The role of company R&D investment and collaborations as mediating drivers of innovation policy effectiveness

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This paper studies the effect of public incentives to company R&D activity (investment and collaboration) and innovative performance. We aim at deepening the following aspects.

First, differently from the current state-of-the-art generally envisaging a unidirectional impact of the public policy on company innovation (*output-additionality*), we provide a new framework incorporating 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*). We consider jointly: the input, the behavioral and the output additionality (Cerulli and Potì (2012) and Antonioli and Marzucchi (2012)).

Second, differently from the conventional approach, we consider the level of own R&D and the R&D cooperation as "endogenous" (thus not "exogenous") outcomes of a (direct) innovation policy. Differently from our approach, Hynloopen (2000) studies the impact on company R&D level of two policies, subsidy innovation policy and a legal framework allowing firms to participate in R&D cooperation. Czarnitzki et al. (2007) study the impact of public incentive policy and collaboration strategy (taken as "exogenous" from the policy) on firms R&D level and patenting. They find out that the R&D collaboration strategy has a general higher positive effect than the subsidy, but strengthened when accompanied with a subsidy.

In our approach the evaluation setting is different as the innovation policy is the (only) exogenous "treatment", whereas firm R&D investment and collaboration performance are (endogenous) mediating responses to this treatment in a first step, and predicting effects of firm innovation output in a second step.

In the first step, we study the subsidy policy treatment effect on R&D cooperation decision and on total firm own R&D investment controlling for other relevant variables, such as: market structure, intra-industry spillover and firm

characteristics such as size, R&D intensity and financial constraints. Working with a cross-section, it is important to control for fixed industry effects (Geroski, 1988), which captures various technology dimensions such as technological opportunity and appropriability regimes. By exploiting the 4th wave of the Italian Community Innovation Survey we construct an "intensity" indicator of collaboration performance rather than a dummy signaling the mere existence of this strategy. We use the number of collaborations with asymmetric/complementary and horizontal/vertical different partners weighted through the relevance of these different kinds of collaborations (firm-firm, firm-university, etc).

Third, in the second-step - when studying the policy impact on firm innovative outputs – we estimate a regression where R&D and collaboration first-step additionalities are considered as innovation predictors along with their combined "interaction". The output is measured as the probability of patenting (invention) and as the share of innovation sales (innovation), using various control variables such as the level of intra-industry spillover and the firm knowledge absorptive capacity.

The novelty of this approach stands in allowing for identifying possible *synergy* or *weakening mechanisms* between the R&D additionality and the collaboration additionality on the innovation output. This may returns relevant policy making implications: for instance, 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.

Our research goal is that of studying the ultimate effect of R&D and innovation support on company invention and innovation activity (*output additionality*) through the *mediating effect* the subsidy has had on company own R&D (*input additionality*) and R&D cooperation strategy (*behavioral additionality*).

We employ a *treatment random coefficient model* (see Wooldridge, 2010, p. 945-951), implemented in STATA through the routine `ivtreatreg` by Cerulli (2012). This model allows to estimate, for each company, an idiosyncratic effect of the support on R&D and cooperation: formally, it is defined as the Average Treatment Effect conditional on a vector of covariates **x**.

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

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

II. $ATE_{behavioral}(\mathbf{x}_i)$ = average treatment effect of R&D support on company *i* degree of cooperation (idiosyncratic behavioral additionality)

We use (I) and (II), as *mediating effects* in the following invention/innovation regression:

$$Y = a + b\ ATE_{input}(\mathbf{x}_i) + c\ ATE_{behavioral}(\mathbf{x}_i) + d\ ATE_{input}(\mathbf{x}_i)\ ATE_{behavioral}(\mathbf{x}_i) + e\ \mathbf{w} + error \quad (1)$$

where:
Y: is either an invention outcome (firm probability of performing at least one patent application), or an innovation outcome (share of the innovative turnover on total company turnover);
W: is a vector of covariates explaining invention/innovation performance.
Our approach will allow us also for taking into account potential synergistic or weakening effects of combined input and behavioral additionality on output additionality.

Finally, 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 rather than unsupported companies. Answering this question has immediate 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 picked up companies to support having lower additionality potential.

The main contribution of the paper is to go a step forward towards a more complete analysis of the etiology of the impact of R&D subsidies extending the David, Hall and Toole (2000) framework in which the R&D subsidy has an impact on the level of financial constraints experimented by the firm: we assume that R&D subsidies may have a simultaneous impact also on firm R&D collaborations.

Results may lead to suggest a better fine tuning of the policy measure. Policy makers have to consider the impact of the subsidy on financial constraint

experimented by firms, but also the possible effect on collaboration efforts (proxy of knowledge spillovers) and the interaction of the two different mediators. The interaction term allow to investigate if substitutability or complementarity is in place.

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