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ABSTRACT

This paper evaluates the effects of a regional R&D policy in the Italian province of Trento from 2002 to 2007, an ideal testing ground for the role of local government and the effectiveness of an R&D place-based policy. Exploiting a unique database and using a counterfactual dose–response regression model, we perform an evaluation exercise of policy targets concerning employment, fixed and intangible assets. We find that two years after the award date, there exists an inverted u-shaped relationship between subsidies intensity and impact size: there exists a range of subsidy doses that is effective in stimulating employment and intangible assets growth. Instead, we do not find any additionality of the policy on fixed assets. At longer time span, i.e. four years after the award, the effect on employment growth persists and we do observe a mild effect on labor quality for intermediate grants spending. Moreover, the effect on intangible assets spending growth is also persistent for a similar interval of R&D subsidies amounts. We discuss the impact deriving some policy considerations.

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1. Introduction

The governance of R&D policies has changed significantly over the past 15 years. Apart from the involvement of the European Union (first through the Seventh Framework Program and now the Horizon 2020 agenda), intensive academic and political discussion has increasingly designated the regional government as the most appropriate locus for R&D policy.

The devolution of power to regional governments is justified on several grounds. Institutionally, the ‘principle of subsidiarity’ established in Europe by the Treaty of Maastricht (1992) gives lower levels of government a major role in devising and administering policies that need to be tailored to the local context.

Theoretically, the literature on Regional Systems of Innovation (Malerba 2002; Edquist 2005) portrays innovation as a set of systemic and spatially bounded processes that can be successfully enacted at sub-national level insofar as they are ‘crucially regulated and enabled by the governance structures in which they are embedded’ (Koschatzky and Kroll 2007, 1116). In a similar vein, an OECD report observes that ‘regions matter’ and calls for transcending the ‘one size fits all’ policy approach usually implemented at the national level (OECD 1999). An authoritative call for place-based regional policy is made also in the Barca report (2009), which significantly enriches the category ‘place-based’ to encompass social, institutional and cultural characteristics and the interaction of local stakeholders

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and policy-makers. To be effective, it is argued, policies should be both place-based and people-based (Barca, McCann, and Rodriguez-Pose 2012).

This paper evaluates the effectiveness of an R&D place-based policy carried out in the northern Italian province of Trento in the past decade. The analysis concentrates on the role played by differential subsidization, i.e. the 'dose' as the amount of funds granted to each project. We aim to go beyond the traditional analyses focusing on average treatment effects of the policy as the latter does not take into consideration that the treatment is not equal for all the firms. In this respect, it is worth noting that while a growing literature has explored the effect of regional policies (García-Quevedo 2004; Caloffi, Mariani, and Sterlacchini 2016; Dimos and Pugh 2016), only a handful of studies (Dai and Cheng 2015; Marino et al. 2016) have tried to cope with a more fined grained analysis of the effects of regional R&D programs. Therefore, the evidence about the effect of an additional euro on R&D additionality is scant and the quest to expand our understanding of this theme is mounting.

The paper is original in three ways.

First, the autonomous Province of Trento constitutes an ideal testing ground for the role of local government and the effectiveness of an R&D place-based policy, in that it has all the necessary institutional ingredients for being 'a showcase example of regional governance and policy implementation' (Koschatzky, 2005, 696). Policymakers enjoy broad regional autonomy and have considerable financial resources to design and implement tailored R&D policies, which is a pre-condition for sound regional policy (Cooke, Boekholt, and Todtling 2000; Cooke and Memedovic 2003; Tödtling and Trippl 2005).

Second, the provincial policy evaluated here was the subject of a substantial financial commitment: average yearly funding of €22.7 millions equal to 33% of total expenses in subsidies in the period 2002–2007 is a high percentage considering that at the national level the percentage is around 17.7% (MET 2009). Nevertheless, to the best of our knowledge, no systematic assessment has been so far carried out of the effectiveness of R&D grants to firms operating in the region.

Third, our econometric approach permits a thorough evaluation of the policy's effectiveness via a counterfactual dose–response approach, allowing to shed some light on the effect of different treatment doses, namely different subsidy intensities.

Such an approach enables us to address the issue of the effect of different doses of euros spent in subsidies by the policymaker. Indeed, knowledge about the amount of money granted with subsidies together with the information about employment figures, labor costs, fixed assets and intangible assets spending, allow us to investigate if and how one additional euros of subsidy expenses increases the magnitude of the effect, thus going beyond the traditional exploration of potential crowding-out phenomenon (González and Pazó 2008).

Exploiting a unique database that covers the population of companies that received at least one R&D grant between 2002 and 2007, we rely on the dose–response treatment model proposed by Cerulli (2015), which builds on the regression adjustment model of Wooldridge (2010). Our model exploits data on the intensity of R&D grants to investigate the effect of increasing the R&D subsidy. The model compares each level of the treatment – calibrated by the amount of euros of the R&D grant – with the performance of non-treated firms. Hence, the reliability of the estimation depends on the comparability of the subsamples of treated and control firms: the higher the similarity between the two groups, the higher the precision of the estimation.

The local nature of the program (only firms that are located and carry out the investment in the province of Trento were eligible) significantly reduces the degree of heterogeneity. Thus, by focusing on a single province, our approach:

(i) ensures greater similarity between treatment and control firms than is typically found in comparisons carried out at national level;
(ii) reduces the heterogeneity that could undermine the robustness of counterfactual methods;
(iii) neutralizes the potential confounding effects of multiple subsidies from different sources, by restricting the analysis to firms that received only R&D and no other subsidies.

Going to our results: we find that two years after the award date, there exists a range of subsidy doses that is effective in stimulating employment and intangible assets growth. Instead, we do not find any additionality of the policy on fixed assets. At a longer time span – i.e. four years after – the effect on employment growth persists and we do observe a mild effect on labor quality for intermediate grants spending. Moreover, the effect on intangible assets spending growth is also persistent for a similar interval of R&D subsidies amounts.

The paper is organized as follows. Section 2 reviews the literature as background to our empirical evaluation; Section 3 describes the relevant legislation, Trento Provincial Law 6/1999. Section 4 details the estimation method, and Section 5 presents the data and the variables. The econometric results are presented in Section 6; Section 7 concludes and outlines some policy implications together with the agenda for future research.

2. The literature

From a theoretical point of view, the economic rationale for R&D subsidies lies on market failures ground (Nelson 1959; Arrow 1962). Such failures are due to the public good nature of knowledge that does not allow firms to fully appropriate the returns of R&D activity. It follows that private R&D investments are below the optimal social level. Another rationale for R&D subsidies is related to the presence of capital market imperfections that make costly for firms, especially new ventures and small ones, to secure the financing needed to support innovative endeavors.

The empirical literature relevant as background to our analysis is divided into two streams: one deals with the regionalization of R&D policy and the second concerns the impact evaluation of R&D subsidies.

Throughout Europe, the role of regions in designing, implementing and evaluating innovation policies, especially those targeted to SMEs (small and medium-size enterprises), increased enormously in importance after the turn of the century (European Commission 2004). This reflected recognition of the systemic nature of innovation, initially advanced by the 'National System of Innovation' school in the 1990s (Malerba 2002; Edquist 2005). Subsequently, increasing interest in Regional Systems of Innovation gained ground, providing a strong rationale for sub-national policy measures in this field.[1] Ribas (2009) emphasizes two factors that justify departure from national policy guidance: 'systemness', whereby regional and local governments may have a better grasp of the formal and informal institutions that shape behavioral patterns and social interactions in the territory; and heterogeneity, which signals that local governments may have a better knowledge of local agents and the socio-economic structure, and hence superior capacity to tailor policy to conditions on the ground. This deeper knowledge of potential awardees and the specific local context should enable the host region to retain a share of the social benefit arising out of the projects funded (Roper, Hewitt-Dundas, and Love 2004) and so to select the marginal projects that are most likely to generate knowledge spillovers (Feldman and Kelley 2006).

As it is emphasized by Bronzini and Piselli (2009, 188), the application of the regional lens is not merely a change of geographical scale. 'By testing if regional R&D is important to explain regional growth, it is implicitly assuming that technological knowledge has a localized scope'. Indeed, several of the arguments for a regional role in formulating and implementing R&D policies relate to the importance of geographical proximity and its nexus with innovation (Audretsch and Feldman 1996): knowledge spillovers are often spatially bounded (Bottazzi and Peri 2003); the spread of tacit knowledge is facilitated by face-to-face contacts (Storper 1997; Morgan 2004); getting partners to work together requires a degree of common identity (Lundvall 1992; Braczyk, Cooke, and Heidenreich 1998); innovation activities are frequently conducted in industrial clusters, by means of collaboration between firms and academic institutions, or through trust-based networks, all of which are highly region-specific (Paci and Usai 2000). This wide-angle background has shaped policy-making, becoming the main toolkit in designing R&D policy in a variety of regional contexts (OECD 2010).

As for the effectiveness of public subsidies on private R&D spending, the number of scientific contributions has been growing in the last decades thanks to the development and refinement of methods for program evaluation in econometrics (Imbens and Wooldridge 2009; Imbens and Rubin 2015). This strand of research (David, Hall, and Toole 2000; García-Quevedo 2004; Caloffi, Mariani, and Sterlacchini 2016; Dimos and Pugh 2016) seeks to determine whether subsidies prompt additional firms' investments in R&D, or they only substitute for investments that firms would have made anyway (infra-marginal projects).

As highlighted by some recent surveys (Zúñiga-Vicente et al. 2014), the bulk of the empirical evidence favors the thesis that public support does not crowd out private R&D investment (Almus and Czarnitzki 2003; Hyytinen and Toivanen 2005; Czarnitzki and Toole 2007; Czarnitzki, Ebersberger, and Fier 2007; Hussinger 2008; Aerts and Schmidt 2008; Bellucci, Pennacchio, and Zazzaro 2018; Vanino, Roper, and Becker 2019). Other scholars have instead found contrasting results (Busom 2000; Lach 2002; Duguet 2004; González, Jaumandreu, and Pazó 2005; Görg and Strobl 2007; Potì and Cerulli 2010; Bronzini and Iachini 2014; Aristei, Sterlacchini, and Venturini 2016; Mariani and Mealli 2018).

Within this stream of literature, it is worth noticing that only two studies have sought to determine whether different amounts of subsidy produce differential impacts on private R&D investment, and by what mechanisms. Marino et al. (2016) examine the effect of R&D subsidies on a sample of French firms during the period 1993-2009, finding evidence of crowding-out, i.e. substitution effects, by public R&D provision, '[…] especially for medium-high level of public subsidies' Marino et al. (2016, 12) Furthermore, the authors find that significant substitution of public for private R&D resources is more likely among low and medium-sized classes (€20,000 to €55,000) for subsidy-only recipients, and among medium-sized and high classes (€145,000 to €1.8 million) for companies that are 'fully supported', i.e. via both grants and tax credits.

Dai and Cheng (2015), on a sample of Chinese manufacturing companies in 2005–2007, find a saturation point beyond which a further increment in public subsidies does not increase the firm's total R&D investment. In addition, they find that there is a minimum threshold value of public subsidies for inducing private R&D spending by a firm.

3. The context of analysis: Province of Trento and Provincial Law 6/1999

Trento is an Alpine province in the Northeast of Italy with nearly 500,000 inhabitants and gross domestic product per inhabitant of €30,400 in 2007, making it one of the 50 richest NUTS2 regions in Europe. A distinguishing feature of the institutional setting is that firms operating in the province of Trento can apply only for subsidies awarded by the local government.[2]

The local financial commitment to R&D has been indeed very strong by comparison with other Italian regions: in 2007 the share of R&D subsidies in overall financial subsidies was 33.1%, against a national average 17.7% (MET 2009). Nevertheless, a review of science and technology indicators (Eurostat 2009) of the EU-27 reveals some weaknesses that might well be redressed by policy intervention. These indicators show that total R&D expenditure amounted to 1.11% of provincial GDP in 2005, higher than the Italian average of 0.89% but below the EU-27 average of 1.28% and significantly short of the target – 3% – set in the Lisbon strategy for the EU as a whole. Similarly, the percentage of researchers in total employment was 0.65%, better than the average of Italian regions (0.5%) but worse than the EU-27 average (0.9%).

Provincial Law 6/1999 (PL6/1999) lays down the guidelines for grants to firms operating in the province. The objectives of the law are quite broadly stated: for example, the R&D policy, the PL6/1999, is meant to support the 'quality' of local firms and investments, stimulate and sustain the growth of local economic activities (Capo 1 Art.1, PL6/99). In line with the Oslo Manual (OECD 2005), PL6/1999 identifies two types of commercial research activities eligible for funding: industrial research and experimental development.

All firms operating in the province of Trento can apply for grants within the PL6/1999 framework, by submitting a project to the local authority. There is no deadline for presenting a project within any given calendar year, but since funds are allocated on a first-in-first-out basis (provided that a panel of experts issues a positive assessment on the project), some firms' research projects may be refused once the year's budget for R&D funding is exhausted.[3] When a firm applies, its research project is examined and evaluated by a technical committee. If the project is judged acceptable, its economic viability and financial sustainability are then examined in a second stage. Only projects that are positively assessed at both stages are eligible for funding.

Firms can apply for co-financing of projects of different amounts, ranging from €25,000 to €3 million. Projects can entail spending during a period stretching for three years from the date of the grant. The expenditures fall into four categories: (1) employment costs; (2) patenting costs and contractual costs of license acquisition; (3) general additional costs related to the project (overhead up to 60% of costs declared under point 1); (4) costs related to the use of tools and machines for the project.

When a firm is awarded a grant, it must satisfy two further conditions for funding: (a) the results of the research have to be used/exploited in the province of Trento; and (b) for subsidies greater than € 500,000, or when the firm applies for additional funding beyond the original amount, a certain level of employment declared in the projects must be guaranteed for at least three years after the award date. If this latter condition is not met, the grant can be recalled for the full amount or else for a percentage based on the extent of the employment shortfall. Note that the employment constraint requested by the Trento Province makes this policy measure quite hybrid. To put it another way, the program cannot be considered a 'true' R&D policy program. This have also implications in terms of the choice of objective variables chosen to investigate the 'success' of the law (see below).

Firms started to apply for subsidies since 2001. At the beginning local firms were quite cautionary in applying for the law in the period under scrutiny (2002–2007) due to a number of reasons: the uncertainty about the 'new' procedure to get money and the rules to obey after having received the money (i.e. there was no experience of other firms to look at to have a better grasp of the procedure); the complexity of the procedure (firm had to prepare a report with technical and financial specification of the project); the need to avoid possible spillover of knowledge toward competitors (firms were afraid that supplying full disclosure of research projects to the financial and technical committees could let, even unintentionally, spillover some information to competitors).

4. The econometric model

We design our analysis to evaluate the impact of the intensity of R&D grants on several policy objective variables measured at the firm level. For this purpose, we set out by considering a continuous treatment (or dose–response) approach, as we observe firms receiving different amounts of R&D funding. In this way, we overcome the limitation of relying on just a binary (treated vs. untreated) treatment variable. Our reference model is the one proposed by Cerulli (2015), extending the regression–adjustment approach proposed in Wooldridge (2010) to a continuous treatment setting. This model is an alternative to the generalized propensity score of Hirano and Imbens (2004), as it can deal with situations in which also untreated units (units that did not receive the subsidy) are available. Below a short account of the model.

The starting point is Rubin's potential outcome equation (Rubin 1977)

$$y_i = y_{0i} + w_i(y_{1i} - y_{0i}), \tag{1}$$

where y_{0i} denotes the potential outcome for firm i when it is not included in the treatment; y_{1i} denotes the potential outcome of unit i when it is treated; w_i is the dummy variable indicating the treatment status.

Substituting the proper expressions for potential outcomes, we can get the following baseline random-coefficient regression (Wooldridge 1997, 2003)

$$y_i = \mu_0 + w_i \text{ ATE} + x_i\delta_0 + w_i\,(x_i - x)\delta + w_i \cdot (h(l_i) - \bar{h})\eta_i\ , \tag{2}$$

where $\eta_i = e_{0i} + w_i \cdot (e_{1i} - e_{0i})$; ATE is the unconditional average treatment effect; x_i is a set of control variables; $h(l_i)$ is the response function of y_i to the level of treatment l_i (equal to zero when $w_i = 0$); μ_0, δ, and δ_0 are parameters; and the 'bar' indicates average values.

Note that the method employs a rescaled treatment intensity (l_i) obtained through the following:

$$l_i = level_i / Max(level_i) * 100, \tag{3}$$

where $level_i$ is the amount of euros of the grant i. For consistent estimation of the causal parameters, we need to make the usual additional assumption of unconfoundedness (Wooldridge 2010). Under this assumption, it can be proved that Ordinary Least Squares (OLS) provide a consistent estimation of all the parameters of interest in (2). We can estimate ATE (Average Treatment Effect) directly from this regression, as well as ATET (Average Treatment Effect on Treated) and ATENT (Average Treatment Effect on Not Treated) indirectly. To complete parameters' identification we assume a parametric form of the dose–response function $h(l)$:

$$h(l_i) = a \cdot l_i + b \cdot l_i^2 + c \cdot l_i^3, \tag{4}$$

where a, b, and c are parameters to be estimated in regression (2).

Once regression (2) is estimated, we can calculate the dose–response function as:

$$\widehat{\mathrm{ATE}}(l_i) = w\left[\widehat{ATET(l_i)}_{l>0} + \hat{a}\left(l_i - \sum_{i=1}^{N} l_i\right) + \hat{b}\left(l_i^2 - \sum_{i=1}^{N} l_i^2\right) + \hat{c}\left(l_i^3 - \sum_{i=1}^{N} l_i^3\right)\right] \tag{5}$$
$$+ (1-w)\widehat{ATENT}(l_i)$$

where $\widehat{ATE}(l_i) = \widehat{ATET}(l_i)$ for $l_i > 0$. plotting the $\widehat{ATET}(l_i)_{l\,i>0}$ as a function of l_i allows for investigating the pattern of the average treatment effect over all the support of the treatment intensity. Furthermore, for every dose level (amount of funding for R&D investment granted to the firm), we can calculate the confidence interval around the dose–response function as:

$$\hat{\sigma}_{ATET(l_i)} = \{L_1^2\hat{\sigma}_{\hat{a}}^2 + L_1^2\hat{\sigma}_{\hat{b}}^2 + L_1^2\hat{\sigma}_{\hat{c}}^2 + 2\hat{\sigma}_{\hat{a},\hat{b}}^2 L_1 L_2 + 2\hat{\sigma}_{\hat{a},\hat{c}}^2 L_1 L_3 + 2\hat{\sigma}_{\hat{c},\hat{b}}^2 L_2 L_3\}^{1/2} \tag{6}$$

where $L_1 = l - \mathrm{E(l)}$, $L_2 = l^2 - \mathrm{E}^2(l^2)$ and $L_3 = l^3 - \mathrm{E}^3(l^3)$. Therefore, the α-confidence interval for $\widehat{\mathrm{ATET}}(l_i)_{l>0}$ is

$$\widehat{\mathrm{ATET}}(l_i) \mp Z_{\alpha/2}\hat{\sigma}_{\widehat{ATET(l)}}. \tag{7}$$

This quantity can be used to check the significance of the effect of treatment as the dose varies.

In the empirical analysis, we propose a series of linear regression models based on Equation (2). In each model, the objective variable is chosen to capture a possible impact of the policy. We investigate the impacts of subsidies on:

(i) employment, specifically on the rate of employment growth and average labor cost growth. The latter is regarded as a proxy of human capital, assuming that labor cost growth signals more skilled workers;
(ii) rate of growth of both intangible and fixed assets investment of firm.[4]

The different treatment doses are measured by a continuous treatment variable, the amount of euros granted as a subsidy to firm.[5]

Figure 1 shows the timeline for the variables used in implementing model (2). Denoting the treatment year (the year of the grant) as t, and the time window of validity of the employment constraint as $[t, t+3]$, we carry out two sets of evaluations. First, we analyze the dose–response function by considering the objective variables at time $t+2$, when the employment constraint is binding for those treated firms with a project beyond the threshold of €500,000 (i.e. 43 units out of 78 treated

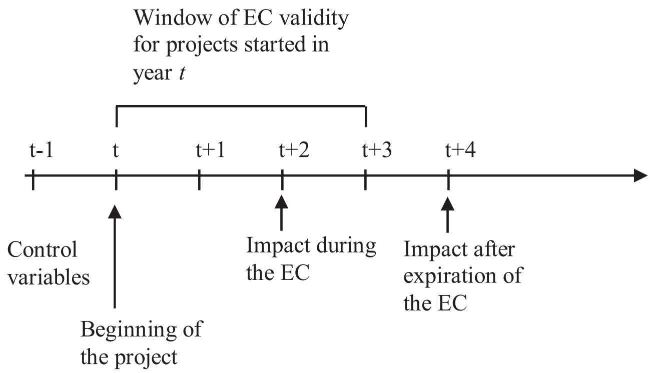

Figure 1. Timeline of the econometric models.

firms), and then taking the objective variables at *t+4*, after the expiration of the constraint, namely when these firms are free from such employment constraint and free to adjust their employment level as desired.

The model is implemented in the following way:

- The treatment group consists of firms that were awarded a public grant to co-finance an R&D project in any year in the period 2002–2007;
- The year of treatment is defined as that in which the firm received notification of the grant from the local government;
- Treatment intensity is the size of the grant in euros;
- The eligible control group consists of firms that did not receive any grant during the time window under scrutiny. Note that, given that the Province of Trento is the only possible source of funds for the group of firms under scrutiny, there is no bias due to policy overlapping; in other words, our firms cannot also be 'treated' by another law at a different level of government;
- Finally, we employ a pre-filtering procedure *à la* Ho et al. (2007), including in the eligible control group those firms that are active in the 5-digit Ateco 2002 sectors where we find at least one treated firm.

5. The data and the variables

5.1. The data

Local government administrative archives are our primary source of data on firms receiving R&D grants and firms receiving all types of grant.

The treatment group of firms is composed by those firms that, in the time window under scrutiny, received a grant specifically referring to Chapter n.5 of Provincial Law 6/99 that regulates the concession of R&D grants. In the years 2002–2007 under analysis, less than 100 firms applied for this particular kind of subsidy. The number of the treated firms used in the paper is 78 given that we operated a further selection in building the treatment group to ensure comparability with the group of control firms and exclude particular and seven unique cases, i.e. companies that followed a slightly different procedure for reasons not related to the economic context (e.g. they started a negotiation with Province of Trento on terms of the concession of the grant). Moreover, in some cases – less than 10 – the subsidy was recalled because the firms that benefited from it did not obey to some of the regulations imposed by the law. For instance, they did not respect the employment constraint or they *de facto* moved the activity of the firm out of the province of Trento.

Once collected data about the subsidies for the treatment group, we also added accounting data retrieved from Bureau van Dijk's AIDA database and the Cerved Group's Pitagora database. We also drew data on firms' employees from Archivio Statistico delle Imprese Attive (ASIA), constructed and managed by ISTAT, the Italian National Statistical Institute. Then, we matched the treatment group with a control group of firms with similar observable characteristics, i.e. operate in the same sector at 5-digit Ateco level, have similar size and age. We excluded from the control group all the firms that received, in one of the years analyzed, other types of grants in order to avoid confounding effects. The final database comprises 78 subsidized firms and 2107 untreated companies over the period 1998–2008.[6]

The number of treated firms is limited but we should consider two methodological aspects: first, having a smaller number of treated compared to the number of untreated units is generally preferred compared to the opposite case (more treated than untreated units). Indeed, the main worry should be to build a soundly counterfactual sample and, in our estimation, we exploit the vast range of possibilities in choosing control firms.

Second, what really matters in interpreting the dose–response model results are the confidence intervals and their significance along the dose values. In fact, the dose–response thus estimated uses interpolation as it is based on a 3-degree polynomial. Fitting a polynomial is a global estimation procedure. So that the values in sparse regions can be 'filled-in' using the abundance of data in other part of the scatter cloud. This allows us to have acceptable results also in zones of the cloud characterized by fewer observations, which is probably our case in some zones.

5.2. The variables

The regression model (2) includes both a dummy variable (w) indicating the treatment – i.e. the concession of an R&D grant –, and a continuous variable representing the treatment intensity (*I*) as measured by the amount of money granted to the firm to co-finance its investment.

The decision about the objective variables to analyze was guided by the need to reconduct our results to literature streams about different kinds of additionality. Hence, we decided to break down the R&D policy aims of Trento Provincial Law 6/1999 into two sets of target variables related, respectively, with input additionality and quasi-output additionality. To investigate input additionality, we use:

the rate of growth of expenditure on tangible and fixed assets (*FA*);
the rate of growth of expenditure on intangible assets (*IA*).[7]

As measures of quasi-output additionality, we refer to:

the rate of growth of unit labor costs (*ULC*), namely the ratio of net labor costs to the total number of employees, a proxy of the level of skill and/or labor quality;
the employment growth rate (*Growth*) that is also recalled in the law as one of the policy aims.[8]

To construct our set of control variables, we first consider all factors that can be presumed to influence the participation decision and the outcome variables; in this way, we seek to satisfy the assumption of ignorable treatment assignment. The selection of factors is guided by economic theory, previous empirical findings, and information on the institutional setting (Rubin and Thomas 1996; Heckman, Ichimura, and Todd 1998; Glazerman, Levy, and Myers 2003; Caliendo and Kopeinig 2008; Stuart 2010).

Second, only variables that are not affected by participation in the treatment should be included in the model (Caliendo and Kopeinig 2008). In order to satisfy this condition, all time-variant control variables are lagged by one period (*t-1*) with respect to the year of treatment (*t*), thus making them predetermined vis-à-vis the treatment. As a result, the control variables – exogenous confounders in model (2) – are all lagged by one year.

They are:

firm size as measured by the number of employees ($Empl_{t-1}$);
per capita labor costs (ULC_{t-1});
rescaled cash flow ($Cashflow_{t-1}$), i.e. the ratio of cash flow to total sales, as a proxy for financial constraints (Hall et al. 2016);
capital intensity ($Capint_{t-1}$), i.e. the ratio of fixed assets to total sales;
a control variable (*year*) to control for business cycle effects.

All the monetary variables are deflated by producer price indices.

Table 1 reports descriptive statistics for the variables, separately for treatment and control firms. The number of treated firms is 78; the number of research projects funded ranges from a low of 6 (in 2007) to a high of 20 (in 2006). The size of R&D projects ranges from €52,000 to around 9 million euros. The size of the R&D grants ranges from €26,000 to €5,201,000, with a mean of about €986,000 and a standard deviation of about €1,036,000. A fourth of the subsidized firms received grants smaller than €250,000 and half of them received a subsidy smaller than €600,000. Only a tenth of the firms received amounts greater than €2.4 million. As it can be seen from Figure 2, the sample distribution[9] of grant intensities is right-skewed (Figure 2).

6. The impact of the policy

In this section, we comment the estimated dose–response functions related to each model that provide information about the effect of an additional dose of treatment (an additional euro spent

Table 1. Descriptive statistics of the sample of firms.

	N	mean	sd	min	Max
untreated firms					
age	2029	24.59	17.39	0.00	98.00
intangibles	2029	193.42	2428.02	0.00	80,754.00
fixed assets	2029	971.01	4371.92	0.00	98,587.30
labor cost	2029	667.62	1729.21	0.00	20,169.89
per capita labor cost	2029	24.07	11.23	0.00	84.77
number of employees	2029	20.09	42.25	1.00	479.00
cash flow rescaled	2029	10.52	39.48	−237.97	1401.33
capint	2029	0.3516	1.2069	−0.1190	27.7505
treated firms					
*Project size**	78	1711.62	1712.78	52.13	8967.76
*Size of the R&D grant**	78	986.74	1036.31	26.06	5201.30
age	78	25.71	17.79	0.00	42.00
intangibles	78	1577.17	4042.90	0.00	23,389.00
fixed assets	78	6641.26	18890.69	0.00	121,941.00
labor cost	78	5225.14	13073.65	0.00	75,322.36
per capita labor cost	78	28.78	13.35	0.00	51.98
number of employees	78	127.69	324.30	1.00	1849.00
cash flow rescaled	78	12.61	16.61	−57.90	72.73
capint	78	0.2369	0.2900	0.0000	1.4462
all firms					
age	2107	24.63	17.40	0.00	98.00
intangibles	2107	244.65	2518.50	0.00	80,754.00
fixed assets	2107	1180.92	5709.64	0.00	121,941.00
labor cost	2107	836.34	3141.57	0.00	75,322.36
per capita labor cost	2107	24.24	11.35	0.00	84.77
number of employees	2107	24.07	77.31	1.00	1849.00
cash flow rescaled	2107	10.60	38.88	−237.97	1401.33
capint	2107	0.3474	1.1858	−0.1190	27.7505

Notes: *Figures expressed in thousands euros.

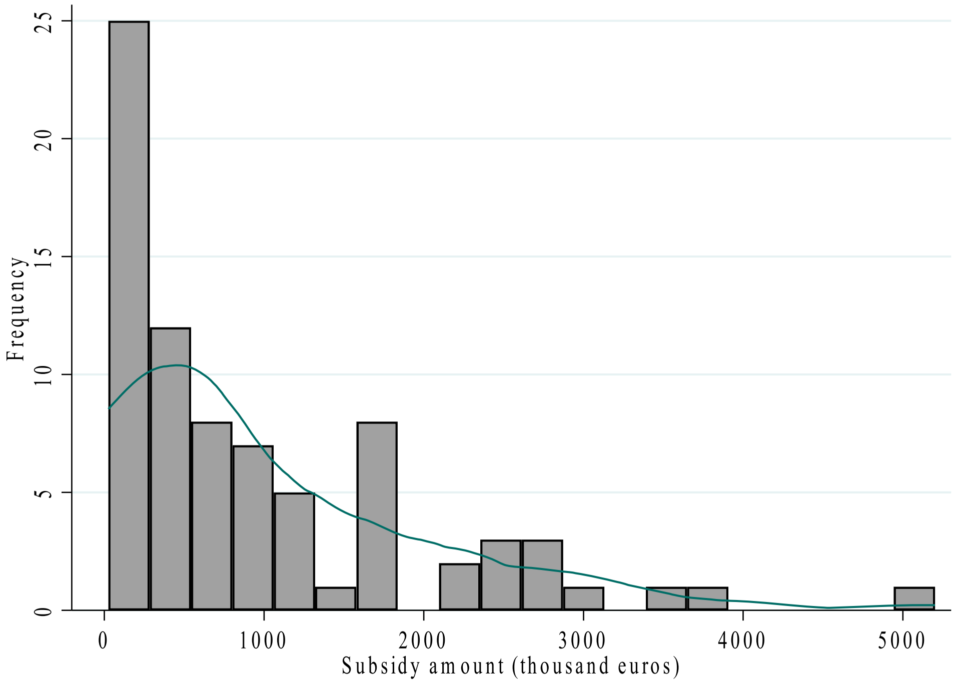

Figure 2. The distribution of R&D grant amounts.

in subsidy by policymaker) on the outcome variable. In order to evaluate the degree of effectiveness of the policy, we suggest that it could be extremely interesting to know better the 'shape' of the dose–response function. As we will see, in our case we get an inverted u-shape for the dose–response function, suggesting that: (i) it is better to use intermediate doses; (ii) if the subsidy is too small, it does not spur any effect. Finally, if it is too big its impact is null, as well. Different dose intensities are represented by values falling in the range 26–100. These values are obtained through the standardization formula in Equation (3) that transforms the minimum subsidy (around 26,000€) into $I = 26$ and the maximum value of the subsidies (around 5200k €) into $I = 100$. The estimated results for these doses can be used to speculate on their likely effects and their implications. We claim that it is only possible to get some insights about the true effect of the policy because, from a methodological point of view, there is no direct meaning to the estimated coefficients in the models (Hirano and Imbens 2004).[10]

We discuss the results of our econometric investigation by looking at each of the policy target variables, starting with our R&D output variables: employment growth and unit labor cost growth.

6.1. Employment growth

We start our analysis from the impact on the employment growth rate of firms.

The dose–response functions for the models in Figure 3 map the subsidies level – horizontal axis – on conditional response on employment growth – vertical axis. The figures show average conditional effects (*ATET(l)*) – the continuous curve – and a 10% confidence interval of the estimation – the dotted line. Figure 3 shows that the employment effects are non-linear in treatment intensity both when the employment constraint is binding (Figure 3, panel a) and after its expiration (Figure 3, panel b).

In both cases, the relation between the amount of additional employment growth and the subsidy dose is non-linear. It is observed an S-shaped effect, i.e. different sensitivity of the objective variable to the cash-flow injection brought by the public support. In the two-years lag model the effect is

(a) (b)

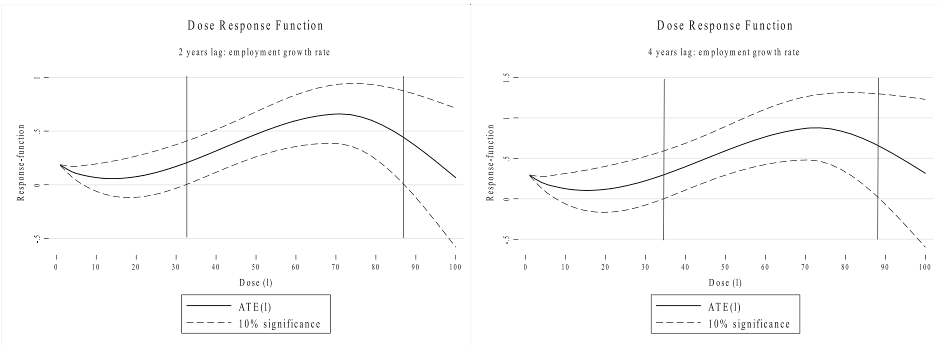

Figure 3. Dose–response function for the objective variable: Employment growth. Results for model during EC (panel a) and after EC expiration (panel b).

increasing up to around *l = 70*, but it is significant only in the interval of *l* between around *33* and *86*. It follows that to achieve an impact on employment growth, the optimal choice is to co-finance at least *l = 33*, but no more than *l = 86*. Subsidizing more than *l = 86* seems, in fact, not to have an additionality effects on employment.[11] Results indicate that 'intermediate' doses intensities – compared to the maximum amount granted to firms – spur some effects, while spending too much is not beneficial to get an impact. Similarly, if the subsidy does not reach a given intensity, it will not induce any impact on subsidized firms. Moreover, the inverted u-shape of the dose–response function suggests that there exists an optimal level of subsidy that spurs the biggest effect.

The evaluation of the policy impact on employment growth, after the expiration of the constraint (four-years lag), shows that the award of an R&D grant has a persistent effect. Indeed, the shape of the dose–response curve is similar to the one discussed above for two-years lag model. The interval of significance of the effect is similar: *l* ∈ *[30, 90]*.

6.2. Unit labor costs

As for the impact of the policy on the growth of per capita labor costs, it can be appreciated an increasing profile for both models – i.e. two and four years after the subsidy concession. Nonetheless, after two years we do not see any significant result (Figure 4, panel a). Instead, in the four years lag model, the range of subsidy intensities for which we find a significant result is from *l = 38* to around *l = 70* (Figure 4, panel b).[12]

6.3. Fixed assets

The results on fixed assets growth show that during and after the period of validity of the employment constraint, a quite flat S-shaped curves of dose–response emerge. Moreover, the impact is not significant on all the doses both in two- and four-years lag model (Figure 5).[13]

6.4. Intangible assets

Figure 6 panel (a) shows that after two years there is an effect on intangible assets growth for doses going from *l = 45* to *l = 85*. In Figure 6 panel (b), we see that such effect persists with a significant interval similar to the previous one: *l* ∈ *[48, 82]*. In both models. the inverted u-shape of the dose–response function signals, as previously seen it, the existence of a subsidy intensity that maximizes the impact on intangible assets growth.

(a) (b)

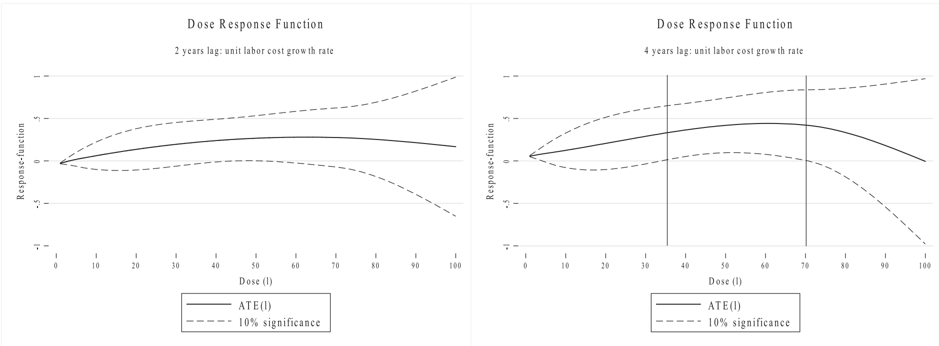

Figure 4. Dose–response function for the objective variable: unit labour cost. Results for model during EC (panel a) and after EC expiration (panel b).

(a) (b)

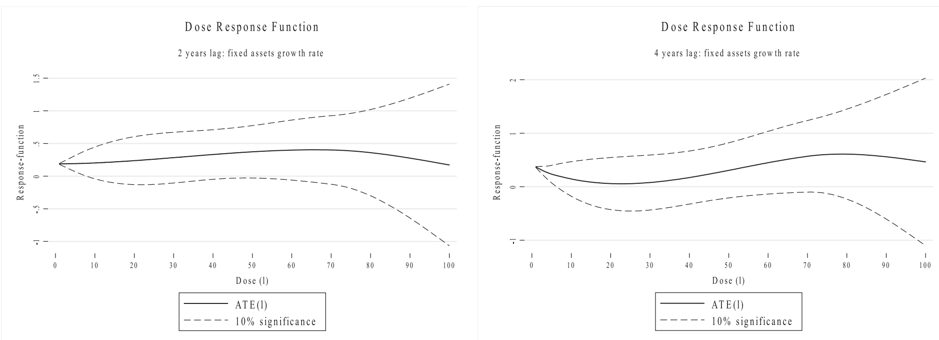

Figure 5. Dose–response function for the objective variable: fixed asset investment. Results for model during EC (panel a) and after EC expiration (panel b).

(a) (b)

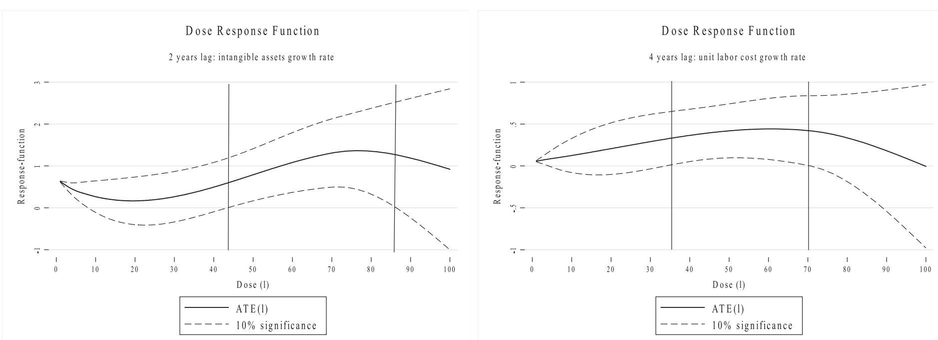

Figure 6. Dose–response function for the objective variable: intangible asset investment. Results for model during EC (panel a) and after EC expiration (panel b).

Table 2 summarizes the dose–response results by different dose levels. Considering all the results, we get a picture of the existence of a range of effectiveness of the law. Specifically, after two years employment growth and intangible asset growth are higher for treated firms in

Table 2. A summary of the results.

	Two years Intensity of the treatment 10	20	30	40	50	60	70	80	90	100
Employment growth	no	no	no	no	+	+	+	+	no	no
Unit labor costs growth	no	no	no	no	no	no	no	no	no	no
Fixed assets growth	no	no	no	no	no	no	no	no	no	no
Intangible assets growth	no	no	no	no	+	+	+	+	no	no
	Four years Intensity of the treatment 10	20	30	40	50	60	70	80	90	100
Employment growth	no	no	no	+	+	+	+	+	no	no
Unit labor costs growth	no	no	no	+	+	+	+	no	no	no
Fixed assets growth	no	no	no	no	no	no	no	no	no	no
Intangible assets growth	no	no	no	no	+	+	+	+	no	no

Note: +: positive and significant effect; no: no effect for the dose.

the dose interval going from around $I = 50$ to $I = 80$. Instead, after four years, in the doses interval going from around $I = 40$ to $I = 80$, the policy has an impact on employment and unit labor costs; while intangible assets growth shows an impact in the interval of doses going from around $I = 50$ to $I = 80$.

7. Conclusions and discussion

This paper evaluates the effects of a place-based R&D policy using a counterfactual dose–response regression model. In particular, the empirical inquiry deals with the evaluation of the impact of different intensities of a public R&D subsidy awarded in the Italian province of Trento over the period 2002–2007.

Our research effort aims at providing some additional insights about the impact of subsidies, taking also into account the amount of money spent on each subsidization project. Nonetheless, it should be taken into account that the comments about 'amounts of subsidies' are purely indicative, given data limitation and the characteristics of the methodology available for this kind of studies.

The results show:

(a) an inverted u-shaped effect on employment dynamics, two years after the awarding of the subsidy.[14] Such an effect is persistent after four years;
(b) an effect on unit labor cost after four-years lag with an inverted u-shape profile. Small doses have a small not significant effect; increasing the doses, the effect increases until we reach a threshold after which the impact decreases;
(c) no effects on fixed assets, whatever the amount of subsidy granted and the lag considered. Nonetheless, such a result can be explained given the 'nature' of the policy under scrutiny that does not explicitly mention the intent to foster investment in 'new' machines to sustain the research project of firms. In a sense, policy-makers seem to assume that the capital endowment of potential pool of recipient firms was already well suited to deal with R&D projects;
(d) an inverted u-shape effect on intangible assets with respect to doses of subsidies. There is an interval of doses intensity that seems to have an impact: subsidizing firms for given amounts have an effect on their investment, i.e. they invest more than non-treated firms in intangible assets (e.g. patents or licenses).

Putting all together the results, the use of subsidies in a given range of intensity – from $I = 50$ to $I = 70$ – induces some effects, that persist after four years. Such firms invested more than non-subsidized firms in employment, labor quality and intangible assets. Interestingly, after the expiration of the employment constraint – four years lag – the impact on the growth of employees of doses in a specific range of intensity persists, and the unit cost of labor force is significantly higher, signaling that there is not only a scale effect on the employment but also an impact on the quality of human capital employed.

The results of our paper show the existence of nonlinear effects in the effects of doses of treatment, that is an inverted u-shaped profile for the dose–response function. In our case, intermediate treatment intensities have an effect, while the French policy analyzed by Marino et al. (2016) was more effective for small and very big doses (u-shaped relationship). This might suggest that different local contexts and different policy design can spur different effects. In our context, it seems reasonable to interpret the results in terms of ineffectiveness of too small and too big projects co-financed.

All in all, our results provide additional evidence in order to better understand the *etiology* of the effect of the policies, considering that there exists only scant literature on the topic (Dai and Cheng 2015; Marino et al. 2016).

Some policy considerations can be derived. The R&D policy design of Law 6/1999 reveals that the policymaker intended to pursue two goals: stimulating R&D investments and sustaining local employment level. Such aims' mix produces an interesting outcome of the policy. Indeed, the employment constraint forces firms to keep the employment level for a given period after the concession of an R&D grant; yet, its effects persist even when such employment constraint expires. Moreover, our results on higher unit labor costs growth reveal that subsidized firms permanently alter their labor force composition towards workers of higher quality: this is regarded as an achievement of the policy as human capital is a key determinant of firms' productivity and its competitive advantage. However, such 'high-quality labor' effect is not accompanied by changes in the firms' fixed assets capital endowment growth but only by the growth of intangible assets.

Some corollary observations can be made to guide future evaluation exercises and ease the understanding of the policy effects.

First, it is advisable to look at disaggregated R&D expenses to disentangle the structure of the R&D investment additionality generated by different doses of subsidies.

Second, calibrating in the right way the subsidies can help in maximizing the effect per dose, in other words: it is crucial to rightly choose the projects that deserve more money.

Accordingly, the technique proposed in this paper could also function as a theoretical framework that suggests qualitative relationships between doses of subsidies and impacts on objective variables and provide some raw quantitative measures of the effects. A better understanding of the policy mechanisms could be used to modify the policy design to achieve larger effects by calibrating the different doses administered. Phrased differently, this means seeking to improve policymakers' ability to go more in depth in the evaluation of potential recipients and different projects to be able to better allocate the available amount of funds and to maximize additionality effects.

While we reach an overall positive evaluation of the effectiveness of Provincial Law 6/1999, we are also aware that several theoretical issues remain to be dealt to carry out a comprehensive investigation of this policy. First, complementarities between the acquisition of knowledge and organizational change deserve further inquiry. Second, localized spillovers may arise as an indirect effect of the regional policy. For example, some scholars (such as Roper, Hewitt-Dundas, and Love 2004) stress the importance of the nature of the R&D project and the surrounding innovation system as two major forces that make it more likely for the host region to appropriate the benefits of private R&D activities. These analyses are beyond the scope of the present paper, they can be the inspiration for future research on the topic.

Notes

1. The literature on Regional Systems of Innovation is vast. For a review of its origins, see Cooke and Memedovic (2003) and Braczyk et al. (1998). See also Fritsch and Stephan 2005, and the special issue of *Research Policy* dedicated to the regionalization of innovation policy. On the distortion that might be caused by the capture of local policy makers by interest groups, see Lerner (2002).

2. In this section, we take into consideration data referred to the period under our scrutiny.
3. This never actually happened during the period examined here (2002–2007): the take-up rate was low, although rising over time.
4. All the objective variables are considered in terms of rate of growth to avoid 'sheer size effect'.
5. One of the potential problems of considering the level of subsidy instead of subsidy percentage is related with possible scale effects. A potential solution to the problem could have been the inclusion of the 'project size' as additional regressor. Nonetheless, it turns out that this variable was highly correlated with the size of firm and consequently cannot be both included in the regression models. Moreover, the inclusion of such variables on the right term side of regressions would imply that, for all the non-subsidized firms, the size of projects is set to zero and this could add noise to our estimations. Hence, we decided: (i) to use the level of the subsidy as continuous treatment variable and to leave to the size of firms the role of correcting for the scale of the projects in the regressions; (ii) to leave out the 'project size'.
6. The overall number of firms in Province of Trento in the time window under scrutiny was around 50,000. The number reduces to 10,000 excluding micro firms with less than 10 employees.
7. See Bronzini and Piselli (2016) for a discussion of these two measures used as objective variables.
8. Note that we do not have the opportunity to identify R&D employees. Hence, we have only indirect evidence of possible behavioral additionality as investigated in Afcha and García-Quevedo (2016). Moreover, if we consider the R&D and innovation policy evaluation literature, outcome additionality refers to the output of the R&D activity, such as product innovation. In our case, we extend the scope of the concept also to economic outcomes (see, for a similar analysis on economic outcome the paper by Wallsten 2000). Consequently, we define quasi-output additionality this set of variables to distinguish our results from literature about output additionality. Indeed, in our case we do not have the availability of detailed labor force employed in R&D that can be properly defined as a measure of output additionality. In a sense, finding a significant effect on overall employment is a prerequisite of having an effect on the subset of R&D workers.
9. For year-by-year descriptive statistics, see Table A1.
10. See Table A2 for a correspondence of amount of money with percentages of maximum amount as expressed in the figures.
11. See Table A3 for details about regression results.
12. See Table A4 for details about regression results.
13. See Table A5 for details about regression results.
14. To fix ideas, the effect is positive and significant if the subsidy ranges between 2100 and 3900 thousand euros. They represent, respectively, 40% and 75% of the interval of maximum amount of subsidies granted.

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No potential conflict of interest was reported by the author(s).

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References

Aerts, K., and T. Schmidt. 2008. "Two for the Price of One? Additionality Effects of R&D Subsidies: A Comparison Between Flanders and Germany." *Research Policy* 37 (5): 806–822.

Afcha, S., and J. García-Quevedo. 2016. "The Impact of R&D Subsidies on R&D Employment Composition." *Industrial and Corporate Change* 25 (6): 955–975.

Almus, M., and D. Czarnitzki. 2003. "The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany." *Journal of Business and Economic Statistics* 21: 226–236.
Aristei, D., A. Sterlacchini, and F. Venturini. 2016. "Effectiveness of R&D Subsidies During the Crisis: Firm-Level Evidence Across EU Countries." *Economics of Innovation and New Technology* 26 (6): 1–20.
Arrow, K. J. 1962. "The Economic Implications of Learning by Doing." *The Review of Economic Studies* 29 (3): 155–173.
Audretsch, D., and M. Feldman. 1996. "Innovative Clusters and the Industry Life Cycle." *Review of Industrial Organisation* 11: 253–273.
Barca, F. 2009. "An Agenda for a Reformed Cohesion Policy: A Place-based Approach to Meeting European Union Challenges and Expectations," Independent Report, Prepared at the Request of the European Commissioner for Regional Policy, Danuta Hubner, European Commission, Brussels.
Barca, F., P. McCann, and A. Rodriguez-Pose. 2012. "The Case for Regional Development Intervention: Place-Based Versus Place-Neutral Approaches." *Journal of Regional Science* 52 (1): 134–152.
Bellucci, A., L. Pennacchio, and A. Zazzaro. 2018. "Public R&D Subsidies: Collaborative Versus Individual Place-based Programs for SMEs." *Small Business Economics*. doi:10.1007/s11187-018-0017-5.
Bottazzi, L., and G. Peri. 2003. "Innovation and Spillovers in Regions: Evidence From European Patent Data." *European Economic Review* 47: 687–710.
Braczyk, H.-J., P. Cooke, and M. Heidenreich. 1998. *Regional Innovation Systems*. London: UCL Press.
Bronzini, R., and E. Iachini. 2014. "Are Incentives for R&D Effective? Evidence From a Regression Discontinuity Approach." *American Economic Journal: Economic Policy* 6 (4): 100–134.
Bronzini, R., and P. Piselli. 2009. "Determinants of Long-run Regional Productivity with Geographical Spillovers: The Role of R&D, Human Capital and Public Infrastructure." *Regional Science and Urban Economics* 39: 187–199.
Bronzini, R., and P. Piselli. 2016. "The Impact of R&D Subsidies on Firm Innovation." *Research Policy* 45 (2): 442–457.
Busom, I. 2000. "An Empirical Evaluation of the Effects of R&D Subsidies." *Economics of Innovation and New Technology* 9: 111–148.
Caliendo, M., and S. Kopeinig. 2008. "Some Practical Guidance for the Implementation of Propensity Score Matching." *Journal of Economic Surveys* 22 (1): 31–72.
Caloffi A., Mariani M., Sterlacchini A. (2016) "Evaluating Public Supports to the Investment Activities of Business Firms: A Meta-regression Analysis of Italian Studies." CREI Working Paper No.1/2016.
Cerulli, G. 2015. "ctreatreg: Command for Fitting Dose–Response Models Under Exogenous and Endogenous Treatment." *Stata Journal* 15 (4): 1019–1045.
Cooke, P., P. Boekholt, and F. Todtling. 2000. *The Governance of Innovation in Europe*. London: Pinter.
Cooke, P., and O. Memedovic. 2003. "Strategies for Regional Innovation Systems: Learning Transfer and Applications." Policy Papers, UNIDO, Vienna.
Czarnitzki, D., B. Ebersberger, and A. Fier. 2007. "The Relationship Between R&D Collaboration, Subsidies and R&D Performance: Empirical Evidence From Finland and Germany." *Journal of Applied Econometrics* 22: 1347–1366.
Czarnitzki, D., and A. A. Toole. 2007. "Business R&D and the Interplay of R&D Subsidies and Product Market Uncertainty." *Review of Industrial Organization* 31 ((3): 169–181.
Dai, X., and L. Cheng. 2015. "The Effect of Public Subsidies on Corporate R&D Investment: An Application of the Generalized Propensity Score." *Technological Forecasting and Social Change* 90: 410–419.
David, P. A., B. H. Hall, and A. A. Toole. 2000. "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence." *Research Policy* 29 (4-5): 497–529.
Dimos, C., and G. Pugh. 2016. "The Effectiveness of R&D Subsidies: A Meta-regression Analysis of the Evaluation Literature." *Research Policy* 45 (4): 797–815.
Duguet, E. 2004. "Are R&D Subsidies a Substitute or a Complement to Privately Funded R&D?" *Revue D'Economie Politique* 114 (2): 245–274.
Edquist, C. 2005. "Systems of Innovation: Perspectives and Challenges." In *The Oxford Handbook of Innovation*, edited by J. Fagerberg, D. Mowery, and R. Nelson, 181–208. Oxford: Oxford University Press.
European Commission. 2004. *Innovation Policy in Europe 2004, DG Enterprise and Industry*. Bruxelles: European Commission.
Eurostat. 2009. Science, technology and innovation in Europe, Eurostat Poketbooks, Office for Official Publications of the European Communities, Luxembourg.
Feldman, M. P., and M. R. Kelley. 2006. "The *Ex-Ante* Assessment of Knowledge Spillovers: Government R&D Policy, Economic Incentives and Private Firm Behaviour." *Research Policy* 35 (10): 1509–1521.
Fritsch, M., and A. Stephan. 2005. "Regionalization of Innovation Policy. Introduction to the Special Issue." *Research Policy* 34 (8): 1123–1127.
García-Quevedo, J. 2004. "Do Public Subsidies Complement Business R&D? A Meta-Analysis of the Econometric Evidence." *Kyklos* 57: 87–102.
Glazerman, S., D. M. Levy, and D. Myers. 2003. "Nonexperimental Versus Experimental Estimates of Earnings Impacts." *The Annals of the American Academy of Political and Social Science* 589 (1): 63–93.
González, X., J. Jaumandreu, and C. Pazó. 2005. "Barriers to Innovation and Subsidy Effectiveness." *The RAND Journal of Economics* 36 (4): 930–950.

González, X., and C. Pazó. 2008. "Do Public Subsidies Stimulate Private R&D Spending?" *Research Policy* 37 (3): 371–389.
Görg, H., and E. Strobl. 2007. "The Effect of R&D Subsidies on Private R&D." *Economica* 74: 215–234.
Hall, B. H., P. Moncada-Paternò-Castello, S. Montresor, and A. Vezzani. 2016. "Financing Constraints, R&D Investments and Innovative Performances: New Empirical Evidence at the Firm Level in Europe." *Economics of Innovation and New Technology* 25 (3): 183–196.
Heckman, J., H. Ichimura, and P. Todd. 1998. "Matching as an Econometric Evaluation Estimator." *Review of Economic Studies* 65 (2): 261–294.
Hirano, K., and G. W. Imbens. 2004. "The Propensity Score with Continuous Treatments." *Applied Bayesian Modeling and Causal Inference From Incomplete-Data Perspectives* 226164: 73–84.
Ho, D. E., K. Imai, G. King, and E. A. Stuart. 2007. "Matching as Nonparametric Preprocessing for Reducing Model Dependence in Parametric Causal Inference." *Political Analysis* 15: 199–236.
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: 729–747.
Hyytinen, A., and O. Toivanen. 2005. "Do Financial Constraints Hold Back Innovation and Growth? Evidence on the Role of Public Policy." *Research Policy* 34 (9): 1385–1403.
Imbens, G. W., and D. B. Rubin. 2015. *Causal Inference in Statistics, Social and Biomedical Sciences: An Introduction*. New York: Cambridge University Press.
Imbens, G. W., and J. M. Wooldridge. 2009. "Recent Developments in the Econometrics of Program Evaluation." *Journal of Economic Literature* 47 (1): 5–86.
Koschatzky, K. 2005. The regionalization of innovation policy: new options for regional change? In *Rethinking Regional Innovation and Change,* 291–312. New York, NY: Springer.
Koschatzky, K., and H. Kroll. 2007. "Which Side of the Coin? The Regional Governance of Science and Innovation." *Regional Studies* 41 (8): 1115–1127.
Lach, S. 2002. "Do R&D Subsidies Stimulate or Displace Private R&D? Evidence From Israel." *Journal of Industrial Economics* 50 (4): 369–390.
Lerner, J. 2002. "When Bureaucrats Meet Entrepreneurs: The Design of Effective 'Public Venture Capital' Programmes." *The Economic Journal* 112: F73–F84.
Lundvall, B. A. 1992. *National Innovation System: Towards a Theory of Innovation and Interactive Learning*. London: Pinter.
Malerba, F. 2002. "Sectoral Systems of Innovation and Production." *Research Policy* 31: 247–264.
Mariani, M., and F. Mealli. 2018. "The Effects of R&D Subsidies to Small and Medium-sized Enterprises. Evidence From a Regional Program." *Italian Economic Journal* 4 (2, July): 249–282.
Marino, M., S. Lhuillery, P. Parrotta, and D. Sala. 2016. "Additionality or Crowding-out? An Overall Evaluation of Public R&D Subsidy on Private R&D Expenditure." *Research Policy* 45 (9): 1715–1730.
MET. 2009. "Rapporto MET 2009: Imprese e politiche in Italia, Monitoraggio Economia e Territorio," Roma.
Morgan, K. 2004. "The Exaggerated Death of Geography: Learning, Proximity and Territorial Innovation Systems." *Journal of Economic Geography* 4: 3–21.
Nelson, R. R. 1959. "The Simple Economics of Basic Science Research." *Journal of Political Economy* 67: 297–306.
OECD. 1999. *Managing National Innovation Systems*. Paris: OECD.
OECD. 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*. 3rd ed. Paris: OECD.
OECD. 2010. *The OECD Innovation Strategy: Getting a Head Start on Tomorrow*. Paris: OECD.
Paci, R., and S. Usai. 2000. "Technological Enclaves and Industrial Districts: An Analysis of the Regional Distribution of Innovative Activity in Europe." *Regional Studies* 34: 97–114.
Potì, B., and G. Cerulli. 2010. "La valutazione *ex-post* di uno strumento di politica della ricerca industriale: modello analitico, processo di realizzazione, eterogeneità degli effetti." *L'Industria* 31: 307–333.
Ribas, A. F.-R. 2009. "Public Support to Private Innovation in Multi-level Governance Systems: An Empirical Investigation." *Science and Public Policy* 36 (6): 457–467.
Roper, S., N. Hewitt-Dundas, and J. H. Love. 2004. "An Ex Ante Evaluation Framework for the Regional Benefits of Publicly Supported R&D Projects." *Research Policy* 33: 487–509.
Rubin, D. B. 1977. "Assignment to Treatment Group on the Basis of Covariate." *Journal of Educational Statistics* 2: 1–26.
Rubin, D. B., and N. Thomas. 1996. "Matching Using Estimated Propensity Scores: Relating Theory to Practice." *Biometrics* 2: 254–268.
Storper, M. 1997. *The Regional World*. New York: The Guilford Press.
Stuart, E. A. 2010. "Matching Methods for Causal Inference: A Review and a Look Forward." *Statistical Science* 25 (1): 1–21.
Tödtling, F., and M. Trippl. 2005. "One Size Fits All? Towards a Differentiated Regional Innovation Policy Approach." *Research Policy* 34 (8): 1203–1219.
Vanino, E., S. Roper, and B. Becker. 2019. "Knowledge to Money: Assessing the Business Performance Effects of Publicly-Funded R&D Grants." *Research Policy* 48 (7): 1714–1737.
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." *The RAND Journal of Economics* 31 (1): 82–100.
Wooldridge, J. M. 1997. "On Two Stage Least Squares Estimation of the Average Treatment Effect in a Random Coefficient Model." *Economics Letters* 56: 129–133.

Wooldridge, J. M. 2003. "Further Results on Instrumental Variables Estimation of Average Treatment Effects in the Correlated Random Coefficient Model." *Economics Letters* 79: 185–191.

Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data*. London: MIT Press.

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