	-2.15 (2.05)	-3.33* (1.83)
ATE_behavioural^2	0.58 (0.68)	0.14 (0.12)	0.10 (0.12)		
ATE_input^2	-49.13 (47.99)	-53.07 (35.15)		-43.98 (34.28)	
ATE_behavioural^3	-0.13 (0.21)				
ATE_input^3	-406.54 (961.36)				
Interaction	8.32* (4.96)	8.37* (4.34)	8.40* (4.34)	6.96* (4.17)	7.34* (4.16)
N	1090	1090	1090	1090	1090
R^2	0.10	0.09	0.09	0.09	0.09
AIC	1516.10	1512.63	1513.03	1512.07	1511.80
F-test	0.0001	0.0000	0.0000	0.0000	0.0000

Note: Standard errors in parentheses. The dependent variable is *inno*, the binary product innovation dummy. Size, sector and location dummies included, but not reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In Table 3 we show the results on various polynomial specifications (until a third-degree polynomial) to test whether the relationship in Eq. (1) is or is not linear. We found no significance

of squared and cubic terms. Therefore, we accept the linear form of Eq. (1) as a good proxy (see the results in the REG_P1Q1 column).

Our results stress a significant effect of the input additionality and of the interaction between input and behavioral additionality, but no significance for the coefficient of the behavioral additionality when it stands alone. As such, this result suggests that only Eq. (4) can be significantly estimated in our data. This equation represents the increment (or decrement) of company innovative performance for any unit change in the input additionality, at a given level of behavioral additionality.

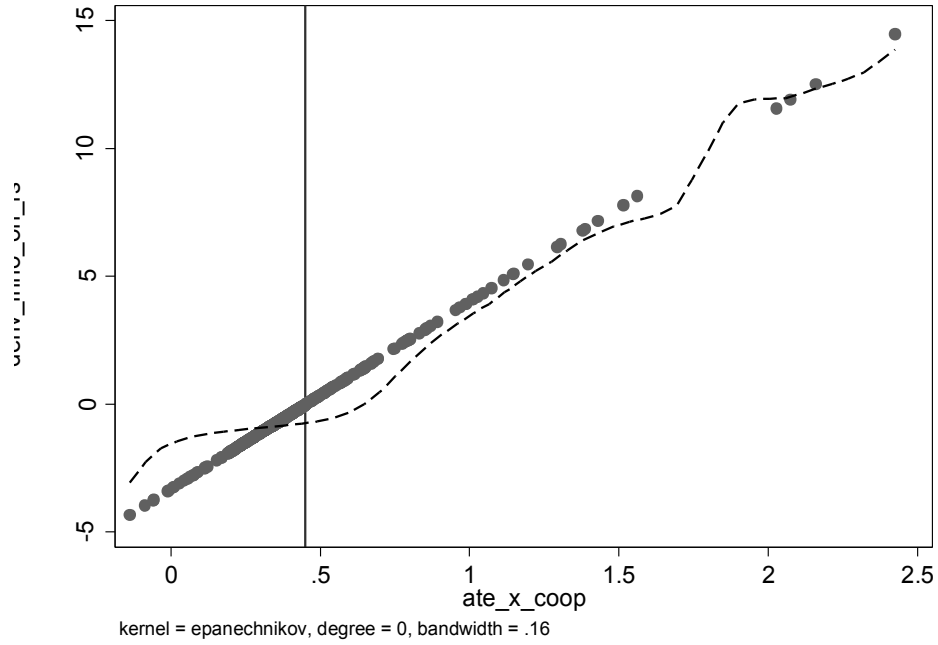
The plot of this equation is reported in Figure 4, where a significant increasing pattern is found out. This means that, as soon as the behavioral additionality increases, the reactivity of product innovation propensity to input additionality increases accordingly. Nevertheless, a *threshold* is found out for a level of the behavioral additionality (labeled as "ate_x_coop" in the Figure) which is around 0.45: indeed, for values lower than this threshold, the previous derivative is negative (i.e. negative effect of input additionality on product innovation propensity), while for values higher than this threshold the derivative is positive (i.e. positive effect of input additionality on product innovation propensity). This implies that, in order to reap an innovation gain from their R&D activity, companies have to perform above a certain level of behavioral additionality.

Table 4. Mean of "coop" above and below the behavioral additionality threshold (0.045).

	Obs	Mean	Std. Dev.	Min	Max
Above	152	1.12	1.41	0	5.25
Below	954	.424	.930	0	5.12

Does it means that firms have to increase their number/quality of cooperation to better exploit the effect of their input additionality on innovation? To answer this question we have calculated the average of our cooperation variable for companies *below* and *above* the 0.45 behavioral additionality threshold. Results in Table 4 illustrate that firms located below the threshold obtain an average cooperation index of 0.42, while those above the threshold obtain an average of 1.13, which is around three times higher. Moreover, Table 4 shows that the most part of the sample is located below the threshold, thus indicating that cooperation induces also costs and uncertain results.

Figure 4. Derivative of firm innovation performance of input additionality at each behavioral additionality point.



Given this picture, we can conclude quite soundly that: (i) companies getting a higher behavioral additionality are also those getting a higher cooperation score (that is, higher quantitative/qualitative degree of the cooperation index); (ii) companies with higher cooperation scores are also those able to reap positive effect of their input additionality on product innovation propensity.

Overall, these results seem to suggest that the main driver of higher innovative performance is the RDI (additional) cooperation activated by the public support: it seems therefore to emerge a "synergy" between this form of behavioral additionality and companies' capacity to profit of higher R&D additionality.

5. Conclusions and policy implications

The main contribution of the paper is to go towards a more comprehensive understanding of the "etiology" of the impact of R&D support policies on innovation: we aim at clarifying why and how the R&D policy has an additionality impact on private R&D efforts. To do so, we extend the existing framework in which the R&D subsidy has an impact on firm financial constraints as experimented by the firm (David et al., 2000), and assume that R&D subsidies may have a simultaneous impact also on firm R&D collaborations (Busom and Fernandez-Ribas, 2008).

We suggest that it is possible to fine tune an RDI policy by taking into account that various mediating factors are in place when a policy is implemented and that they can play a key role in

determining the final (innovation) outcome. Policymakers have to consider the impact of the subsidy on financial constraint experimented by firms (the basic driver to increase the R&D performance), but also the possible effect on the collaboration effort and the interaction of the two different mediators (i.e., the input and the behavioral additionality).

Our results go further the unique generalization which is possible to derive from the literature review (see section 2 in the paper), that the best performance in innovation is found when financial subsidy and cooperation are combined. Our results suggest that the main driver of higher innovative performance is the RDI cooperation activated by the public support. It seems to emerge a "synergy" between this form of behavioral additionality and the company capacity to profit of higher R&D effort induced by the policy.

A positive synergistic effect takes however place only beyond a threshold value of the cooperation additionality. This threshold identifies a demarcating point where the level of cooperation additionality produces positive synergistic effects. By assuming that cooperating embodies both costs and benefits, the threshold may identify the point at which benefits overcome costs. Below that threshold, the combination of subsidy and R&D collaboration gives negative outcome.

Complex cooperation agreements, above a certain threshold, are more sensible to additional R&D investments and this interaction produces an innovative outcome. This result is coherent with the fact that the propensity to develop collaborations among the Italian companies which realized an innovation during the period 1998-2000 was strongly correlated with their size: only 5% of firms with 10 to 19 employees had cooperation agreement, 13% of firms with 10 to 19 employees, while 38% of large firms, with > 250 employees (Community Innovation Survey).

The only presence of collaboration in RDI programs does not assure *per se* a successful innovative performance of companies, but it needs two other side-conditions: a high level of spillover, due to the relevance and variety of partners and network linkages (whose costs and risks are supported by the policy), and the presence of an additional R&D investment.

References

Aerts, K., and Czarnitzki, D.,2004, "Using Innovation Survey Data to Evaluate R&D Policy: The Case of Belgium", *ZEW Discussion Paper* No. 04‐55, Mannheim.

Aerts, K., and Czarnitzki, D**.,** 2006, *The Impact of Public R&D Funding in Flanders*, 54, IWT M&A study.

Aerts, K and Schmidt, T., 2008, "Two for the price of one? Additionality effects of R&D subsidies: comparison between Flanders and Germany", *Research Policy* 37, pp. 806–822.

Almus M, Czarnitzki D. ,2003, The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany, *Journal of Business and Economic Statistics* 21(2), pp. 226–236.

Antonioli D. and Marzucchi A., 2012, "Evaluating the additionality of innovation policy. A review focused on the behavior dimension", *World Review of Science, Technology and Sustainable Development*, 9, 2/3/4, pp. 124-148.

Aschhoff B. and Schmidt T., 2008, Empirical Evidence on the Success of R&D Cooperation—Happy Together?, *Review of Industrial Organization*, 33, pp. 41–62

Barney, J. B., 1991, Firm resources and sustained competitive advantage, *Journal of Management*, 17(1), pp. 99-120

Becker W. and Dietz J., 2004, "R&D cooperation and innovation activities of firms—evidence for the German manufacturing industry", *Research Policy* 33, pp. 209–223

Belderbos R., Carreeb M., Diederenc B.,Lokshinb B.,Veugelers R., 2004, "Heterogeneity in R&D cooperation strategies", *International Journal of Industrial Organization*, 22 , pp.1237– 1263.

Bronzini R., Piselli P., "The impact of R&D Subsidies on Firm Innovation", presented at the workshop *Innovazione, produttività e crescita in Italia* organized by Università di Calabria, 15-16 marzo 2013

Buisseret, T. J., Cameron, H. M., & Georghiou, L., 1995, What Difference Does It Make - Additionality in the Public Support of R-and-D in Large Firms, *International Journal of Technology Management,* 10 (4-6), pp. 587-600.

Busom I. , 2000, "An empirical evaluation of the effects of R&D subsidies", *Economics of Innovation and New Technology* **9**(2), pp.111–148.

Busom I. and Fernandez-Ribas A., 2008, "The impact of firm participation in R&D programmes on R&D partnerships", *Research Policy,* 37, pp. 240–257.

Cassiman B., Veugelers R., 2002, "R&D cooperation and spillovers: some empirical evidence from Belgium", *American Economic Review*, 92 (4), pp.1169–1184.

Clarysse B., Wright M. and Mustar P., 2009, "Behavioural additionality of R&D subsidies: A learning perspective", *Research Policy*, 38, pp. 1517–1533.

Clausen T.H., Ljunggren E. and Madsen E.L., 2008, *Input, output and behavioral additionality: concepts and relationships*, paper presented at the 25th Celebration DRUID Conference 2008 Copenhagen, Denmark, June 17 – 20.

Cerulli G., 2010, "Modelling and Measuring the Effect of Public Subsidies on Business R&D: A Critical Review of the Econometric Literature", *Economic Record*, n. 86.

Cerulli G., 2014, "IVTREATREG: A Stata routine for estimating binary treatment models with heterogeneous response to treatment and unobservable selection", *The Stata Journal*, 14, 3, 2014.

Cerulli G. and Potì B., 2012, "Designing ex-post assessment of corporate RDI policies: conceptualization, indicators and modeling", *World Review of Science, Technology and Sustainable Development*, 9 (2/3/4), pp. 96-123.

Corsino M., Gabriele R. and Giunta A., 2014, Research an Development subsidies: the effectiveness of a regional policy, ch.10, pp. 223-251 in The Economics of Knowledge Generation and Distribution (Patrucco P., ed by) Routledge, New York.

Czarnitzki, D and Fier, A**.** ,2001, "Do R&D Subsidies Matter? - Evidence for the German Service Sector", *ZEW Discussion Paper* No. 01 - 19, Mannheim.

Czarnitzki D., Ebersberger B. and Fier A. , 2007, "The Relationship between R&D collaboration, Subsidies and R&D Performance: empirical evidence from Finland and Germany", *Journal of Applied Econometrics*, 22, pp. 1347-1366.

Czarnitzki D. and Hussinger K. (2004), The Link between R&D Subsidies, R&D Spending and Technological Performance, ZEW - Centre for European Economic Research, *Discussion Paper* No. 04-056.

D'Aspremont, C., & Jacquemin, A. ,1988, "Cooperative and noncooperative R&D in duopoly with spillovers", *American Economic Review, 78*(5), pp.1133–1137.

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*, 29(4/5), pp. 407-529.

De Bondt R., Veugelers R., 1991, « Strategic investment with spillovers", *European Journal of Political Economy*, 7, pp. 345–366.

Doz, Y. ,1988, 'Technology partnerships between larger and smaller firms: Some critical issues', in F. Contractor and P. Lorange (eds.), *Cooperative Strategies in International Business*. Lexington Books, Lexington, MA, pp. 317-338.

Duguet E. ,2004, "Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non experimental data", *Revue d'Economie Politique ,*114(2),pp. 263–292

Feldman M.P.*,* Kelley M. R., 2006, "The *ex ante* assessment of knowledge spillovers: Government R&D policy, economic incentives and private firm behavior" , *Research Policy*, 35, pp. 1509–1521

Folster S., 1995, "Do subsidies to cooperative R & D actually stimulate R& D investment and cooperation?, *Research Policy,* 24, pp. 403-417

Gemünden, H. G., Ritter T. and Walter A., (eds) 1997, *Relationships and Networks in International Markets*, Oxford, Pergamon.
Georghiou, L., and Clarysse, B., 2006, *Introduction and synthesis, in Government R&D Funding and Company Behaviour. Measuring Behavioural Additionality*, OECD, Paris.

Georghiou, L., 2002, *Impact and additionality of innovation policy,* Innovation Science and Technology 40, Brussels, IWT.

Georghiou, L. and Roessner, D., 2000, "Evaluating technology programs: tools and methods", *Research Policy*, 29(4), pp. 657-678

Geroski, P. ,1988, "Competition and Innovation", *Economic Papers*, Commission of the European Communities.

Geroski P., 1993, "Antitrust Policy towards Cooperative R and D Ventures", *Oxford Review of Economic Policy*,5, pp. 20-36

González, X. and Pazó, C. 2008, "Do public subsidies stimulate private R&D spending?" *Research Policy*, 37, pp. 371–389.

González, X., Jaumandreu, J., and Pazó C., 2005, "Barriers to innovation and subsidy effectiveness" *The Rand Journal of Economics* 36 (4), pp. 930–950.

Görg, H. and Strobl, E., 2007, "Money for Nothing? Do R&D Subsidies Add to or Crowd Out Private R&D?", *Economica*, 74, pp. 215 - 243.

Heijs, J. and Herrera, L., 2004, "The distribution of R&D subsidies and its effect on the final outcome of innovation policy", *Working paper* Instituto de Analisis Industrial y Financiero 46, Madrid.
Hinloopen, J. ,1997, "Subsidizing Cooperative and Noncooperative R&D in Duopoly with Spillovers." *Journal of Economics/Zeitschriftf~r Nationalrkonomie* 66, pp. 151- 175.

Hinloopen J. , 2000, "More on subsidizing cooperative and non-cooperative R&D in duopoly with spill-overs", *Journal of Economics,* 72(3), pp. 295–308.

Hinloopen J, 2001, "Subsidizing R&D Cooperatives", *De Economist* 149, N. 3.

Hussinger, K., 2008, " R&D and Subsidies at the Firm Level: An Application of Parametric and Semi - Parametric Two - Step Selection Models", *Journal of Applied Econometrics* 23, pp.729 - 747.

Kaiser, U., 2004, "Private R&D and public subsidies: microeconomic evidence from Denmark", *Danish Journal of Economics* 144 (1), pp. 1–17.

Kamien, M., Zang, I., 2000. Meet me halfway: Research Joint Ventures and Absorptive Capacity. *International Journal of Industrial Organization*, 18 (7), pp. 995-1012

Katz M.L. and Ordover J.A., 1990, "R&D Cooperation and Competition", *Brookings Papers: Microeconomics*, 1990, pp.137-202

Janz, N., Lööf, H., Peters, B. , 2004, "Firm Level Innovation and Productivity – Is there a Common Story Across Countries", *Problems and Perspectives in Management*, No. 2, 22.

Lach S., 2002, "Do R&D subsidies stimulate or displace private R&D? Evidence from Israel", *Journal of Industrial Economics* **50**(4), pp. 369–390.

Lopez, A. , 2008, Determinants for R&D cooperation: evidence from Spanish manufacturing firms. *International Journal of Industrial Organization*, 26, pp. 113–136.

Lhuillery S., Pfister E., 2009, "R&D cooperation and failures in innovation projects: Empirical evidence from French CIS data", *Research Policy*, 38, pp. 45–57

Lööf, H., and Broström, A. , 2008, "Does knowledge diffusion between university and industry increase innovativeness?", *The Journal of Technology Transfer, 33*(1), pp.73–90

Lööf and Heshmati, 2005, *The Impact of Public Funding on Private R&D investment. New Evidence from a Firm Level Innovation Study*, Centre of Excellence for studies in Science and Innovation http://www.infra.kth.se/cesis/research/publications/working papers.Elim

Luukkonen T., 1998, "The difficulties in assessing the imopacts of EU framework programmmes", *Research Policy*, 27, pp.599-622

Merito M., S. Giannangeli and A. Bonaccorsi (2007), Gli incentivi per la ricerca e lo sviluppo industriale stimolano la produttività della ricerca e la crescita delle imprese?, *l'Industria*, 27(2), pp. 221-241.

Metcalfe, J.S., L. Georghiou and A. James, 1997, "Adaptation and Learning in European Technology Policy", paper presented to the 1997 Annual Meeting of the American Association for the Advancement of Science, Seattle, 13-18 February.

OECD, 2006, Government R&D Funding and Company Behaviour: Measuring Behavioural Additionality, OECD, Directorate for science, technology and industry, Comittee for scientific and technological policy, Paris

Pisano G., 1990, "The R&D boundaries of the firm: an empirical analysis", *Administrative Science Quarterly*, 35, pp. 153–176.

Sakakibara M. 2001. The Diversity of R&D Consortia and Firm Behaviour: Evidence from Japanese Data, *The Journal of Industrial Economics* 49(2), pp. 181–196.

Sinha, D. and M. Cusumano, 1991, Complementary Resources and Cooperative Research: A Model of Research Joint Ventures among Competitors, *Management Science*, 37 (9), pp. 1091-1106.

Suetens, S., ,2002, "R&D subsidies and production effects of R&D personnel: evidence from the Flemish region", *CESIT Discussion Paper* 2002/03, Antwerp.

Teece, D., 1992, Competition, Cooperation and Innovation, *Journal of Economic Behavior and Organization,* 18, pp. 1-25.

Teece, D. J., Pisano, G., & Shuen, A., 1997, Dynamic capabilities and strategic management,

Strategic Management Journal, 18(7), pp. 509-533.

Veugelers R.,1998, "Technological collaboration: an assessment of theoretical and empirical findings", *De Economist,* 149, pp. 419–443.

Wallsten, S.J., 2000, "The effects of government‐industry R&D programs on private R&D: the case of the Small Business Innovation Research Program" *RAND Journal of Economics* 31 (1), pp. 82–100.

Wiethaus, L. (2005). Absorptive Capacity and Connectedness: Why competing firms also adopt identical R&D approaches, *International Journal of Industrial Organization*, 23, pp. 467-481.

Wooldridge J.M., 2010, *Econometric Analysis of cross section and panel data*. Cambridge: MIT Press.

Zúñiga-Vicente J., Alonso-Borrego C., Forcadell F.J., Galán J.I., 2014, "Assessing The Effect Of Public Subsidies On Firm R&D Investment: A Survey", *Journal of Economic Surveys*, 28(1), pp. 36–67.

Appendix

Table A.1. presents a numerical example to clarify the procedure followed to build the collaboration indicator used in the paper. The indicator is a weighted average of the sum of the different kind of collaborations of the firm. In the example firm 1 and firm 2 have the same number of collaborations (3) with the same kind of partners, namely other firms of the group, suppliers and public research institutes. Nonetheless, the collaborations have different importance for the two firms. Firm 1 judge highly important the collaboration with suppliers, and not important those with other firms of the group and with public research institutes. While, firm 2 gives high relevance to the collaboration with public research institutes and medium relevance to collaboration with its suppliers and low importance to that with other firms of the group. Our measure for firm 1 has the value: Coop(1)=1.50 and for firm 2: coop(2)=2.25. A comparison of these values allow us to conclude that collaborations for firm 2 are more important than for firm 1.

Table A1. A numerical example of calculation of the cooperation relevance indicator for two firms

	Firm 1		
Type of collaboration	***(a) presence of a collaboration***	***(b) Importance of collaboration****	***(c) (a)*(b)***
other firms of the same groups	1	0.25	0.25
Suppliers	1	1	1
Customers	0	0	0
competitor firms	0	0	0
Consultants	0	0	0
public research institutes	1	0.25	0.25
Coop(1)			**1.50**
	Firm 2		
Type of collaboration	***(a) presence of a collaboration***	***(b) Importance of collaboration****	***(c) (a)*(b)***
other firms of the same groups	1	0.5	0.5
Suppliers	1	0.75	0.75
Customers	0	0	0
competitor firms	0	0	0
Consultants	0	0	0
public research institutes	1	1	1
Coop(2)			**2.25**

*: importance of collaboration can assume the following values: 0.25 (not important), 0.5, 0.75, 1 (high importance).

List of recent papers published un the same series

2014/10 Jointness in Sites: The Case of Migratory Beekeeping, Luciano Pilati, Vasco Boatto

2014/09 Sustainability vs. credibility of fiscal consolidation. A Principal Components test for the Euro Zone, Giuliana Passamani, Roberto Tamborini, Matteo Tomaselli

2014/08 Fitting Spatial Econometric Models through the Unilateral Approximation, Giuseppe Arbia, Marco Bee, Giuseppe Espa, Flavio Santi.

2014/07 Il modello di scoring del Fondo Centrale di Garanzia: un'analisi d'impatto, Davide Panizzolo

2014/06 Going abroad on regional shoulders: The role of spillovers on the composition of regional exports, Mariasole Bannò, Diego Giuliani, Enrico Zaninotto

2014/05 The role of covenants in bond issue and investment policy. The case of Russian companies, Flavio Bazzana, Anna Zadorozhnaya, Roberto Gabriele

2014/04 Efficiency or Bounded Rationality? Drivers of Firm Diversification Strategies in Vietnam, H. Thu Tran, E. Santarelli, E. Zaninotto

2014/03 Where Gibrat meets Zipf: Scale and Scope of French Firms, M. Bee, M. Riccaboni and S. Schiavo

2014/02 Competition in the banking sector and economic growth: panel-based international evidence, E. Gaffeo and R. Mazzocchi

2014/01 Macroprudential Consolidation Policy in Interbank Networks, E. Gaffeo and M. Molinari

2013/18 Bio-Economics of Allocatable Pollination Services: Sequential Choices and Jointness in Sites, L. Pilati and V. Boatto

2013/17 Resilience and specialization in volatile environments: evidence from the Italian Air Force Tornado crews learning practices, M. Laura Frigotto, Marco Zamarian

2013/16 Monetary Policy when the NAIRI is unknown: The Fed and the Great Deviation, Ronny Mazzocchi

2013/15 Intertemporal Coordination Failure and Monetary Policy, Ronny Mazzocchi

2013/14 Investment-Saving Imbalances with Endogenous Capital Stock, Ronny Mazzocchi

2013/13 Scope and Flaws of the New Neoclassical Synthesis, Ronny Mazzocchi

2013/12 Approximate Maximum Likelihood Estimation of the Autologistic Model, Marco Bee, Diego Giuliani, Giuseppe Espa

2013/11 Do middle managers matter?, Elena Feltrinelli, Roberto Gabriele, Sandro Trento

2013/10 Transatlantic contagion 2010-…, Roberto Tamborini

2013/09 Interbank contagion and resolution procedures: inspecting the mechanism, Edoardo Gaffeo e Massimo Molinari

2013/08 Using information markets in grantmaking. An assessment of the issues involved and an application to Italian banking foundations, Edoardo Gaffeo

2013/07 A spatial and sectoral analysis of firm demography in Italy, Giuseppe Espa, Danila Filipponi, Diego Giuliani, Davide Piacentino

2013/06 Reassessing the spatial determinants of the growth of Italian SMEs, Roberto Gabriele, Diego Giuliani, Marco Corsino, Giuseppe Espa

2013/05 At the core of the international financial system, Valentina Feroldi, Edoardo Gaffeo

2013/04 Uses And Motivations For Credit Derivatives: An Empirical Investigation Into Italian Banks, Eleonora Broccardo, Maria Mazzuca and Elmas Yaldiz

2013/03 Origins and prospects of the Euro existential crisis, Luigi Bonatti and Andrea Fracasso

2013/02 Employer moral hazard and wage rigidity. The case of worker-owned and investor-owned firms, Marina Albanese, Cecilia Navarra and Ermanno Tortia

2013/01 A regular multidistance among fuzzy numbers, Franco Molinari.