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R&D Incentives: The Effectiveness of a Place-Based Policy

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Abstract

The ability of policy makers to design an effective incentive system that spurs welfare-enhancing innovations is still contended both in academic research and public debates. Indeed, a review of the empirical literature suggests that findings concerning the impact of R&D subsidies on both sides of the innovation process (input and output) and the overall performance of the firm are mixed. Moreover, while the role of regions in implementing and assessing innovation policies has increased since the last decade, the bulk of empirical evidence deals with the effectiveness of public policy implemented at the national level, thus providing no clue on the efficacy of local interventions.
Our paper contributes to the debate on the effectiveness of R&D subsidies analyzing a local policy implemented in the Italian province of Trento in the past decade. The empirical analysis draws upon a very detailed and informative database, profiling the population of firms which were awarded at least one R&D grant during the years 2002-2007. The econometric analysis is based on counterfactual models. First, treated firms are matched with "twins" alongside a series of relevant predetermined variables. Secondly, a matching estimator is employed to estimate the average effect of treatment on treated. We evaluates the achievements of the local policy maker with respect to the following objectives: *(i)* enhance the overall competitiveness of the business sector in the regional area; (*ii*) prompt additional investment in innovation. We find that R&D incentives are effective on intangible assets and have a confined to one year impact on firms' operating margin, while they have no effect on firms' labour productivity.

Keywords: Regional Innovation Policy, Ex Post Evaluation, Subsidies, Research and Development, Counterfactual Models

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1. Introduction

Beyond traditional rationales pointed out in the economics literature (Lerner, 1999; Wallsten, 2000), arguments concerning economic growth, quality of human capital, and firm competitiveness have represented common justification for government intervention to engender innovation (Lundvall and Borras, 2005). As declining population in many countries and diminishing returns from investment in physical capital have neutralized two major channels of long-term growth, the role of innovation as a key enabler of economic prosperity appears unquestionable. This is particularly so in the aftermath of the recent economic downturn. What is still contended, however, is the ability of policy makers to rectify market failures, provide effective incentives to spur welfare-enhancing innovations, and avoid the introduction of additional distortions in the economic system.

Despite the relevance of this issue, a review of the empirical literature (Klette and Moen, 1999; Lerner, 1999; Wallsten, 2000; Czarnitzki *et al.*, 2007; Merito *et al.*, 2007; Piekkola, 2007; Hussinger, 2008; Potì and Cerulli, 2010) suggests that findings concerning the effect of R&D subsidies on the outcomes of the innovation process and the overall performance of the firm are mixed. Moreover, it has to be underlined that the number of government layers intervening in several areas of business soared over time. Across European countries, for instance, the role of regions in implementing and assessing innovation policies, targeting in particular small and medium-sized firms, has strongly increased since the early 2000 (European Commission, 2004).

Notwithstanding, with a few exceptions (Bronzini and Iachini, 2011), most of the recent empirical evidence deals with the effectiveness of public policy implemented at the national level, thus providing no clue on the role of place-based policy and the ability of host regions to retrieve social benefits from sponsored activities (Roper *et al.*, 2004).

The primary goal of our paper is to contribute to the debate and provide novel evidence by analyzing the effectiveness of R&D subsidies implemented within a local design of public intervention. Specifically, our investigation evaluates the achievements of the local policy maker with respect to the following objectives: *(i)* prompt additional investments in innovative activities by private organizations; (*ii*) enhance the overall competitiveness of the business sector in the regional area. As to the local dimension, our paper explores the effectiveness of R&D subsidies in the Italian northern province of Trento in the past decade[1]. Using Fritsch and Stephan (2005, p. 1125) classification, in the case under study, regionalization of the innovation policy is based "on local innovation initiatives that emerge from within a region". Such initiatives operate entirely in Trento, with specific instruments, act autonomously in the sense that administration and decision competencies are completely intra-regional and that the resources spent are entirely raised in the region.

Since 2001 the local government has played an active role in financing R&D projects carried out by private enterprises. The financial commitment of local policy-maker on this particular target has been considerable. Indeed, the percentage of budget for incentivizing private firms devoted to this aim was by far the highest compared to other Italian regions: in years 2007 and 2008 it was, respectively, 33.1% and 46.7%, of the total of financial subsidies, while the average of other regions was 17.7% and 17.5% (Met, 2009). The average yearly value of total spending along the time window under analysis was €22.7 million. Despite this effort, to the best of our knowledge, no systematic assessment of the impacts of such an impressive intervention has been so far carried out.

We evaluate the effectiveness of the public endeavor, relying upon econometric methods commonly used to evaluate technology programs (Klette *et al*., 2000; Hussinger, 2008). Such methods recognize the counter factual nature of the analysis and allow the researcher to clean out most of the confounding effects associated with factors like technological opportunities, appropriability conditions, endowment of knowledge capital, other type of incentives granted to enterprises, which may eventually influence a firm's ability to benefit from innovation activities.

To this end, we have built up a very detailed and informative database, profiling the population of companies awarded at least one R&D grant during the years 2002-2007 which consists of around 13 firms per year with an average amount of grants equal to € 1,800,000. A distinguishing feature of our data set (as in Mairesse and Mohnen, 2010) is the merge of balance sheet data of limited liability companies operating in the province of Trento in 2001-08 (around 800 firms per year in the 3 digit Ateco 2002 sectors that fall into the scope

[1] Trentino province belongs to an autonomous region (Trentino Alto Adige) with a "special status" , granted in Italy to Sicily, Sardinia, Aosta Valley and Friuli Venezia Giulia, as well.

of our investigation) with the administrative archives, which contain information on the specific projects that subsidized firms carried out. In particular, the latter source allows us to map all the subsidies granted to each firm operating in the province of Trento within the Law 4/1981 for the period 1991-2004 and within the LP6 for the period[2] 2002-2007. Furthermore, these data are enriched with quali-quantitative data coming from face to face interviews to entrepreneurs and policy makers, undertaken in the period ranging from November 2009 to December 2010.

The investigation of the effectiveness of the PL6 is carried out using the counterfactual paradigm (Trivellato *et al*., 2009). The treatment consists of an incentive to co-finance a R&D oriented project. Each treated firm is matched with a control firm which is the most similar along a series of predetermined variables such as: technological sector of activity; size; past innovative activity; capital intensity and the funds availability (a measure of financial constraints). Matched firms are then compared with respect to the objective variables under scrutiny that is level of intangible asset, as a proxy of R&D investments; labor productivity and operating margin as proxies for firm's competitiveness. Finally, the mean value of such differences gives us the effect of subsidies on treated firms.

The reliability of the estimation is strictly related with the quality of matches: the more control firms are similar to treated ones, the more is precise the estimation. In this respect, as underlined by Bronzini and Iachini (2011), the local dimension of the intervention (a firm to be eligible must be located and must implement the investment in the province of Trento) mitigates potential heterogeneity among firms, as it allows to compare firms that are more similar than in nationwide programs.

The paper is organized as follows. Section 2 briefly summarizes the recent empirical literature on the effectiveness of R&D policy, based on firm-level observations, and outlines the goals of our paper; section 3 illustrates the main characteristics of the Provincial Law 6/99 (PL6) implemented in the province of Trento, PL6 supplies, among other interventions, financial incentives to promote research activity among local firms, aiming to enhance

[2] The LP6 substitutes in all respects the previous Provincial Law 4/1981 and subsequent modifications. Nonetheless the two laws present a period of overlapping in the years going from 2002 to 2004, due to pending procedures of requests for grants presented before the date of 31 December 2001 which was the last term for presenting such requests within the PL 4/81. Note that starting from 2002 the PL6 was still in force for all firms.

regional competitiveness and growth. Estimation method and the presentation of data set are in Section 4. Section 5 presents the results of the econometric analysis, while Section 7 concludes.

2. Literature review

Government programs that subsidize innovative activity, in general, and R&D spending, in particular, are justified on the grounds that market failures prevent firms from opportunely investing in and reaping the benefits of R&D activities, with the result that firms invest in R&D below the social optimum level. Two major rationales[3] have been emphasized in the theoretical and empirical literature that clarifies the nature of these market failures. The primary line of reasoning states that profit-maximizing firms do not face sufficient incentives to make a socially optimal investment in R&D. This occurs because R&D investments are likely to generate positive spillovers,[4] thus implying that the firms making the investments are unlikely to appropriate the entire gains originating from their innovative effort (Nelson, 1959; Arrow, 1962). An extensive econometric literature (Griliches, 1992; Hall *et al*., 2009) has shown that the external economies associated with R&D effort are important as they engender productivity gains at both industry and firm level. R&D spillovers have been found to positively affect the inventive performance of competing units especially if a certain degree of relatedness exists among research programs (Jaffe, 1986; Henderson and Cockburn, 1996). Moreover, external economies are larger in magnitude when the R&D effort is directed towards product rather than process innovation (Ornaghi, 2006). It is then conceivable that, from the social point of view, the gains from private R&D are often higher than private returns; hence a number of research projects would be worth undertaking even if they are privately unprofitable. A public policy that re-balances the marginal costs and revenues for the firm that undertakes the R&D effort, can make these projects privately profitable as well.

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[3] Hall (2002) addresses additional considerations in favor of policy intervention: *(i)* the existence of industries that are strategic for national security or to foster technological advances in other industries; *(ii)* the promotion of technological standards.

[4] Nelson (1959) recognizes that, beyond R&D spillovers, two other factors may create a gap between private and social returns to R&D and prevent profit maximizing firms from carrying out the desirable level of investment: *(i)* the often long time elapsing between the inception of a research project and the time when some valuable outcome arises may discourage firms concerned with short-run performance; *(ii)* the increasing variance of the profit distribution as one moves from the basic-research towards the end of the spectrum may cause a risk-averse firm to value projects at that stage significantly less than their expected profitability.

A second rationale that can explain the under-investment in R&D is related to the presence of capital market imperfections that make costly for firms, especially new ventures, to secure the financing needs to support their innovative endeavor from external sources. Hall (2002) discusses three types of factors that may make raising external capital very expensive as compared with the internal costs of capital: *(i)* information asymmetries between investors and inventors; *(ii)* moral hazard problems; *(iii)* tax considerations that can differently impinge on alternative sources of financing. Although a venture capital industry can ameliorate these problems, limits still exist that call for governments' intervention. By making R&D awards, the latter may convey information to other potential investors, certify the quality of start-ups, thus easing the financing constraint that might have otherwise precluded the undertaking of socially valuable projects (Lerner, 1999, 2002).

A review of the empirical literature suggests that unambiguous conclusions on the effectiveness of policy interventions can be hardly derived. Moreover, differences in the characteristics of firms under scrutiny - e.g., the average size of awardees ranges from a minimum of 45 employees among US companies, (Wallsten, 2000) to 500 employees for Western Germany firms (Czarnitzki *et al*., 2007), to a maximum of 1622 employees for Spanish firms (Busom, 2000)-; in the dependent variables (e.g., R&D investment, output of the innovation process, overall firm performance), and, finally, in the econometric methods adopted (e.g., the way in which control groups are identified widely varies among studies), recommend extreme caution in deriving general implications from the bulk of evidence thus far collected. Bearing in mind these limitations, we provide a tentative summary of results from the recent empirical literature based on firm-level observations.

Most of the empirical literature concentrates on the impact of public policy on private R&D spending: this stream of research tests the hypothesis that subsidies prompt additional R&D investments rather than substituting investments that firms might have in any case carried out. David *et al*. (2000) and Garcia-Quevedo (2004) provide a systematic assessment of major results from studies published before year 2000 that address this theme at different levels of analysis. Recent contributions differ from extant studies primarily because they recognize the counter factual nature of the evaluation exercise and rely upon methods that address the endogeneity of the R&D treatment (Klette *et al*., 2000; Cerulli, 2010).

Although the bulk of evidence conveys the idea that public support do not crowd out private investment in R&D activities (Almus and Czarnitzki, 2003; Hyytinen and Toivanen, 2005; Czarnitzki and Tool, 2007; Czarnitzki *et al*., 2007; Hussinger, 2008; Aerts and Schmidt, 2008), a number of other scholars point out contrasting results. Busom (2000) and Potì and Cerulli (2010) find that crowding out exists for a non negligible share (i.e., thirty and fifty per cent, respectively) of firms awarded with R&D grants, respectively in Spain and Italy. Lach (2002) presents evidence on Israeli enterprises according to which additionality only concerns small firms, whereas no significant effect emerges among large companies that are, nonetheless, the more likely to gain access to public funding. Similarly, Gorg and Strobl (2007) show that in Ireland only small R&D grants awarded to domestic firms spur additional private investment in innovative activities. On the contrary, no significant effect arises for foreign multinationals and crowding-out is observed when relatively large grants are awarded to domestic firms. Duguet (2004) and Gonzalez *et al*. (2005) do not find any significant relationship between public funding and R&D intensity in France and Spain; in the case of Spanish firms, however, subsidies induce firms to perform research activities. Finally, Wallsten (2000) provides evidence of crowding-out in a sample of US ventures which received awards from the Small Business Administration.

Public R&D subsidies positively affect the propensity to patent of Italian firms (Potì and Cerulli, 2010), although the effect is significant only in the short run (Merito *et al*., 2007). Positive effects emerge among Finnish companies, whereas the propensity to patent and the actual number of patents per employee are not significantly higher among Western Germany firms that received R&D awards (Czarnitki *et al*., 2007). Alongside, the scant evidence (Berubè and Mohnen, 2009; Hussinger, 2008) seems to suggest that R&D policy engenders positive bearings on the propensity to innovate[5] and the stream of revenues generated by newly commercialized products.

Once ascertained that public funds do stimulate private R&D investment, does it follow that successful results will be for sure reached? The question is a very controversial one. According to some authors (Klette and Moen 1999; Wallsten, 2000; Merito *et al*., 2007; Piekkola, 2007), R&D subsidies do not generally produce significant effects on firm

[5] It is worth underlying that Berubè and Mohnen (2009) consider a set of establishment receiving R&D tax credits as a control group, while treated firms are those receiving both tax credits and R&D grants.

performance, measured in terms of productivity growth, sales and employment growth, profitability. The only two cases where public support spurs improvements in firm performance reveal that some mediating factors impinge upon the estimated relationship. In particular, Piekkola (2007) finds that R&D grants drive productivity growth only among small and medium sized enterprises in Finland, while Lerner (1999) finds that grants awarded by the Small Business Administration generate growth in sales and employments only for firms located in area with substantial venture capital activity.

The present study contributes to the existing literature in two ways: *(i)* it provides original evidence on the effectiveness of innovation policy implemented at regional level, taking into account both immaterial assets and firms' performance; *(ii)* it deals with the distortions that may render the identification of the causal effect of regional R&D policy on input and output extremely cumbersome.

The first issue we address concerns the increased role that regional governments play in several areas of business. Across European countries, for instance, the role of regions in designing, implementing and evaluating innovation policies, targeted in particular to small and medium-sized firms, soared since the early 2000 (European Commission, 2004). The academic debate, however, has only recently focused on the rationales and perspectives of regional innovation policy. This debate has emphasized that a regional orientation to innovation policy may help achieve nation-wide goals insofar as it accounts for the uneven distribution of innovation processes across space (Fritsch and Stephan, 2005). Also, it has been argued that because of differences in the way regional innovation systems function a one-size-fits-all approach to innovation policy is unlikely to be efficient (Asheim and Coenen, 2005; Todtling and Trippl, 2005; Howell, 2005). Still, the empirical evidence[6] at this level of analysis is scarce. On the other side it is clear that the effectiveness of a place-based policy cannot be easily inferred from estimated relationships based on national programs.

Diverse and, sometimes, contrasting forces can influence the effectiveness of a place-based policy. In principle, regional policy makers may better select those projects with high social returns but insufficient private returns since local authorities have better knowledge of

[6] Among the few exceptions, Hyytinen and Toivanen (2005) show that the provision of government funding at the regional level can pin down constraint on R&D investment and the expected growth of firms operating in industries that are dependent on external finance.

potential awardees and local market conditions. This preferential stance should help them to ascertain whether submitted projects and firms applying for a grant display those attributes that are more likely to generate knowledge spillovers (Feldman and Kelley, 2006). Moreover a place-based policy should allow the host region to retain a share of the social benefit arising out from the financed projects (Roper *et al*., 2004).

On the other hand, local authorities may be more easily captured by lobbies and therefore, prone to finance R&D projects that are privately profitable and would be pursued even without R&D subsidies (Wallsten, 2000). As underlined by Lerner (2002), there is an extensive political economy literature that has emphasised this kind of distortions and the several ways these distortions can manifest themselves (Eisinger, 1988; Cohen and Noll, 1991; Lerner, 1999; Wallsten, 2000).

The second concern that we try to address in this paper is a methodological one. Government typically deploys a range of industrial policies to support business activities (e.g., subsidizing investments in tangible assets) where R&D policies represent just one measure in this broader policy set. Moreover, an R&D program can rely on multiple instruments to channel finance towards enterprises (Potì and Cerulli, 2010). To the extent that firms apply for various subsidies that, contemporaneously, affect their performance, an identification problem may arise that prevents the researcher from isolating the causal effect associated with each subsidy. The identification problem can become even more severe any time the central and the regional governments share competences on the funds required to promote innovation activities (Cook *et al*., 1997; Fritsch and Stephan, 2005). Such an occurrence makes it difficult to isolate confounding factors. In these circumstances a proper evaluation of the effectiveness of R&D subsidies requires comprehensive information on measures that agencies, at different levels of government, undertake and firms, eventually, exploit.

The present study tackles this methodological problem by analyzing a specific case where the resources firms receive for R&D investments are entirely raised in the host region. Moreover we have complete information on all types of grants that firms have been awarded. An in depth discussion of the technology program under scrutiny and the data used to carry out the analysis unfold in the following section.

3. The Law 6/99 in the province of Trento

The regional policy for stimulating R&D is regulated by the PL6. The PL6 is a general tool of intervention into economic activities in the province of Trento, covering all the sectors (e.g., tourism, manufacturing, construction, etc.). The PLS comprises a large set of incentive schemes that are meant to foster fixed investments; research and development expenditures; firm restructuring; the adoption of production processes to safeguard the environment; the re-localization of firms within the Province.

The LP6 devotes a specific section to the regulation of subsidies promoting research and development activities in business firms. In particular, the law identifies two types of commercial research worth to be financed: (i) industrial research; (ii) experimental development. Industrial research is defined as a planned activity aiming at acquiring new knowledge in order to enable firms to introduce new products, new processes and services. Activities that can improve the quality of existing products, processes and services also fall into such category. The creation and the construction of prototypes is excluded from this category.

Experimental development is defined as the acquisition, recombination and utilization of existing scientific, technological and commercial knowledge in order to produce projects, products, processes new to the firm or enhanced. This category includes the development of prototypes and their testing.

The objectives that the local authority is targeting through the provision of R&D incentives are twofold. On the one side, the PL6 aims at stimulating additional expenditures in research activities by firms operating in the region (compared to the normal research and development activity undertaken by firms). On the other side, the PL6 aims at stabilizing the employment rate, and enhancing the competitiveness of local firms.

All firms operating in the province of Trento can apply for grants within the framework of the PL6. In order to apply for a grant firms must submit a project to the Province. There is no deadline to submit a project during the calendar year; however, since a first-in-first-out criterion is used to assign financial resources (provided that a panel of expert gives a positive assessment of the project), some firms might get a refusal once the budget for financing R&D activities is exhausted. Nonetheless, this situation never occurred in the period of analysis (2001-2007): the, so called, take up rate was quite low, even if it was increasing along time.

After the presentation of the application for a grant, the project is examined by a technical committee (evaluation procedure). If the application is judged viable, an economic committee evaluates the economic viability and the financial sustainability of the project. Only If the project gets a positive evaluation at both stages, it can be co-financed. The projects that are positively evaluated are co-financed by the Province using the scheme reported in Table 1. Firms are divided into three size classes, defined according to the OECD classification system: among them, smaller firms benefit of higher percentages of contribution. Projects involving industrial research are awarded a higher share of financial support than programs focusing on pre-commercial development.

Table 1. Co-financed percentages of incentivized projects by type of R&D activity, firm size and priority of intervention in the case of evaluation procedure

	Small firms		Medium firms		Large firms	
	PRP*	NoPRP**	PRP*	NoPRP**	PRP*	NoPRP**
Industrial research	70	60	60	55	50	45
Maximum %	80	70	75	65	65	65
Experimental development	45	40	35	30	25	20
Maximum %	60	50	50	40	40	30

*Activity included in the long term Provincial Research Program (PRP). ** Activity not included in the long term Provincial Research Program (NoPRP).

Firm can ask for co-finance projects of different magnitudes ranging from € 25.000 to € 3 mln. Projects can entail expenses referred to a period going from the date of concession to the following three years. The costs that can be co-financed are the following: (1) employment costs: additional high skilled workforce employed to work on the project; (2) patenting costs and contractual costs of licenses acquisition; (3) general additional costs related to the project (overhead up to 60% of costs declared at point 1); (4) part of costs related to the use of the tools and machines employed within the project; (5) other costs: materials, supply of products. Once a firm is awarded a grant, it must obey to some constraints in order to actually get financed: (a) the results of the research have to be used/exploited in the province of Trento; (b) in the case the subsidy is bigger than € 500,000 or if the firm ask for an additional percentage to the amount of investment financed, it must guarantee, for at least two years since the grant is awarded , the level of employment declared in the projects. A valuable feature of our study is the impossibility for firms operating in the province of Trento to request grants and subsidies from other public institution[7] (national level and EU level).

4. Data and estimation method

4.1. Data

We relied upon several sources to construct the database. Administrative archives, held by the local government, are the primary source we used to gather information on firms receiving the R&D grants and on firms that received any type of grants throughout the period of analysis.

Data from the profit and loss account together with balance sheet data of limited liability companies operating in the province of Trento come from two sources: the Bureau Van Dijk's AIDA database and the Cerved Group's Pitagora database. Although both databases collect data from a common source, the Italian Chambers of Commerce, they differ as for the number of companies surveyed. Thereafter, the joint use of both databases allowed us to obtain information on a wider set of firms as well as the opportunity to run a double check on the data used, thus significantly improving the quality of information at hand. The final collection of data comprises about eight thousand companies observed over the period 1998-2008.

One typical concern with data from secondary sources is the low quality and often the lack of employment figures. To deal with this problem we recovered data on the working force of firms in our sample from the Archivio Statistico delle Imprese Attive (ASIA), constructed and managed by the National Statistical Office (ISTAT). The database ASIA represents the most comprehensive and reliable collection of information on the localization, sector of economic activity, legal form and employment figures for business firms operating in Italy. Table 2 summarizes the major characteristics of subsidized and control firms during the period 2001-2008, along with basic statistics on the amounts of co-financed projects in each year.

[7] Few exceptions are allowed. For instance few firms (around three per year) have been allowed to get financial incentives within the national program called "Sabatini law".

Table 2. Sample firms by technological sector, year and treatment status (inclusion in the program LP6) - amount of subsidies per year[8]

	low tech		low-mid tech		high-mid tech		high tech		total		Co-financed amount of subsidies (current values €)			
	NSF*	SF**	NSF*	SF**	NSF*	SF**	NSF*	SF**	NSF*	SF**	average	std. dev.	min	max
2001	57	0	166	0	77	0	39	0	339	0				
2002	52	1	142	0	69	3	37	3	300	7	706,394.8	1,276,796.0	30,180.0	4,720,260.0
2003	52	2	154	2	54	3	46	8	306	15	993,488.5	617,534.5	46,559.9	1,717,250.0
2004	46	2	121	2	41	5	47	1	255	10	603,212.8	3,376,766.0	133,499.6	12,000,000.0
2005	49	2	134	2	55	3	52	5	290	12	2,068,161.0	864,055.0	47,362.5	2,606,848.0
2006	77	2	200	5	71	6	66	7	414	20	916,883.0	770,804.0	59,187.1	2,746,977.0
2007	81	2	226	6	73	8	72	9	452	25	887,238.8	1,287,379.0	241,817.2	4,666,648.0
2008	166		359		159		142		826					
Total	580	11	1502	17	599	28	501	33	3182	89				

*Notes: * NSF: not subsidized firm; **SF: subsidized firm*

[8] Table 2 includes both treated firms and all the “potential controls”. Among the latter in each evaluation exercise we choose a subset of controls.

4.2. Estimation method

Our goal is the estimation of the effect of the policy on different objective variables (Y). The concession of an R&D grant represents our binary treatment (T). We follow the notation of Rubin (1973, 1977) that denotes with $Y_i(0)$ the potential outcome for a firm *i* in the case that it is not included into treatment and $Y_i(1)$ the potential outcome of the same firm in the case of inclusion into the treatment. Obviously, we can observe each firm *i* only in one of these two states. Formally, we have:

$$Y_i = \begin{cases} Y_i\,(0)\; if\; T_i = 0 \\ Y_i(1)\; if\; T_i = 1 \end{cases} \quad (1)$$

We define the average treatment effect on the treated (ATT), which represents the average impact of the R&D program on the subset of subsidized firms, as follows:

$$ATT = E[Y_i\,(1) - Y_i\,(0)|T_i = 1] \quad (2)$$

Unfortunately, the quantities in the second member of equation (1) are not both observable. A matching estimator is needed in order to estimate the missing observations. In particular, the estimator we employ uses sample observations to find adequate substitutes of the quantities we cannot observe. Following Abadie e Imbens (2002) we implement a bias corrected estimator, which has two main advantages: (i) it is possible to calculate analytically the variance; (ii) it allows for a bias correction – where the correction is due to the fact that covariates can differ in treated and control observations. The estimator is defined as follows:

$$\widehat{ATT}\ \frac{1}{N}\sum_{i \in N}[\hat{Y}_i(1) - \hat{Y}_i(0)] \quad (3)$$

where the two quantities $\hat{Y}_i(1)$ and $\hat{Y}_i(0)$ are estimated by:

$$\hat{Y}_i(1) = \begin{cases} Y_i\;\; if\; T_i = 1 \\ \frac{1}{M}\sum_{j \in J0} Y_j\;\; if\; T_i = 0 \end{cases} \quad (4)$$

and

$$\hat{Y}_i(0) = \begin{cases} Y_i\;\; if\; T_i = 0 \\ \frac{1}{M}\sum_{j \in J1} Y_j\;\; if\; T_i = 1 \end{cases} \quad (5)$$

The identification of the treatment effect is conditioned on two assumptions: (a) unconfoundedness given a set of k predetermined variables (X): T is independent of Y(0),Y(1) conditional on X=x; (b) the probability of being included into the treatment is bigger than zero given any set of covariates (overlapping): Prob(T=1|X=x) ϵ (0,1). Under the two assumptions we can identify the treatment effect for the subsample of treated firms as follows:

ATT=E[ATT(x)=E[Y(1)-Y(0)|T=1,X=x]] (6)

This estimator requires the definition of the metric for measuring the distance between two vectors of covariates - the distance measure in terms of the predetermined variables. We have chosen the Mahalanobis metric that weights the differences in respect to the values assumed for each covariate in terms of the inverse of their variance and covariance matrix. Formally, we have: $||x||_V=(x'Vx)^{1/2}$ be the vector norm with positive definite matrix V, we define $||r - x||_V$ to be the distance between the vectors x and r. Mahalanobis metric assumes: $V = S^{-1}$, where S is the covariance matrix of the covariates X_i. We used the nearest neighbor matching on the X's with three neighbors for each treated firm.

We define a firm as treated if it is awarded a grant to carry out an R&D project. The year of treatment corresponds to the period in which the firm receives a notification of allowance from the local government. From this moment through the following three years, the firms are co-financed for costs entailed in the project.

The definition of "control firm" is more subtle and is crucial to correctly identify the impact of the policy. Because of the wide range of activities that the law under scrutiny promotes and because of its non-competitive design, it is likely that a large number of firms in our sample received at least one grant during the period of analysis (2002-2007). Thereafter, we classify a firm as eligible in the control group only if it did not receive any grant in the three years before the period under investigation. In other words, we compare a treated firm in period t, t=2002,…,2008 with a set of control firms which: a) did not receive any grant in the periods t-1, t-2, t-3; b) did not receive an R&D grant in the whole period. A further condition we impose to include a firm either in the group of treated or in the control group is that it was a business organization active in at least one year before the notification of the grant.[9] The exact knowledge of which firm received what grant for the population of companies operating in the region allows us to neutralize the bias arising from a wrong choice of units to be included in the control group.

Our estimation strategy comprises a pre-filtering stage (Ho *et al.*, 2007), in which units in our sample are classified according to their economic activity. Thus, we kept only the three digit Ateco 2002 sectors in which at least one treated firm is present while discarding the others sectors. This cleaning procedure guarantees that treated firms and control ones carry out economic activities that are as much as possible similar.

Given the small number of subsidies per year (around 13 on average, see Table 2) we pooled the data across years, i.e. we consider the group of treated firms regardless of the calendar year in which they receive the subsidy. Accordingly, a set of time dummies is used to control for time related aggregate shocks. Furthermore, in order to make comparable monetary amounts we use production prices indices to deflate all the monetary variables.

Note that the matching estimator chosen allow us to look for exact matches with respect to a set of discrete covariates. This is an important point for our estimations given that we are able to stratify control and treated firms along three relevant dimensions:

- The calendar year;
- The technological sector (OECD, 2003): low tech, low-mid tech, high-mid tech, high tech;[10]
- The firm size (size classes used are those defined in the LP6: micro, small, medium and large firm).

[9] This conditions let us to exclude two research centers and three business organizations from the set of awardees.

[10] Note that we extended the OECD classification in order to take into account also services sectors present in our database.

Table 3. Description of variables

Variable:	Name	Description
Treatment indicator	Flagrd0207	Dummy indicating if in the current year the firm has a co-financed R&D project within the LP6 in the time window 2002-2007
Technological sector	Tech_sec	Technological sector as defined by OECD (2003). Original classification is extended to take into account services: Low technology sector(DUtech_sech=1) , low-mid tech. sector(DUtech_sech=2), mid-high tech. sector(DUtech_sech=3), high tech. sector (DUtech_sech=4)
Size class	sizeEU	Size classes as defined by LP6 (in accordance to the EU definition) based on number of employees and sales: micro firms (DUsizeEU=1), small firms (DUsizeEU=2), medium firms (DUsizeEU=3), large firms (DUsizeEU=4)
# of employees	add	Total number of employees at the year end
Calendar year	year	Calendar year of observation
Firm age	Age	Age of the firm (in years) calculated for each year and based on the date of firm birth
Capital intensity	Capint	Fixed asset over total turnover
Innovation intensity	Innoint	Intangible assets over total turnover
Financial constraint indicator	Cashflow	Cash flow over total turnover
Intangible assets	Imimm	Intangible assets of the firm
Fixed assets	Immat	Fixed assets of the firm
Operating margin	Mol/VA	Earnings before interest and taxes over value added
Labor productivity (based on output)	Tsxadd	Sales over number of employees
Labor productivity (based on value added)	Vaxadd	Value added over number of employees

The set of predetermined variables includes: firms' age (Age); firms' capital intensity - proxied by the ratio fixed asset over turnover- (Capint); past innovative performance, measured by intangibles assets over total turnover (Innoint); the degree of financial constraints measured by the ratio of cash flow over total turnover (Cashflow). The objective variables of the study are the innovative effort as measured by the intangible assets of the firm (Imimm) and a set of indicators that gauge the overall performance of the firm, such as sales per employee (Tsxadd), labor productivity (VAxadd) and operating margin (MOLxadd). Table 3 summarizes the variables included in our study.

5. Results

Table 4 compares the average value of the variables of interest for treated and control firms, before and after the matching procedure. The figures signal that the selection of a proper comparison group was mandatory, because differences between awardees and controls were statistically significant in the unmatched sample. In particular, the matching procedure helps us to mitigate the estimation bias that might arise because of the disparities in the cash flow indicator, the number of employees, the stock of intangible and tangible assets.

Table 5 reports the estimates of the average treatment effect of the regional policy on the firms that were awarded at least one R&D grant during the period of analysis. Results shown in Table 5 refer to the performance differences of awarded firms in terms of two measure of labor productivity - sales per employee and value added per employee – a measure of profitability – operating margin – and an indicator that gauges the firm's involvement in innovative effort – intangible assets. In order to fully explore the time dimension of input and output effectiveness, for each of these variables, we evaluate how firms receiving a R&D grant fared with respect to non-granted ones at one, two and three periods after obtaining the financing.

The results suggest that the R&D grant had a positive and significant effect on the input side of the innovation process. One year after receiving the financial support, the group of treated firms recorded a significantly higher level of intangible assets, more than 1 million €, than the control group. The differential appears stable over time and tends to last even three years after the assignment of the R&D grant: this result is quite robust even if the number of treated firms on which we can assess the causal effect significantly shrink when we carry out our investigation on a longer span of time.

Table 4. t-tests on predetermined variables before and after matching

		Mean value			
		Treated	Control	t-test	t p>t
Age	Unmatched	24.944	24.342	0.320	0.751
	Matched	25.624	27.239	-0.590	0.555
Capint	Unmatched	0.239	0.392	-0.980	0.325
	Matched	0.230	0.181	1.140	0.256
Innoint	Unmatched	0.124	0.070	1.550	0.121
	Matched	0.124	0.067	1.440	0.152
Cashflow	Unmatched	2200.000	326.990	7.980	0.000
	Matched	2233.100	1717.800	0.620	0.538
Add	Unmatched	115.760	18.753	12.420	0.000
	Matched	120.390	65.050	1.610	0.110
Vaxadd	Unmatched	140.4	172.58	-1.19	0.233
	Matched	150.78	196.65	-1.5	0.136
Tsxadd	Unmatched	165.02	230.95	-1.91	0.057
	Matched	190	267.36	-1.86	0.065
MOL/VA	Unmatched	0.053	-0.016	0.300	0.764
	Matched	0.059	0.060	-0.020	0.985
Imimm	Unmatched	1417.100	240.310	2.590	0.010
	Matched	1531.000	452.990	0.940	0.362
Immat	Unmatched	6223.900	1149.900	6.060	0.000
	Matched	6306.800	4734.600	0.560	0.574

Notes: All the variables refer to the year before the incentive was awarded

As for the effect of the policy intervention on the competitiveness of the firm we observe a positive and significant effect of the R&D grant on the operating margins of treated firms the year after financing is awarded. The positive bearings vanish when we evaluate the effect of the policy over a longer time span.

Furthermore, irrespective of the time horizon we focus on, there does not appear any statistically significant impact of the policy on both measures of productivity. In particular, although the differential in terms of labor productivity between treated and controls is positive, its magnitude is modest and it does not support the idea that the policy intervention has raised the efficiency of R&D awardees.

Table 5. Estimates of the average treatment effect of the treated – several time lags

	Performance after one year				
	Treated (N=85)	Controls (N=1987)	ATT	S.E.	*t* stat
Sales per employee	178.2996	192.0578	-13.7583	21.449	-0.64
Labor productivity	155.9999	155.1362	0.8637	17.073	0.05
Operating margin	0.0581	-0.0423	0.1005	0.053	**1.90**
Intangible assets	1281.927	242.598	1039.329	284.452	**3.65**
	Performance after two years				
	Treated (N=60)	Controls (N=1342)	ATT	S.E.	*t* stat
Sales per employee	200.587	200.282	0.305	25.674	0.01
Labor productivity	162.991	147.041	15.950	15.829	1.01
Operating margin	0.079	0.054	0.025	0.022	1.14
Intangible assets	1332.587	254.305	1078.283	314.477	**3.43**
	Performance after three years				
	Treated (N=41)	Controls (N=902)	ATT	S.E.	*t* stat
Sales per employee	209.763	234.043	-24.280	41.912	-0.58
Labor productivity	153.853	146.377	7.476	14.496	0.52
Operating margin	0.051	0.051	0.000	0.031	0.00
Intangible assets	1226.085	191.737	1034.348	359.175	**2.88**

Overall, a comparison of our results with prior evidence at the national level (Merito *et al.*, 2007) corroborates the idea that R&D policy may be expected to leverage, on average, the innovative effort of firms that are awarded a grant. Hence, public support does not seem to crowd out private investment in knowledge accumulation. Nonetheless, this increased level of investment does not translate into higher levels of efficiency at the firm level. And more, it only temporally conveys a competitive advantage to treated companies.

The foregoing piece of evidence may indicate that while companies are readily prone to adopt new knowledge and technologies, they are less able to exploit efficiently and to profit from the investment done. Such an interpretation is consistent with previous findings in Pedrotti *et al*. (2008) which investigate the dynamics and the determinants of labor productivity in the province of Trento, over a period that is almost overlapping with the one we covered in this analysis. The authors show that the labor productivity is stagnant over the period 2001-2006 for the entire economic system, and even declining in the manufacturing and construction industries. Moreover, they decompose the labor productivity indicator into two components: (i) an index that captures the evolution of capital deepening and (ii) an index that gauges the dynamics of the multi-factor productivity. This decomposition highlights that a contraction in the total factor productivity entirely accounts for the flattering, or even decreasing, pattern observed in labor productivity. Accordingly, while the work force has been endowed with renewed capital along the period of analysis, the organization did not succeed in effectively combining capital and labor to enhance their operational performance.

This outcome is by no mean a surprising one. Similar results for Italian firms have been found by Merito *et al*., 2007. The null effect on labor productivity may well be caused by two other factors. First, there might be a question of close micromplementarities between intangible assets investments, skilled labour force and firms' reorganization. In other words, intangible asset investments might need an adequate level of human capital and firms' reorganization, for example the presence of an R&D function inside the firm, in order to manifest their full potential and, consequently, have an impact on labour productivity. Secondly, the LP6, by forcing firms to keep a predetermined workforce level for two years, after receiving the incentive, may have caused a lower labour productivity.

6. Conclusions

This paper empirically investigates whether public R&D project funding in the province of Trento by the LP6, from 2001 to 2008, foster private firms R&D investment (intangible assets investments) and improve firms' performance (labour productivity and operating margin). In order to accomplish these aims, we build up a very appropriate dataset which combines information from firms' balance-sheet data with the administrative archives. The latter gather information on the specific projects that subsidized firms carried out. Furthermore, these data are enriched with quali-quantitative data coming from face to face interviews to entrepreneurs and policy makers, undertaken in the period ranging from November 2009 to December 2010.

The investigation of the effectiveness of the PL6 is carried out using counterfactual methods: treated firms (the population amounted to 89) were matched with around 335 control firms each year. The latter were carefully selected, against predetermined variables, in order to guarantee the closest similarity with treated firms.

This paper contributed to the existing literature on the effects of incentives for firms' R&D investment and firms' performance in several ways. It takes into account the effectiveness of R&D place-based intervention, a topic that has received so far little scrutiny, despite the increasing regionalization of innovation policy. Moreover, confining our ex post R&D policy evaluation to the province of Trento guarantees a much closer similarity among treated and non-treated firms than one can find comparing nationwide firms. Thus alleviating firms' heterogeneity that could undermine the robustness of counterfactual methods. By choosing the firms, which only received R&D subsidies (and none of other incentives), we have been able to "isolate" the treatment, thus mitigating the effect of one relevant confounding factor, often raised as a cumbersome problem in the recent applied literature.

Unlike most of the current empirical studies, in our evaluation exercise, we take into consideration several variables, both input and output ones, thus enlarging the number of outcome variables that might be influenced by R&D subsidies.

In terms of our results, we find that: *i)* R&D grant had a positive, significant and lasting effect on the input side of the innovation process. One year after receiving the financial support, the group of treated firms record significantly higher level of intangible assets than the control group. The differential appears stable over time and tends to last even three years after the assignment of the R&D grant; *ii)* as for the effect of the policy intervention on the competitiveness of the firm, we observe a positive and significant effect of the R&D

grant on the operating margins of treated firms only in the year after financing is awarded; *iii)* there does not appear any statistically significant impact of the policy on both measures of productivity.

While providing a partial positive assessment of the effectiveness of the PL6, we are aware that there other issues needing to be addressed in order for the law to fully express its potential. Among these, the question of microcomplementarities deserves further research. It seems quite relevant, as our exercise shows, that awarded firms are not able to render fully productive the R&D investments fostered by the PL6. To this end, we intend to make better use of the data concerned with the internal organization of the firm and the human capital employed.

Another issue concerns the presence of localized spillovers, which may well be main advantage of a place-based policy. Existing research, based on ex post evaluation, sheds some light upon the likely determinants for the host region to accrue the potential benefits of R&D (Roper, 2004). They are the nature of R&D project itself and the innovation system of the region. Both are worthwhile further investigation in order to provide a thorough assessment of PL6 effectiveness.

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