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## RESEARCH PAPER

# The differential impact of privately and publicly funded R&D on R&D investment and innovation: the Italian case

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*This paper explores the impact of a specific R&D policy instrument, the Italian* Fondo per le Agevolazioni della Ricerca *(FAR), on industrial R&D and technological output at the firm level. Our objective is threefold: first, to identify the presence or absence of private R&D investment additionality/crowding-out within a pooled sample and in various firm subsets (identified by region, size, level of technology, and other features), while also taking into account the effect of single policy instruments or mixes of them. Secondly, to analyse the output (innovation) additionality by comparing the differential impact of privately funded R&D and publicly funded R&D expenditure on applications for patents filed by firms. Thirdly, the paper will compare the structural characteristics of firms showing additionality with those of firms showing crowding-out, in order to determine the firm characteristics associated with successful policy interventions. Our results suggest that FAR is effective in the pooled sample, although no effect emerges in some firm subsets. In particular, while large firms seem to have been decisive for the success of this policy, small firms present a more marked crowding-out effect. Furthermore, the firms' growth strategies and ability to transform R&D input into innovation output (patents) seem to have a positive effect in terms of additionality.*

## Introduction

This paper explores the impact of a specific R&D policy instrument, the Italian *Fondo per le Agevolazioni della Ricerca* (hereafter FAR), on industrial R&D and technological output at the firm level. It uses results from a three-year national strategic research project funded by the Italian Ministry of Research.[1] The objective of the study was threefold.

Firstly, we identify the presence or absence of private R&D investment additionality and crowding-out within a pooled sample and in various subsets of firms (identified by regional, dimensional, technological, and other features), while also taking into account the effect of single policy instruments as well as of mixes of them. Compared with previous R&D policy evaluation studies [see the review by David *et al.* (2000); also see García-Quevedo (2004) and Cerulli (2010)] that focus mainly on the estimation of a single causal effect parameter, this study also provides an estimation of the entire distribution of the treatment effect of FAR according to the observed firms' heterogeneity. We identify the group of firms performing additionality and that of firms performing crowding-out by comparing the structural

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characteristics of the two groups, in order to determine the factors that lead to the successes and failures of FAR.

Secondly, the paper analyses the effect of FAR on the output (i.e. innovation) additionality (Georghiou and Larédo, 2006) by comparing the differential impact of privately and publicly funded R&D expenditure on the number of patents filed by firms. We use a two-step procedure (Crèpon *et al.*, 1998; Busom, 2000; Czarnitzki and Hussinger, 2004), the first step being a nearest neighbour matching (Cerulli and Potì, 2008), to calculate the additional own R&D component. The second step applies a Poisson (multiple) regression of the number of patents on own R&D, on subsidy, and on additional own R&D as calculated in the first step. If the additional component has a positive and significant value we can conclude that the considered policy also has a positive impact on the firms' innovative performance.

Thirdly, the paper analyses the supporting effect of R&D on a firm's economic performance in relation to innovation by adopting three indicators: productivity, profitability, and growth rate. This is done by comparing the additionality and crowding-out groups, using results from the analysis performed above. Despite the limited time span (five years), the study of performance effects seems to be worthwhile.

## The rationale for R&D subsidisation

Neoclassical theory suggests that, because R&D is a public good, the level of private R&D expenditure would be systematically lower than the socially optimal level (Arrow, 1962). This occurs since the benefits associated with R&D activities are easily and freely available to subjects not engaged in R&D. Indeed, the lack of full appropriability of R&D outcomes reduces the incentive to undertake R&D on the part of private for-profit firms so that, as in a classical Pigouvian context, government intervention through subsidisation can reduce the extent of this market failure.

This argument has been widely criticised. From an evolutionary perspective for example, Cohen and Levinthal (1989) argue that knowledge cannot be so easily absorbed unless imitative firms also invest some of their resources in R&D: imitation is not costless and needs some pre-existing R&D 'hard core'. This standpoint might lead to a paradoxical consequence: in an environment characterised by many spillover effects, firms might be more motivated to perform R&D since, in doing so, they might increase their absorptive capacity (i.e. their ability to benefit from the R&D efforts of others). In this way, they would be able more easily to imitate and exploit market surpluses. Paradoxically, and as a consequence, the level of R&D might be too high (rather than too low), since many firms might make more R&D effort than that required to achieve the same social results (for example, duplications in R&D expenditure might increase).

Similarly, the new industrial organisation perspective in its 'patent race' version (Dasgupta and Stiglitz, 1980; Dasgupta, 1988; D'Aspremont and Jacquemin, 1988) reaches conclusions that are quite different from those of the standard neoclassical model. When a number of firms in a given industry compete to obtain a patent that grants a lifelong monopoly, they might have to bear costs that cannot be recovered once the race is lost. In such a case, a large amount of R&D expenditure does not lead to innovation and industrial exploitation, thus representing a cost for society as a whole (with duplication of R&D efforts, or losses associated with asset specificity allocation). Consequently, the R&D effort might be excessive for society, and cooperative alternatives (such as research joint ventures or other cooperative strategies) might lead to welfare improvements. Other scholars hold that R&D should not be considered a pure public good. A firm has a wide range of tools to protect its inventive capacity, such as patents, secrecy, and so on (see, for example, Nadiri, 1993). Therefore, the positive externalities produced might be very limited and/or industry specific, and the need for supporting R&D activities more contentious than might appear at first glance.

Nevertheless, many authors maintain that the case for subsidisation of R&D goes beyond positive externalities since other market failures are at work, such as imperfect capital markets for high-risk investments, overly high barriers to entry and exit, excessive market power (or, conversely, excessive fragmentation of market power), lack of technological infrastructure and bridging institutions, and failure to coordinate profitable R&D joint ventures, causing duplication of R&D efforts, waste of resources, and so on [for a general discussion of these points, see Martin and Scott (2000)]. In the first case, failure can arise because R&D investments are too risky and there is asymmetric information between lenders and borrowers, generating heavy rationing of funds. In the second case, financial markets and instruments might not be developed enough to provide resources for highly innovative ideas and technologies. In the third case, a sub-optimal level of R&D expenditure might be caused by imperfect competition caused by such barriers as very high fixed costs incurred to enter a market and/or excessively high costs to exit it (high sunk costs). In the fourth case, market structure and firm size determine industrial R&D performance, depending on the complex system of incentives this market structure generates at different sectoral levels.[2] Cases five and six might be caused by scarce material and immaterial knowledge infrastructures and various traps in the functioning of the national system of innovation (Malerba, 1993; Mowery, 1995; Metcalfe, 1995).

As for spillovers, one important aspect to consider is the type of effect subsidies generate. As suggested by Klette *et al.* (2000), a subsidy can generate additional spillover effects, so that non-subsidised firms can benefit from the R&D efforts made by subsidised firms. This leads to another paradoxical conclusion: a subsidy can be used as a tool to internalise positive externalities and correct for market failure, while the same subsidy can generate additional spillovers by causing incremental market failure. In the evolutionary literature particularly, it is held that spillovers are advocated more for the dynamic complementarities they can generate than for their static (neoclassical) allocation distortion; indeed, since not only direct but also indirect R&D diffusive effects are at work, subsidies seem to be especially useful and necessary to overcome dynamic traps.

## Some findings from the literature

OECD countries spend large amounts of public money on programmes aimed at stimulating firms' research activity (Klette *et al.*, 2000). However, country comparisons that analyse the relation between public subsidies and private R&D performance are difficult as many institutional differences can affect a subsidised firm's decision to invest in additional R&D (David *et al.*, 2000). A critical aspect is the design of the various statistical settings under which R&D policy evaluation is performed. Studies often have an empirical and descriptive approach, establishing mainly sign and level of the aggregate effect. As suggested by David *et al.* (2000), starting from a common conceptual framework that identifies the arrays of hypothetical micro-level determinants of private sector investment in R&D (i.e. a model of firm-level investment behaviour) could significantly improve such comparisons. Indeed, 'a broader understanding of the mechanism through which governmental R&D and private R&D interact is imperative if one is to begin to understand the subtleties of existing empirical findings' (Leyden and Link, 1991, p.1673) as 'observed complementarity […] is the result of a complex balancing of forces' (p.1664). So, it is necessary to identify the circumstances and characteristics in which the substitution effect is predominant, but econometric models sometimes lack sufficient specification. Moreover, the ex-post effect of public aid on firms' R&D additionality reflects different designs and mixes of public incentives. Clausen (2009), for instance, suggests comparisons on the basis of taxonomies of R&D incentive designs, and distinguishing between the relative impact on the research compared with the development component. Finally, studies that do not take adequate account of the distribution of the additionality effect of public aid could support a misleading generalised conclusion that does not fit the heterogeneity of firms' responses. Given these warnings and the fact that a comprehensive review of the literature evaluating the impact of public subsidies on firm R&D cannot find a place here, we simply report the evidence from two recent reviews on the so-called 'input-additionality' (which gives an idea of the main effect on firm R&D) without specifying the effect on innovative output.

David *et al.* (2000) review empirical studies on the relation between public and private R&D spending by grouping them according to the level of aggregation at which the relation was examined (firm and lower level, industry, country) and by distinguishing between US-based data and other countries' data. US-based data represent the majority (two-thirds of the set of assembled data) in their survey. This taxonomic distribution of the econometric studies shows that net substitution effect is relatively higher in studies at firm level (9/19) and for US-based data, while net complementarity is generally more important (12/14) for studies at the more aggregate level. The authors advance the warning that 'heterogeneities and asymmetries among firms' together with 'problems arising from the interdependence of enterprises' behaviour in imperfectly competitive markets […] render invalid the attempt to pass from the micro to the macro-analytic level directly' (p.525). It is still an open question whether the difference between the micro and macro effect depends on the strength of inter-firm and inter-industry spillovers (p.527).

A more recent review of the literature (García-Quevedo, 2004) adopting a similar taxonomy of studies (level of aggregation and type of country-based data) applies a quantitative technique (meta-regression analysis) to identify whether the particular choice of method, design, and data may affect reported results (p.88). The meta-regression analysis is applied to 39 empirical studies and the aim is to explain the variation in sign or magnitude of the relation between R&D public funding and private R&D expenditure. As maintained by the author, 'results show that there are no specific study characteristics that lead to a particular result' (p.96); for example, neither panel data nor a dynamic approach incorporating time lags (which looks suitable for complicated behavioural models) lead more frequently to a definitive conclusion. At the descriptive level, the author finds greater substitutability when the analysis is done at firm level (p.92). The latter case is the type developed here and outlined below, with the distribution of results suggesting that complementarity effects are 17/38, insignificant effects 10/38, and substitutability effect 11/38. In summary, complementarity between public R&D financial aid and private R&D prevails at firm level, but there is also a large variance among results that can be ascribed to the high heterogeneity of these empirical findings.

## A theoretical framework to identify the effects of public subsidies on business R&D

The long-standing measurement without theory controversy within the econometric discipline seems to have experienced an unexpected revival in the study of how public subsidies affect firm R&D expenditure. The majority of works in this field, in fact, seem to focus on measuring the presence or absence of additionality[3] generated by public incentives, and skip, at least implicitly, the essential step of providing an explicit theoretical framework explaining this causal relation.

David *et al.* (2000) and David and Hall (2000) denounce this attitude towards R&D incentives and try to provide a sounder theoretical basis for understanding the effects of public subsidies on private R&D investment.[4] Their structural model identifies the optimal level of R&D investment as the point at which the marginal rate of return (MRR) and the marginal capital costs (MCC) associated with R&D investments are equal. This is a classic profit maximisation strategy. The MRR curve derives from sorting R&D projects according to their internal rate of return, as happens in an investment plan. This curve is a decreasing function of R&D expenditure since firms will first implement projects with higher internal rates of return and then those with lower rates. The MCC curve, instead, reflects opportunity costs of investment funds, at any level of R&D. This curve has an upward slope because of the assumption that, as soon as the number of projects to be implemented increases, firms have to shift from financing them through retained earnings to financing them by means of equity and/or debt funding (i.e. a shift from internal to external and more costly resources).[5]

Obviously, both curves depend on a number of variables other than R&D expenditure ($R$), which can cause them to move either downward or upward. In fact, according to the structural model of David *et al.* (2000), we can write:

$$\begin{aligned} \mathrm{MRR} &= f(R, \mathbf{X}) \\ \mathrm{MCC} &= g(R, \mathbf{Z}) \end{aligned} \tag{1}$$

where $\mathbf{X}$ and $\mathbf{Z}$ are variables that move the curves accordingly. In particular, the $\mathbf{X}$ variables include some proxies of:

(1) technological opportunities;
(2) state of the demand; and
(3) appropriability conditions.

The variables contained in $\mathbf{Z}$ depend on:

(1) technological policy instruments;
(2) macroeconomic conditions;
(3) external costs of funds; and
(4) availability of venture capital.

The technological policy tools depend, in turn, on tax treatment, public subsidies and public–private cost-sharing research projects activated through government procurement.[6] The equilibrium condition, MRR=MCC, indicates the optimal level of firm R&D investment (which is labelled $R^*$). In its explicit form, it is:

$$R^* = h(\mathbf{X}, \mathbf{Z}) \tag{2}$$

Provided that **X** and **Z** are exogenous factors, Equation (2) is the reduced form associated with the structural model (1). Drawing on this framework, we wish to determine what effect a subsidy has on the equilibrium level of R&D expenditure $R^*$. If we indicate the amount of subsidy with $S$ and call $H$ the incremental R&D expenditure activated by subsidy $S$, we can observe that:

$$R = R^* + H \tag{3}$$

The following five cases are possible:

$H=S$: neither additionality nor crowding-out;

$H>S$: additionality;

$0<H<S$: crowding-out;

$H=0$: full crowding-out;

$H<0<S$: more than full crowding-out.

Each of these cases can actually occur, and it is the aim of econometric techniques to determine the relevant case for each specific context.

## Dataset construction and features

The R&D support programme we analysed within the research project is the *Fondo per le Agevolazioni della Ricerca* (FAR), managed by the Italian Ministry of Research (Miur). FAR is one of the two pillars on which national R&D and innovation supporting policies are based. The second pillar is FIT, *Fondo per l'Innovazione Tecnologica*, managed by the Ministry of Economic Development (Mise). FIT focuses upon pre-competitive upgrading and, to some extent, on the applied research that FAR tries to promote. FAR is a sort of 'mini-mix' policy instrument; that is, it contains bottom-up and top-down measures as well as some automatic measures to support SMEs. The subsidies consist of standard grants as well as favourable loans and tax credit. FAR also concerns R&D projects in the Mezzogiorno in the South of Italy (Law 488, that is now one of the instruments included within FAR) as well as research programmes co-funded by the European FESR and FES for Objective 1 (less developed) regions.

We use a database (hereafter panel_Firb) developed through a collaboration among ISTAT (Italian National Institute of Statistics), Cilea (an agency working on behalf of Miur), Confindustria (the main Italian employers' association), and Ceris (one of the institutes of the National Research Council of Italy, CNR), all of which contributed to the FIRB project mentioned above. Panel_Firb includes information on supported and non-supported firms taken from *Anagrafe della Ricerca*, a Miur dataset managed by Cilea. All the firms planning to apply for Miur project funding must be registered in the database, which also indicates if these firms have received Miur support year by year. Panel_Firb provides information on the accepted projects and on firm R&D expenditure by year, merged with firm balance sheet data. Panel_Firb covers a period of five years (2000–2004), for which matching with R&D data is available.

Once the datasets were merged together, the sample was reduced to 2321 firms, observed for five years. The first version had a cross-section form and was named panel_Firb_c. In panel_Firb_c, the number of supported units is 900 (39%) and there are 1421 (61%) non-supported units. For two-thirds of the firms, there is no public commitment in FAR or Law 488 projects. A wide range of information about the financed R&D projects is included, such as total cost, type of received public aid (grants, favourable loans, tax credit, and interest discounted contributions), type of project by specific article and law (Law 297 bottom-up or top-down, Law 488 bottom-up, automatic procedure, others), project details (duration, presence of inter-firm collaborations, localisation in Objective 1 areas, main orientation toward either research or development, etc.), and general firm information (sector, region, number of financed projects, etc.).

Once panel_Firb_c took on a longitudinal structure, we turned to the dataset called panel_Firb, whose main characteristics are shown in Table 1. This dataset is used for our investigation and it is described here in detail. Its unit of analysis is firm per year (and not simply the firm, as in panel_Firb_c), so that the number of

**Table 1.** Main features of the panel_Firb dataset

| Name | Panel_firb |
|---|---|
| Unit of observation | Firm per year |
| Time span | 2000–2004 |
| Number of years | 5 |
| Number of firms | 2321 |
| Number of observations | 11,605 |
| Number of supported firms | 1845 (1200) |
| Number of non-supported firms | 9760 (10405) |
| Average firm size | 386 employees |
| Method for the calculus of the subsidy | GGE (gross grant equivalent) |
| Average financing share of project costs | 0.49 |
| Average project duration | 2.7 years |
| Number of observations with one project in period | 56% |
| Firms located in the North of Italy | 65% |
| A. Average R&D expenditure per year | 4.95 million euros |
| B. Median R&D expenditure per year | 491,000 euros |
| C. Maximum R&D expenditure per year | 467 million euros |
| D. Average subsidy per year | 624,000 euros |
| E. Median subsidy per year | 234,000 euros |
| F. Maximum subsidy per year | 38.2 million euros |
| D/A in percentage (mean) | 12.5% |
| E/B in percentage (median) | 49.4% |
| F/C in percentage (maximum) | 8.1% |
| Average turnover | 40.7 billion euros |
| Median turnover | 16 million euros |
| Median R&D intensity | 3.06% |

Note: The term ‘subsidy’ refers to the level of the public financing according to the gross grant equivalent method.

supported units becomes 1200 and the number of non-supported firms 10,405, for a total of 11,605 observations. This increase in supported units depends on the fact that, within the considered timeframe (2000–2004), many firms saw more than one of their projects approved. Moreover, since a project generally lasts longer than one year, the firm in question must be consider 'treated' for the entire duration of the project. In other words, a firm presenting a three-year project in 2000 is treated for the following three years, i.e. 2000, 2001, and 2002 (but not supported in 2003 and 2004, of course). Accordingly, the subsidy must be considered for each of the three years, thus increasing the number of supported units (basic unit: firm per year). By following this spreading procedure, the number of treated units increased to 1845 (versus 9760 non-supported observations), as illustrated in Tables 1 and 2.

Table 1 shows that public intervention (which is a gross measure of proper intervention and needs to be calculated according to the Gross Grant Equivalent (GCE) method) covers, on average, 49% of the costs of the proposed projects and that the average firm size is 386 employees (with a non-reported median of 71). Without considering the projects presented in relation to Art. 14 (tax credit), the average duration of a project is 2.7 years. R&D expenditure is, on average, 4.95 million euros, with a median of 491,000 euros (i.e. strong asymmetric R&D distribution with a very long right tail), whereas the average subsidy (calculated with the gross grant equivalent method) is about 624,000 euros (median: 234). The ratio of GGE subsidy to R&D expenditure is 12.5% (mean) and 49.4% (median). Moreover, the median R&D intensity of the sample is about 3%, a high value compared with the national aggregate value.

Table 3 presents a simplified outline of the panel_Firb dataset, underlining its main features. For the sake of brevity, it refers to just one firm observed in the five years considered, and should be seen as a representative case. The firm has a total of five projects, three of which began in 2000, one in 2002, and one in 2004. We can observe from the type of financing section that in 2000 the firm worked on two bottom-up research projects and on one Law 488 project. From the project characteristics section, we can see clearly that in 2000 at least one of the three accepted projects was a collaboration and at least one of them was oriented towards research (and not development).

Table 4 shows the differential weight of each single financing instrument. Most observations (i.e. firm per year) received bottom-up financing (54%); 14% received support from Law 488; top-down projects were only about 4%, while projects with only tax credit (only Art. 14) accounted for 24%. Firms presenting projects in Objective 1 areas (less developed regions) were 20% of the sample, whereas those involved in collaborations were around 13%;[7] finally, 25% of the projects were

**Table 2.** Supported and non-supported firms in the panel_Firb_c and panel_Firb dataset

| Dataset | Panel_Firb_c Number of firms | Panel_Firb Number of firms per year | Panel_Firb after subsidy redistribution Number of firms per year |
|---|---|---|---|
| Supported whose: | 900 | 1200 | 1845 |
| only ART. 14 | 223 | 346 | 575 |
| other | 677 | 854 | 1270 |

**Table 3.** Schematic structure of the longitudinal dataset used in the analysis

| | | | | TYPE OF FINANCING | | | | | | | PROJECT CHARACTERISTICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Year | Number of project in the period | Number of project in the year | Bottom-up research | Bottom-up training | Top-down | Law 488 | Tax credit art. 14 | Only art. 14 | Other | Collab. | Ob1 | Res Dev | Res–Dev | Max duration (2000–2004) |
| 1 | 2000 | 5 | 3 | 2 | | | 1 | | | | 1 | 0 | 1 | | 36 |
| 1 | 2001 | 5 | | | | | | | | | | | | | |
| 1 | 2002 | 5 | 1 | | | 1 | | | | | 0 | | 1 | | 12 |
| 1 | 2003 | 5 | | | | | | | | | | | | | |
| 1 | 2004 | 5 | 1 | 1 | | | | | | | 0 | | | 1 | 24 |

**Table 4.** Weight of single instruments in the panel_Firb dataset

| Instrument | Frequency | Percentage |
|---|---|---|
| Only art.14 | 346 | 28.83 |
| At least one bottom-up research project | 649 | 54.08 |
| At least one bottom-up training project | 13 | 1.08 |
| At least one Law 488 project | 166 | 13.83 |
| At least one top-down research project | 47 | 3.92 |
| At least one art. 14 research project | 83 | 6.92 |
| At least one other research project | 13 | 1.08 |
| At least one collaborative research project | 153 | 12.75 |
| At least one Objective 1 research project | 229 | 19.08 |
| Research and development | Frequency | % |
| Research | 199 | 25.42 |
| Research and development | 475 | 60.66 |
| Development | 109 | 13.92 |
| *Total* | 783 | 100 |

oriented towards research and about 14% towards development.[8] To sum up, in the period under observation (2000–2004), FAR was more suitable for bottom-up (evaluation procedure) projects than for automatic (no evaluation procedure) or top-down (negotiated procedure) projects.

Table 5 looks at the share of project costs covered by public financial support. On average, grants cover 38% of the total admitted project costs, while this value is equal to 57% for favourable loans and (only) 34% for interest discounted contributions. As already indicated in Table 1, public financing covers, on average, 49% of the total admitted project costs, while its maximum value is 86%.

Two important aspects should be emphasised. Firstly, the dataset includes all the public measures for firm support related to FAR and Law 488 by year. Secondly, additionality is assessed by comparing own R&D expenditure (which excludes all the subsidies received each year within total R&D expenditure) in the treated and untreated firms.[9] Each measure will be evaluated in isolation from other measures. Further, where measures are applied as an element of a mix, additionality will be evaluated by both including and excluding it from the mix of subsidies. It is worth pointing out that the panel_Firb dataset lacks information on the presence of R&D subsidies other than those from FAR and Law 488. In particular, there is no information on the presence of subsidies from FIT or European Framework Programmes (EUFP). This is because of insufficient communication between Miur and Mise, as well as among the different Miur departments.

**Table 5.** Incidence of the type of public financing on projects costs

| Number of observations | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|
| Admitted cost on total cost 619 | 0.974 | 0.117 | 0.046 | 1 |
| Total financing on admitted cost 619 | 0.49 | 0.139 | 0.008 | 0.861 |
| Grant on admitted cost 618 | 0.386 | 0.19 | 0.002 | 0.813 |
| Favourable loans on admitted cost 385 | 0.576 | 0.115 | 0.113 | 0.75 |
| Interest discount on admitted cost 38 | 0.341 | 0.122 | 0.082 | 0.55 |

Our results would not be modified if we could hypothesise that the distribution of FIT (or EUFP) is uniform among firms. However, it is more likely that firms which did not receive any FAR subsidy during the observed period (2000–2004) received some other type of R&D subsidy (FIT or EUFP), or no subsidy at all. This more likely hypothesis should reinforce our results. Finally, it is necessary to present two important assumptions on subsidy measurement which underlie our analysis:

(a) We work under the assumption that, when a firm's project is accepted for public funding, the firm starts its R&D project immediately (before receiving the funds) because banks can provide the needed resources in advance if the approval of the project works as collateral, or because the firm decides to finance the project itself.[10]

(b) We use the GGE (gross grant equivalent) method, as recommended by the European Union, to calculate own R&D expenditure of each treated firm. When, among other alternatives, the supporting scheme takes on the form of favourable loans and tax credit, the right way to calculate the proper level of subsidy is the GGE. This methodology allows us to measure the exact amount of subsidy received according to an actualisation formula for the distributed loan payments in the contracted years (which, in our case, is a period of 10 years).

### Description of the variables and selected sample

Following the model developed by David, Hall and Toole (2000) (hereafter the DHT model), a series of control variables is considered to complete the dataset, in order to evaluate econometrically the effectiveness of FAR policy. We start with the dependent variable, firm own R&D, equivalent to a firm's total R&D expenditure minus the subsidy (calculated according to the gross grant equivalent method and then spread throughout the duration of the project). Table 6 shows the name and definition of each variable.

- *Treatment*: this is the 0/1 variable indicating whether a given firm is supported. This is a common 'flag', whose coefficient represents the net effect of the policy, as explained below. In the terms of the DHT approach, this is our 'technological policy tool'.
- *Size*: besides accounting for the different economic scale of the firms, this can be seen, within the DHT model, as a proxy for the state of demand, since it is strictly collinear with firm turnover.
- *Knowledge*: this variable takes into account a firm's past experience in R&D and innovation performance. Moreover, since it is built on capitalised patent expenditure, it approximates quite well the degree of appropriability conditions of the market in which the firm operates (the higher this variable, the greater a firm's need to protect its inventions).
- *Cash flow*: this is the self-financing (or internal) component within the corporate financing structure of a firm (the other components are external resources, such as leverage and equity). It represents a firm's internal liquidity constraint and should be seen as the cheapest way to finance investments.

**Table 6.** Dependent and independent variable descriptions

| | |
|---|---|
| DEPENDENT VARIABLE | |
| Own R&D | =total R/S expenditure – subsidy |
| | |
| COVARIATES | |
| Treatment (t) | 0/1 dummy at time *t* |
| Knowledge | Stock of capitalised expenditures for patents to total turnover |
| Leverage | Debt to turnover |
| Cash flow | Non-distributed profits to turnover |
| Equity | Owners' equity to turnover |
| Labour cost | Labour costs to turnover |
| Capital intensity | Stock of equipments to turnover |
| Size | Number of employees |
| Only Art. 14 | dummy: 1=observation with only an ART. 14 project |
| Objective 1 | dummy: 1=observation with at least one project in area Objective 1 |
| Collaboration | dummy: 1=observation with at least one collaborative project |
| Subsidy allocation | dummy: 1=presence of some support supply |
| Sector | dummy: sector NACE two-digit |
| Region | dummy: regional localisation of the firm |
| Year | dummy: year (2000–2004) |

- *Leverag*e: debt financing is a key resource for a firm's R&D and non-R&D investments. In Italy, this is strengthened by the prevalence of SMEs, characterised by low propensity to rely on financing from the stock market.
- *Equity*: besides being the second external source of financing, this is a proxy of venture capital availability (as indicated by the DHT model) or, more generally, of the ability a firm has to find resources other than those it has internally or from banks.
- *Labour cost*: labour intensity seems important in determining the R&D performance of a firm so that, although not considered in the DHT model, this variable is added to account for differences in cost structure.
- *Capital intensity*: like labour cost, this is a key variable, especially in sectors oriented toward automation or the manufacturing of high technology products.
- *Sector*: technological opportunities and other technical aspects are undoubtedly sector-dependent. Including this variable is essential to avoiding potential biases because of different firm specialisations and accounting for sampling differences.
- *Region*: regional differences are important, especially in countries characterised by uneven economic development, like Italy. This variable also accounts for the different weights of firms located in different Italian regions.
- *Time*: according to the DHT model, the last variable refers to macroeconomic conditions. The dummy for time serves as a proxy for differences in time within the sample period.

Finally, another four variables concerning the characteristics of the projects are introduced:

- *Only Art. 14*: a 0/1 dummy indicating if the subsidy concerns tax credit. Tax credit is different from other subsidy measures, since it does not follow any evaluation procedure, but it is an automatic tool, granting fiscal advantages based on past R&D expenditures reported.
- *Objective 1*: a 0/1 dummy indicating if the R&D project concerns an Objective 1 area (such as the Mezzogiorno area of Italy). This characteristic seems to be rather important and needs to be considered separately as a specific variable.
- *Collaboration*: the value of this dummy is 1 if the firm is engaged in collaborative projects with other firms or institutions. This variable is of great relevance because of the potential internal spillovers and synergies it can produce.
- *Subsidy allocation*: once a firm is deemed eligible for financing, it immediately starts its R&D project, since banks provide the needed resources (the public agency's commitment works as a guarantee) or, more probably, the firm resorts to self-financing. Nevertheless, during the same period, the firm might receive further public funding (mainly from previously accepted projects, not directly related to the current one). This occurrence is taken into account in order to reach fairer conclusions about the effects of the subsidies associated with current accepted project (s) (according to the year considered). Therefore, this dummy has a value 1 if the firm receives some subsidies in the year considered; otherwise its value is 0.

These variables are then jointly considered for a regression analysis. Because of the numerous values missing from the dataset, the number of observations decreases to 4000. More specifically, the number of treated units drops to 853, while untreated units are 3147 (see Table 7).

## The econometric model

The econometric methodology used to evaluate the input (R&D outlay) and output (patents) additionality of FAR is based on the programme evaluation literature. The main objective of this literature is to estimate the so-called 'average treatment effect' on the beneficiaries of the policy in question. A review of this literature, applied to various R&D policy models, can be found in Cerulli (2010). This section presents the logic of the applied model and its estimation.

As is customary within this literature, a selection-into-programme equation is the first step for the estimation of own R&D expenditure in reduced form within a longitudinal (panel) dataset. It is necessary to consider carefully the role played by firm heterogeneity in the observable variables. For the use of longitudinal data, we

**Table 7.** Characteristics of the sample used in the regression analysis

| | |
|---|---|
| Number of observations | 4000 |
| Number of treated | 853 |
| Number of untreated | 3147 |
| Average size | 366 Size |
| Prevailing sectors (2) | 29 (mechanics), 24 (chemicals and pharmaceuticals) |
| Prevailing regions (2) | Lombardia, Emilia Romagna |
| Prevailing year of treatment | 2002 |

refer to the model proposed by Lach (2000), while for the heterogeneity analysis, we refer to the model presented by Wooldridge (2002, pp.608–14).

The starting point is the modelling of three behavioural equations: one for the public agency (aimed at selecting the firms/projects to be financed on the basis of a specific objective function), one for the supported (or treated) firms, and one for the untreated firms. The public agency's behavioural (or selection) equation takes on the following form, where $w^*$ is the optimal level of subsidy provided by the agency to the firm, with characteristics given by the vector of covariates $\mathbf{x}_1$,[11] while $w$ is the index function (having 0/1 values) regarding the rule according to which the agency decides whether to finance a firm with a certain $\mathbf{x}_1$. The scalar $a$ identifies all the firm/project features that the analyst is unable to observe:

$$\begin{aligned} w^* &= \eta + \mathbf{x}_1\theta + a \\ w &= \begin{cases} 1 & \text{if } w^* \geqslant 0 \\ 0 & \text{if } w^* < 0 \end{cases} \end{aligned} \tag{4}$$

As for firm behaviour, there is an equation for treated units (denoted by the subscript 1) and one for untreated units (denoted by the subscript 0):

$$\begin{aligned} y_0 &= \mu_0 + g_0(\mathbf{x}) + e_0 \\ y_1 &= \mu_1 + g_1(\mathbf{x}) + e_1 \\ E(e_1) &= E(e_0) = 0 \end{aligned} \tag{5}$$

Based on equations in (5), the so-called 'benefit from treatment', $(y_1 - y_0)$, is:

$$y_1 - y_0 = (\mu_1 - \mu_0) + [g_1(\mathbf{x}) - g_0(\mathbf{x})] + (e_1 - e_0) \tag{6}$$

where $y_0$ and $y_1$ is the "own R&D expenditure" (total R&D minus subsidy) for the untreated and treated status respectively, $\mu_0$ and $\mu_1$ are constant terms, $g_0(\cdot)$ and $g_1(\cdot)$ are functions (assumed to be different in the two groups) of the covariates $\mathbf{x} = [\mathbf{x}_1; \mathbf{x}_2]$. Also, $\mathbf{x}_2$[12] refers to firm characteristics affecting R&D behaviour other than those affecting the selection behaviour of the agency, and $e_0$ and $e_1$ are unobservable components affecting R&D and having unconditional zero mean. Two types of parameters are particularly relevant in our estimation: the 'average treatment effect' (ATE) and the 'average treatment effect on treated' (ATET), defined as functions of $\mathbf{x}$ as follows:

$$\text{ATE}(\mathbf{x}) = E(y_1 - y_0 | \mathbf{x})$$

$$\text{ATET}(\mathbf{x}) = E(y_1 - y_0 | \mathbf{x}, w = 1)$$

The problem in estimating these parameters is that each firm can be observed only in one of the two conditions (treated or non-treated), so that a missing observation problem arises in relation to firm behaviour. Additional hypotheses are needed to overcome this limitation. Hence, we introduce the hypothesis of conditional mean independence (CMI), which allows estimating the parameters of interest through standard OLS. According to the CMI hypothesis, we assume that the unobservable variables affecting the selection into programme equation are not correlated to the unobservable variables affecting firm R&D behaviour, once we have conditioned on the observable variables $\mathbf{x}$. Technically, this means that:

$$a \perp (e_0, e_1) | \mathbf{x}$$

which, in terms of conditional mean, becomes:

$$E(e_0|\mathbf{x}, w) = E(e_0|\mathbf{x}) = 0 \quad \text{and} \quad E(e_1|\mathbf{x}, w) = E(e_1|\mathbf{x}) = 0$$

After this hypothesis, the previous parameters become:

$$\text{ATE}(\mathbf{x}) = (\mu_1 - \mu_0) + [g_1(\mathbf{x}) - g_0(\mathbf{x})]$$

$$\text{ATET}(\mathbf{x}) = E(y_1 - y_0|w = 1, \mathbf{x}) = \text{ATE}_{(w=1)}(\mathbf{x})$$

To get the ATE and ATET (unconditional on $\mathbf{x}$), we only need to average over the support of $\mathbf{x}$, obtaining:

$$\text{ATE} = (\mu_1 - \mu_0) + E_{\mathbf{x}}[g_1(\mathbf{x}) - g_0(\mathbf{x})]$$

$$\text{ATET} = E_{\mathbf{x}}[\text{ATE}_{(w=1)}(\mathbf{x})]$$

The final step is to achieve a sample estimate of the parameters, which, of course, has to be done in terms of observable variables. So, we introduce the so-called ‘switching regression’:

$$y = wy_1 + (1 - w)y_0$$

where $y$ is observable. By replacing $y_1$ and $y_0$ with their expressions from (5), we obtain the following relation:

$$y = \mu_0 + g_0(\mathbf{x}) + w(\mu_1 - \mu_0) + w[g_1(\mathbf{x}) - g_0(\mathbf{x})] + u$$

where $u = e_0 + w(e_1 - e_0)$. Moving towards a parametric form of $g_1(\cdot)$ and $g_0(\cdot)$ by setting: $g_1(\mathbf{x}) = \eta_1 + \mathbf{x}\beta_\mathbf{1}$ and $g_0(\mathbf{x}) = \eta_0 + \mathbf{x}\beta_0$, simple manipulations lead to the following reduced form regression equation:

$$E(y|\mathbf{x}, w) = \gamma + \mathbf{x}\beta_\mathbf{0} + w \cdot \alpha + w \cdot [\mathbf{x} - \mu_\mathbf{x}]\delta \tag{7}$$

where it can be proved that $\gamma = \mu_0 + \eta_0$, $\alpha = \text{ATE}$, $\delta = (\beta_1 - \beta_0)$ and $\mu_\mathbf{x} = E(\mathbf{x})$. Equation (5) can be consistently estimated by OLS and, once the OLS parameters are calculated, the various treatment effects can be obtained through simple transformations:

$$\begin{aligned}
&\hat{\text{ATE}} = \hat{\alpha} \\
&\hat{\text{ATE}}(\mathbf{x}_i) = \hat{\alpha} + (\mathbf{x}_i - \bar{\mathbf{x}})\hat{\delta} \\
&\hat{\text{ATET}} = \hat{\alpha} + (1/N^T)\sum_{i=1}^{N} w(\mathbf{x}_i - \bar{\mathbf{x}})\hat{\delta} \\
&\hat{\text{ATE}}(\mathbf{x}_i) = [\hat{\alpha} + (\mathbf{x}_i - \bar{\mathbf{x}})\hat{\delta}]_{w=1}
\end{aligned} \tag{8}$$

The relations in Equations (8) are all estimable since they are functions of observable components. The only difficulty is that of obtaining standard errors for the ATET, a problem which can be overcome through bootstrapping. As for the control group, it is important to stress that it includes firm/year units that:

(i) did not apply for subsidies at all;
(ii) applied for subsidies, but were turned down (i.e. the public agency did not commit itself to providing funds for projects presented during the period in question, 2000–2004). However, since projects generally last more than one year, a firm whose project is accepted becomes treated for that year as well as for the following year(s), depending on the project's time span. After this adjustment is made, the number of treated observations (firm/year) increases and the number of untreated observations drops accordingly.

The firms in the control group are all registered within the *Anagrafe della ricerca*, which shows their willingness or propensity to apply for FAR/Law 488 subsidies. In other words, there is a certain degree of homogeneity between the control group and the treated units. Moreover, within our sample, treated and untreated firms have very similar structural characteristics, except for size and knowledge. Nevertheless, since we use a linear multiple regression, we do not need to generate a similar-to-treated control group, as required, for instance, by matching approaches. In our case, it is sufficient to consider (in particular) the covariates controlling for firm differences, as done for size and knowledge in our application. However, when looking at output additionality (i.e. the effect of subsidies on the number of filed patents), we will use a matching model, since it is more suitable in this context of analysis. In what follows we present our results by estimating the parameters of Equations (8). When looking at the firm subgroups, we will work with the additional hypothesis that $g_1(\mathbf{x}) = g_0(\mathbf{x})$, which makes ATE=ATET, thus greatly simplifying our analysis.

## Results

Based on the model proposed above, this section presents our main results on input additionality, the ability of firms to top up their observed R&D performance with additional R&D expenditure, net of the subsidy component (i.e. what firms would do in the absence of subsidies). On average, additionality occurs when the value of parameter $\alpha$ is positive and statistically significant. Nevertheless, the possibility of estimating ATE($\mathbf{x}$) as well as ATET($\mathbf{x}$) does shed light on the distributional characteristics of the single parameters, ATE and ATET. Indeed, going beyond an aggregate average value seems of great importance for an in-depth understanding of the policy effect under investigation. The results are organised as follows.

(a) Results are provided for the pooled regression to detect, at an aggregate level, if there exists a crowding-out or an additionality effect on the firm's own R&D investment. Here we work under the hypothesis that $g_1(\mathbf{x}) = g_0(\mathbf{x}) = g(\mathbf{x})$, so that parameter $\alpha$ estimates both ATE and ATET.
(b) Allowing for $g_1(\mathbf{x}) \neq g_0(\mathbf{x})$ so that $\alpha$=ATE$\neq$ATET, the results focus on estimating the distribution of ATET($\mathbf{x}$), showing its graphical representation and main

characteristics. This is a firm-specific measure of the causal effect of FAR on firm R&D performance.

(c) The results go beyond the aggregate result by splitting the sample according to different and heterogeneous firm characteristics. In particular, we estimate regression (5) for subsets of firms based on size, Italian macro-regions, type of technology, and the share of the project costs covered by the subsidy. Finally, an analysis of the mix of instruments is also provided to ascertain if different portfolios of subsidies generate differential effects.

(d) Evidence is provided of the differences, in terms of economic and structural characteristics, between the group of firms performing additionality and the group of firms performing crowding-out. This step draws upon the results of the second step and its aim is to identify the main factors leading to policy success and, possibly, their relations with agency selection criteria.

**Table 8.** Average treatment effect on treated (ATET): OLS in the pooled sample

| Dependent variable | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Firm own R&D expenditure | T-TEST (total sample) | T-TEST (total sample + no supply) | T-TEST (no supply + cleaning) | REG-F (fundamental regression) |
| Treatment (t) | 4300.45*** | 3676.47*** | 579.72*** | 801.13*** |
| | (969.69) | (939.71) | (157.70) | (291.91) |
| Knowledge | | | | 514.87 |
| | | | | (518.92) |
| Leverage | | | | 64.28* |
| | | | | (36.22) |
| Cash flow | | | | 113.46 |
| | | | | (216.48) |
| Equity | | | | 15.65 |
| | | | | (78.27) |
| Labour cost | | | | –238.94 |
| | | | | (424.13) |
| Capital intensity | | | | 216.89** |
| | | | | (89.44) |
| Size | | | | 4.18*** |
| | | | | (0.40) |
| Only Art. 14 | | | | –2280.78*** |
| | | | | (502.76) |
| Objective 1 | | | | 2306.74* |
| | | | | (1227.07) |
| Collaboration | | | | 9812.97*** |
| | | | | (2402.34) |
| Subsidy allocation | | | | 3264.48*** |
| | | | | (1136.20) |
| $N$ | 5971 | 5793 | 5690 | 4000 |
| Number of treated | 1159 | 985 | 942 | 853 |
| Adj. $R^2$ | 0.007 | 0.006 | 0.002 | 0.387 |
| $R^2$ | 0.01 | 0.01 | 0.00 | 0.40 |
| F | 19.67 | 15.31 | 13.51 | 14.36 |
| Ll | –67,488.79 | –65,024.62 | –55,505.88 | –40.140.13 |

Notes: Results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Values are thousand of euros.

***Input additionality: overall sample***

Table 8 considers results from the aggregate sample under the $g_1(\mathbf{x}) = g_0(\mathbf{x})$ hypothesis. Column 1 shows the effect of the treatment dummy on own R&D expenditure without covariates (simple *t*-test comparison between the two groups), while columns 2 and 3 introduce some cleaning of the data. The most important regression is in column 4, where a series of covariates is introduced. It shows that FAR has a positive and significant average treatment effect on treated (ATET) in relation to a firm's own R&D expenditure of about 801,000 euros. This means that the additionality (which can be seen as own R&D of treated units minus own R&D of untreated units) is equal to about 40% of the untreated firms' R&D average.[13]

Size is also positive and strongly significant, with an increase of about 4000 euros in own R&D expenditure per additional employee. The presence of collaborative projects (collaboration) has a positive and highly significant effect (about 9.8 million euros), and the same is true for subsidy allocation by the agency (3.3 million euros). Observe the negative significance of the automatic policy instrument (Art. 14; i.e. tax credit),[14] which leads to strong crowding-out (about –2.3 million euros).

Besides leverage (only slightly positive and significant), the other financing variables (cash flow and equity) are not significant in explaining own R&D performance, despite their positive sign. Cost variables are not significant either. It seems that liquidity constraints and the ability to find external sources of financing are not relevant in explaining a firm's additionality capacity. As explained below, this aspect deserves further investigation.

***Estimation and distribution features of ATE(x) and ATET(x)***

Based on the estimation of Equation (7) and on the formulas in (8), it is possible to calculate the firm-specific ATE($\mathbf{x}$) and ATET($\mathbf{x}$), with their distributional characteristics. In this section, we are working under the hypothesis that $g_1(\mathbf{x}) \neq g_0(\mathbf{x})$.

Figure 1 shows the graphical representation of ATE($\mathbf{x}$) and ATET($\mathbf{x}$) for FAR in the overall sample, while the descriptive characteristics of the ATET($\mathbf{x}$) distribution are set out in Table 9.

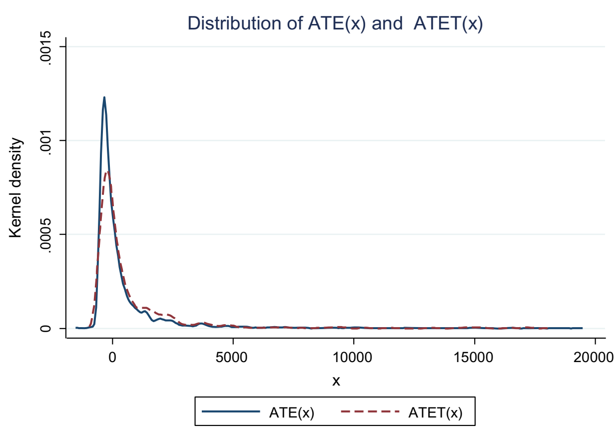


**Figure 1.** Comparison between the distribution of ATE($\mathbf{x}$) and ATET($\mathbf{x}$) in the regression sample

**Table 9.** Distributional features of the ATET(x)

| ATET(**x**) | |
|---|---|
| Observations | 853 |
| Mean | 878.30 |
| Median | ≈0 |
| Standard deviation | 3187 |
| Minimum | –971 |
| Maximum | 41,281 |

Table 9, like Figure 1, emphasises one of the most important results of our research – the median of ATET(**x**) is about zero. This means that half of our sample displays crowding-out, whereas the other half displays additionality. Also, the ATET(**x**) mean is positive (and significant), but only because of the strong right asymmetry of the ATET(**x**) distribution, with positive values significantly higher than negative values in absolute terms. This is a surprising peculiarity of FAR, which can be detected only by looking at the entire distribution of the effect. Observe that the mean of ATET(**x**) in Table 9 is about 878,000 euros, slightly different from the value of 801,000 euros obtained in Table 8. This is because of the $g_1(\mathbf{x}) \neq g_0(\mathbf{x})$ hypothesis of the ATET(**x**) model. Nevertheless, this difference is largely negligible and in the rest of the paper we will work under the assumption that $g_1(\mathbf{x}) = g_0(\mathbf{x})$.

## Results by subsets of firms

So far the discussion has considered results from an aggregate perspective. Nevertheless, firms are strongly heterogeneous and we expect to find differences in the effect of FAR across the various subgroups of firms. In particular, we will focus on firm size, sector of specialisation, geographical location, and degree of financial support.

### *Additionality by size*

Table 10 clearly shows that there is significant positive additionality only for large (and very large) firms (about 1,148,000 euros and 2,273,000 euros, respectively). The effect is neutral (neither crowding-out, nor additionality) in the case of SMEs, while small firms display a non-significant negative sign (–174). As with the pooled sample, size is always positive and significant, but its magnitude decreases when moving from small to very large firms. As expected, knowledge is positive and significant only for large and very large firms, since they rely on patenting more than SMEs. The only Art. 14 (tax credit) dummy is negative and significant for SMEs. The variables collaboration (R&D projects involving collaborations) and Objective 1 (depressed areas) are positive and significant only for large and very large firms. The variable collaboration is not significant for SMEs: the estimator has a wide range of variation. There are differences between small firms (with a positive sign) and medium firms (with a negative sign).[15]

Leverage is (slightly) positive and significant only for medium enterprises (50–100 employees), while cash flow has a negative and significant effect only on large and very large firms. Notice, however, the positive and significant (but only by 10%) coefficient of equity for large firms. Larger firms seem to prefer external

**Table 10.** Average treatment effect on treated (ATET): OLS comparison for small and medium enterprises

| Dependent variable<br>Firm own R&D expenditure | (1)<br>SMALL <50 | (2)<br>MEDIUM >50 & <250 | (3)<br>SME <250 | (4)<br>LARGE >250 | (5)<br>VERY LARGE >500 |
|---|---|---|---|---|---|
| Treatment (*t*) | –174.05 | 70.00 | 101.24 | 1148.59* | 2273.50** |
| | (125.45) | (141.98) | (138.45) | (607.15) | (1045.15) |
| Knowledge | –82.69 | 82.88 | 133.30 | 104,033.24*** | 106,828.48*** |
| | (312.79) | (389.80) | (140.67) | (21,732.52) | (23,138.66) |
| Leverage | –12.34 | 188.76*** | 86.14* | 31.06 | –6.87 |
| | (19.42) | (68.80) | (46.67) | (55.83) | (264.94) |
| Cash flow | 70.47 | 951.69* | 273.59 | –3789.42** | –6605.69** |
| | (147.42) | (509.76) | (169.77) | (1787.77) | (2651.60) |
| Equity | 60.37 | 674.67 | 22.36 | 1272.50* | –232.36 |
| | (54.17) | (417.19) | (71.66) | (736.39) | (1046.37) |
| Labour cost | 99.99 | –1525.81*** | 76.49 | –3514.24** | –1859.12 |
| | (282.11) | (554.20) | (323.95) | (1762.88) | (3795.70) |
| Capital intensity | –37.72 | 8.25 | 189.83* | –1505.64*** | –449.14 |
| | (173.42) | (324.09) | (112.73) | (578.11) | (732.24) |
| Size | 11.93*** | 6.86*** | 8.52*** | 3.62*** | 3.30*** |
| | (4.54) | (1.00) | (1.04) | (0.46) | (0.52) |
| Only Art. 14 | 100.05 | –428.07** | –335.82** | dropped | dropped |
| | (148.00) | (170.55) | (147.04) | | |
| Objective 1 | –332.19 | 488.37 | –12.32 | 6807.71** | 9201.00*** |
| | (444.45) | (356.40) | (309.22) | (2977.24) | (3557.85) |
| Collaboration | 339.22 | –837.71 | 599.82 | 10,381.63*** | 14,295.03*** |
| | (305.05) | (1171.66) | (524.52) | (3548.07) | (5029.32) |
| Subsidy allocation | 18.00 | 746.07** | 405.05* | 5397.01 | 2956.78 |
| | (144.39) | (305.26) | (209.93) | (4670.41) | (5287.58) |
| *N* | 1053 | 1814 | 2867 | 1133 | 644 |
| Adj. $R^2$ | 0.108 | 0.525 | 0.285 | 0.491 | 0.468 |
| $R^2$ | 0.16 | 0.54 | 0.30 | 0.52 | 0.52 |
| F | n.a. | n.a. | n.a. | 14.71 | n.a. |
| Ll | –9183.03 | –16,365.72 | –26,057.26 | –11,824.64 | –6847.02 |

Notes: Results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Thousands of euros.

rather than internal resources to finance their R&D projects, while SMEs seem to prefer internal resources (indeed, for medium-size enterprises the cash flow variable is positive and quite significant).

### *Additionality by manufacturing specialisation sector*

Quite surprisingly, Table 11 shows a positive and significant effect of FAR on low technology manufacturing firms (about 868,000 euros), although high and medium technology firms display positive values too (the value for high technology firms is twice that for medium technology firms). These low technology firms are quite large (around 320 employees), even though they are a minority when compared with the number of other types of firms observed (only 366 low technology firms). Furthermore, the level of additionality of these low technology firms is very close

**Table 11.** Average treatment effect on treated (ATET): OLS comparison for high, medium and low technology enterprises

| Dependent variable<br>Firm own R&D expenditure | (1)<br>High | (2)<br>Medium | (3)<br>Low |
|---|---|---|---|
| Treatment ($t$) | 427.17 | 266.83 | 868.32** |
| | (633.75) | (213.05) | (339.66) |
| Knowledge | 93,200.62*** | 3047.91 | 497.16 |
| | (6960.00) | (2462.45) | (3052.91) |
| Leverage | –86.77 | 49.24 | –4.83 |
| | (208.78) | (42.53) | (168.15) |
| Cash flow | –1013.09 | –346.52* | 485.82 |
| | (674.02) | (201.96) | (1565.20) |
| Equity | 64.46 | 246.91** | –95.59 |
| | (177.91) | (113.78) | (308.90) |
| Labour cost | –2585.50 | –1115.43** | 1083.88 |
| | (2106.77) | (512.14) | (1437.85) |
| Capital intensity | –237.49 | –312.83 | 689.61 |
| | (946.69) | (533.86) | (638.47) |
| Size | 5.75*** | 4.42*** | 3.97*** |
| | (0.30) | (0.11) | (0.17) |
| Only Art. 14 | –3306.47** | –460.68 | –431.40 |
| | (1517.44) | (455.27) | (765.38) |
| Objective 1 | 8085.20*** | 1462.07* | –4184.89*** |
| | (1928.48) | (801.53) | (1526.92) |
| Collaboration | 14,299.08*** | –13.56 | 2346.56 |
| | (1980.74) | (2031.81) | (2278.93) |
| Subsidy allocation | 3809.93** | –101.33 | 837.95 |
| | (1573.95) | (701.80) | (1902.57) |
| Mean emp. | 403 | 326 | 317 |
| $N$ | 1001 | 1861 | 366 |
| N. of treated | 238 | 387 | 81 |
| Adj. $R^2$ | 0.512 | 0.528 | 0.636 |
| $R^2$ | 0.53 | 0.54 | 0.67 |
| $F$ | 31.00 | 52.92 | 18.23 |
| Ll | –10,301.03 | –17,666.94 | –3317.55 |

Note: Results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Thousands of euros.

to that of the full sample. As expected, the knowledge variable is highly positive and significant for high technology manufacturing firms, and only positive (but not significant) for medium and low technology firms. Size is an important factor in explaining own R&D performance for all types of firms, while tax credit (only Art. 14) produces significant crowding-out only in high technology firms.

### *Additionality by Italian macro-regions*

Table 12 shows that the effect (the ATET) is positive and significant in the North and Centre of Italy, amounting to around 735,000 and 1,600,000 euros, respectively. As for the South, the ATET is not significant and also negative. Nevertheless, it should be underlined that the number of observations is not equally distributed: the available observations for the north are about 3000 while they are just 242 for the South. Another element worth noting is the joint significance of size, collaboration,

**Table 12.** Average treatment effect on treated (ATET): OLS comparison by Italian macro-regions

| Dependent variable<br>Firm own R&D expenditure | (1)<br>North | (2)<br>Centre | (3)<br>South |
|---|---|---|---|
| Treatment (*t*) | 735.90** | 1588.83*** | –1105.99 |
| | (293.30) | (550.86) | (1630.86) |
| Knowledge | 561.96 | 1521.80 | –3109.81 |
| | (463.27) | (1993.52) | (3042.30) |
| Leverage | 94.38 | –20.38 | 20.40 |
| | (59.81) | (61.65) | (51.49) |
| Cash flow | 9.34 | –39.81 | 653.43 |
| | (264.94) | (628.28) | (409.01) |
| Equity | 86.24 | –141.17 | –52.11 |
| | (100.58) | (177.01) | (333.10) |
| Labour cost | –544.31 | 77.09 | 799.79 |
| | (533.16) | (1381.02) | (519.54) |
| Capital intensity | 162.61 | 140.86 | –2371.62** |
| | (116.32) | (898.72) | (1170.16) |
| Size | 4.04*** | 4.62*** | 7.75*** |
| | (0.12) | (0.28) | (0.50) |
| Only Art. 14 | –1657.76** | –3065.68*** | –12,762.22*** |
| | (681.94) | (963.92) | (3036.42) |
| Objective 1 | 5430.52*** | –3866.05*** | 859.32 |
| | (1000.40) | (1431.11) | (1572.21) |
| Collaboration | 9878.90*** | 12,034.62*** | 4037.87* |
| | (1085.33) | (1968.37) | (2262.10) |
| Subsidy allocation | 2362.08** | 3152.82*** | 20,188.93*** |
| | (919.52) | (1055.99) | (2759.20) |
| $N$ | 3004 | 754 | 242 |
| N. of treated | 605 | 189 | 59 |
| adj. $R^2$ | 0.374 | 0.446 | 0.680 |
| $R^2$ | 0.39 | 0.48 | 0.74 |
| $F$ | 32.51 | 13.13 | 12.15 |
| ll | –30,191.76 | –7461.40 | –2351.45 |

Notes: Results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p$<0.1, ** $p$<0.05, *** $p$<0.01. Thousands of euros.

**Table 13.** Average treatment effect on treated (ATET): OLS comparison according to three percentile classes of financing intensity (as subsidy share on the total project cost)

| Dependent variable: Firm own R&D expenditure | Low intensity | Medium intensity | High intensity |
|---|---|---|---|
| $w_1$ | 503.74* | | |
| | (305.20) | | |
| $w_2$ | | 506.38 | |
| | | (484.65) | |
| $w_3$ | | | 1890.66*** |
| | | | (624.64) |
| Knowledge | 474.27 | 625.58 | 432.04 |
| | (414.65) | (541.50) | (405.20) |
| Leverage | 75.78** | 65.63* | 43.60 |
| | (38.52) | (38.08) | (33.67) |
| Cash flow | 165.11 | 193.78 | 308.05 |
| | (197.25) | (238.34) | (236.88) |
| Equity | 46.94 | 51.99 | 34.57 |
| | (77.48) | (81.76) | (77.78) |
| Labour cost | –70.19 | –97.87 | 192.93 |
| | (390.90) | (458.40) | (435.65) |
| Capital intensity | 132.94 | 150.56 | 153.19 |
| | (93.70) | (95.78) | (93.91) |
| Size | 3.50*** | 3.63*** | 3.88*** |
| | (0.37) | (0.37) | (0.40) |
| Only Art. 14 | dropped | dropped | dropped |
| Objective 1 | 312.71 | 2985.69 | 1064.51 |
| | (1542.82) | (1897.94) | (1579.60) |
| Collaboration | 7968.01*** | 12,268.31** | 5523.92* |
| | (2584.57) | (5168.28) | (3290.55) |
| Subsidy allocation | 4012.15 | 6819.81* | 11,055.01** |
| | (3007.59) | (3656.54) | (4604.12) |
| $N$ | 3358 | 3387 | 3376 |
| Adj. $R^2$ | 0.323 | 0.336 | 0.371 |
| $R^2$ | 0.34 | 0.35 | 0.38 |
| $F$ | n.a. | 11.12 | 11.58 |
| Ll | –33,294.92 | –33,747.71 | –33,791.20 |

Note: $w_1$, $w_2$ and $w_3$ are treatment dummy variables for low, medium and high financed firms respectively; results on sectoral, regional and time dummies omitted; standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Thousands of euros.

Objective 1 and subsidy allocation for all three regressions. Finally, only Art. 14 remains negative and significant, as in the pooled regression.

### *Additionality by intensity of financing*

Table 13 displays a regression comparison according to three percentile classes of financing intensity (defined as the share of total project costs financed through the subsidy): $w_1$, $w_2$ and $w_3$ are treatment dummy variables for firms with low, medium and high intensity of financing, respectively. We can observe that, as the level of financing increases, the level of the effect also increases: from about 500,000 euros of additionality in the first and second class to 1,890,000 euros in the third. Furthermore, the effect is truly significant only for the third percentile class. These results confirm that the subsidy starts to have a positive effect only above a certain financing intensity threshold, which in our case corresponds to about 50% of the total cost.

## Impact by instrument and mix of instruments

In order to analyse the effect of single instruments as well as of mixes of instruments, we must first define a dummy for each instrument:

*D1*=bottom-up Law 297 (Art. 5 and 6); 1410 cases in total, of which 1204 are D1 alone.

*D2*=top-down measures (Art. 11 and 12); 140 cases in total, of which 79 are D2 alone.

*D3*=bottom-up Law 488; 413 cases in total, of which 312 are D3 alone.

*D4*=other instruments.

According to their definition, for each instrument these dummies compare two groups of firms: a group in which the instrument is used by a firm with or without other instruments, and another group in which the measure in question is not present (i.e. only other instruments are used or the firm receives no subsidy).[16] In this way, we can calculate additionality by single instrument and compare the effects of different measures. Moreover, we can test the additionality effect of different mixes of instruments (for instance: $D1 \times D2$). Table 14 shows the effects for single policy instruments as well as for some of their combinations. It clearly emerges that bottom-up projects (*D1* for Law 297 and *D3* for Law 488) generate significant additionality in line with the average value (pooled regression of Table 8). On the contrary, top-down projects display a negative and significant effect. However, the latter result is based on only 35 observations.[17]

When bottom-up projects are combined, their strength increases considerably (see the coefficient of *D1D3*). The other results do not really warrant further comments, since the number of observations is too low for reliable conclusions to be drawn. In order to analyse further mixes of instruments, we also perform single regressions (results not reported in the Table) using a new dummy for each instrument, which is built in the following way: we compare two groups of firms, those using a single instrument (without any other measure), and those using the same instrument combined with other measures. The results are elaborated only for bottom-up instruments (Law 297 and Law 488) because of the limited number of observations. It emerges that the difference is positive in the case of combined instruments for both measures, but statistically significant only for Law 488. In particular, we obtain a coefficient of 2,643,000 euros with a *p*-value of 0.155 for bottom-up measures regarding Law 297 (552 observations), and a coefficient of 7,447,000 euros with a *p*-value of 0.039 for bottom-up measures regarding Law 488 (167 observations).

## Structural differences between the crowding-out and the additionality group

This section identifies the distinguishing characteristics of the group of firms performing crowding-out contrasted with those performing additionality. This distinction seems important, analytically, because it allows going beyond the aggregate

**Table 14.** Analysis of single and mix of instruments

| Dependent variable:Firm own R&D expenditure | |
|---|---|
| D1 (541) | 936.00*** |
| | (266.07) |
| D2 (35) | –4618.00*** |
| | (1305.78) |
| D3 (157) | 837.81* |
| | (501.25) |
| D4 (51) | –1977.01 |
| | (3081.32) |
| D1D2 (7) | –2615.21 |
| | (2460.99) |
| D1D3 (14) | 75,081.04*** |
| | (3782.48) |
| D1D4 (34) | –216.04 |
| | (3204.71) |
| D2D3 (5) | –12,638.57** |
| | (5106.31) |
| D2D4 (3) | 6031.46 |
| | (4510.81) |
| Objective 1 | 1621.28** |
| | (721.76) |
| Only Art. 14 | –1170.69** |
| | (500.74) |
| Size | 3.38*** |
| | (0.10) |
| Collaboration | 6494.31*** |
| | (841.27) |
| Subsidy allocation | 2039.00*** |
| | (676.88) |
| $N$ | 3985 |
| Adj. $R^2$ | 0.441 |
| $R^2$ | 0.45 |
| $F$ | 41.30 |
| Ll | –39,700.96 |

Note: D1=bottom-up research projects (Law 927), D2=top-down research projects, D3=bottom-up research projects (Law 488), D4=other. Standard errors in parentheses; * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Thousands of euros.

result of the ATET, and normatively, since it can provide key information to policy makers. As seen above, half of the supported units display additionality, whereas the other half display crowding-out. This means that we can determine a clear-cut threshold, the median of the ATET distribution, which gives rather clear indications on the composite effect of the policy at stake.

Operatively, we create two groups, the crowding-out and the additionality group, according to the (zero) median of ATET(**x**), and we try to characterise them by comparing a wide set of variable characteristics in order to shed more light on the essential (structural) differences between these two groups. Our aim is to identify the factors associated with the creation of additionality through the effective use of the support that a firm has received. The literature suggests considering three groups of variables: industrial organisation, corporate financing, and innovative capacity. The results are reported in Tables 15 and 16. By looking at the mean – and, more appropriately, at the median of the distribution of these variables (since many

**Table 15.** Structural characteristics of the crowding-out group

| | N | Mean | Median | Min | Max | CV | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| Average treatment effect on treated | 426 | –294 | –300 | –971 | –6.6 | –0.55 | –0.31 | 3.1 |
| Number of employees | 426 | 74 | 65 | 0 | 289 | 0.65 | 0.8 | 4.1 |
| Turnover | 426 | 43,206 | 13 | 0.11 | 1.60E+07 | 18 | 21 | 424 |
| Turnover per capita | 424 | 69 | 0.18 | 0.0063 | 1970 | 2.8 | 4.7 | 34 |
| R&D in-house expenditure | 426 | 1082 | 378 | 0 | 35,045 | 2.8 | 7.5 | 70 |
| R&D per employee | 424 | 21 | 6.5 | 0 | 1577 | 3.9 | 16 | 288 |
| Number of patents | 179 | 1.3 | 1 | 0 | 15 | 1.7 | 3.4 | 17 |
| Patents (capitalised expenditure at book value) | 426 | 0.011 | 0.00072 | 0 | 0.62 | 4.2 | 9 | 103 |
| Cash flow 1 | 426 | –0.0041 | 0.0055 | –1.1 | 0.55 | –30 | –4.4 | 34 |
| Cash flow 2 | 426 | –0.057 | 0.0053 | –5.5 | 2.9 | –8.9 | –6.3 | 61 |
| Leverage 1 | 426 | 0.63 | 0.67 | 0.013 | 1.9 | 0.32 | –0.0034 | 5.9 |
| Leverage 2 | 426 | 1.1 | 0.65 | 0.0051 | 57 | 2.9 | 13 | 200 |
| Equity 1 | 426 | 0.24 | 0.086 | 0.00075 | 6.7 | 2.6 | 6.2 | 48 |
| Equity 2 | 426 | 0.11 | 0.082 | 0.00084 | 0.82 | 0.99 | 2.4 | 12 |
| Labour costs | 426 | 0.33 | 0.23 | 0 | 6.7 | 1.7 | 8.8 | 95 |
| Capital intensity | 426 | 0.068 | 0.033 | 0 | 0.55 | 1.4 | 2.3 | 9 |
| (Current assets–current liabilities) / total assets | 424 | –0.34 | –0.36 | –1.5 | 0.64 | –0.9 | 0.67 | 4 |
| Retained earnings/total assets | 426 | –0.0041 | 0.0055 | –1.1 | 0.55 | –30 | –4.4 | 34 |
| ROI (return on investment) | 426 | 0.034 | 0.04 | –1 | 0.33 | 3.5 | –4 | 33 |
| Book value of equity/total liabilities | 426 | 0.79 | 0.31 | –0.52 | 73 | 4.7 | 18 | 343 |
| Turnover/total assets | 426 | 0.98 | 0.95 | 0.012 | 3 | 0.46 | 0.76 | 4.8 |
| Altman *z*-score (risk indicator) | 424 | 2.7 | 2.8 | 0 | 4 | 0.15 | –1.4 | 13 |
| Return to R&D | 380 | 15 | 0.027 | 0.0001 | 944 | 4.7 | 8.2 | 89 |
| Subsidy share on total project costs | 273 | 0.47 | 0.46 | 0.0046 | 1 | 0.32 | 0.045 | 4.4 |
| OPM (opeartive profit margin) | 426 | –0.0036 | 0.043 | –3.2 | 1.1 | –92 | –6.6 | 56 |
| Investment rate 1 (equipment) | 355 | 250 | –0.17 | –1 | 18,508 | 4.4 | 7 | 67 |
| Investment rate 2 (equipment) | 382 | –32 | –0.002 | –1238 | 0.31 | –3.3 | –6.6 | 61 |
| Investment rate 3 (material assets) | 387 | 410 | –0.065 | –1 | 40,096 | 6.3 | 12 | 171 |
| Investment rate 4 (material assets) | 377 | 365 | –0.065 | –1 | 45,530 | 6.7 | 15 | 254 |

**Table 16.** Structural characteristics of the additionality group

| | N | Mean | Median | Min | Max | CV | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| Average treatment effect on treated | 427 | 2048 | 779 | –4.8 | 41,281 | 2 | 5.3 | 40 |
| Number of employees | 427 | 791 | 403 | 6.1 | 12,270 | 1.6 | 4.8 | 34 |
| Turnover | 427 | 70,985 | 141 | 0.13 | 8,108,655 | 6 | 16 | 306 |
| Turnover per capita | 427 | 81 | 0.23 | 0.0027 | 823 | 1.9 | 2.1 | 7.3 |
| R&D in-house expenditure | 427 | 7678 | 1775 | 0 | 100,587 | 1.9 | 3.6 | 18 |
| R&D per employee | 427 | 12 | 5.2 | 0 | 186 | 1.9 | 4.4 | 26 |
| Number of patents | 257 | 6.4 | 3 | 0 | 74 | 1.5 | 3 | 16 |
| Patents (capitalised expenditure at book value) | 427 | 0.0067 | 0.00099 | 0 | 0.4 | 3.5 | 13 | 209 |
| Cash flow 1 | 427 | 0.0063 | 0.0076 | –0.74 | 0.42 | 14 | –2.6 | 25 |
| Cash flow 2 | 427 | –0.044 | 0.0086 | –25 | 0.89 | –28 | –20 | 417 |
| Leverage 1 | 427 | 0.59 | 0.61 | 0.081 | 1.4 | 0.32 | –0.28 | 3.3 |
| Leverage 2 | 427 | 1 | 0.66 | 0.16 | 23 | 2 | 8.5 | 81 |
| Equity 1 | 427 | 0.35 | 0.11 | 0 | 66 | 9.2 | 20 | 416 |
| Equity 2 | 427 | 0.13 | 0.088 | 0 | 0.81 | 0.93 | 2.2 | 9.1 |
| Labour costs | 427 | 0.28 | 0.21 | 0.048 | 16 | 2.7 | 19 | 393 |
| Capital intensity | 427 | 0.33 | 0.085 | 0 | 65 | 9.6 | 20 | 417 |
| (Current assets–current liabilities) / total assets | 424 | –0.35 | –0.36 | –1.4 | 0.69 | –0.68 | 0.59 | 5 |
| Retained earnings/total assets | 427 | 0.0063 | 0.0076 | –0.74 | 0.42 | 14 | –2.6 | 25 |
| ROI (return on investment) | 427 | 0.037 | 0.032 | –0.52 | 0.5 | 2.2 | –0.38 | 14 |
| Book value of equity/total liabilities | 427 | 0.71 | 0.42 | –0.35 | 7.4 | 1.3 | 3.4 | 18 |
| Turnover/total assets | 427 | 0.89 | 0.87 | 0.0083 | 2 | 0.41 | 0.26 | 3.4 |
| Altman *z*-score (risk indicator) | 424 | 2.8 | 2.8 | 1.6 | 3.9 | 0.11 | –0.9 | 5.3 |
| Return to R&D | 401 | 33 | 0.063 | 0.00002 | 2775 | 5.4 | 11 | 155 |
| Subsidy share on total project costs | 407 | 0.47 | 0.46 | 0.1 | 0.8 | 0.29 | 0.17 | 2.7 |
| OPM (operative profit margin) | 427 | –0.022 | 0.041 | –25 | 0.46 | –54 | –20 | 408 |
| Investment rate 1 (equipment) | 366 | 1550 | –0.073 | –1 | 483,117 | 16 | 19 | 363 |
| Investment rate 2 (equipment) | 372 | –73 | –0.0032 | –2144 | 0.92 | –3.1 | –5.3 | 35 |
| Investment rate 3 (material assets) | 373 | 359 | –0.029 | –1 | 4.60E+04 | 7.3 | 15 | 261 |
| Investment rate 4 (material assets) | 371 | 1668 | –0.046 | –1 | 496,572 | 15 | 19 | 364 |

variables are strongly asymmetric with a long right tail) – we can observe some important aspects. The size variable (number of employees) is a clear demarcation factor; the group of firms performing additionality is, on average, more than 10 times larger than the group of firms displaying crowding-out. As for the median, since we deal with very long right tails, this value remains rather high (about six times larger).

In terms of Turnover, both the mean and median of the additionality group are considerably higher than those of the crowding-out group. This is in line with our results on size, since the additionality group displays median turnover about 10 times higher than that of the crowding-out group. What is surprising is that the two groups yield very similar results in terms of R&D per employee (i.e. in terms of firm input capacity or R&D competence in an innovation function). The median performance of the crowding-out group is 6,500 euros of R&D per employee, while that of the additionality group is 5,200 euros. Hence, R&D intensity capacity does not seem to be a key factor in explaining additional R&D expenditure, once the proper support has been received.

To sum up, by analysing all the corporate financing variables (cash flow, leverage, equity, etc.), we can observe general similarities between the two groups, so that no differential financial constraints are associated with different additionality performance. Note that the only small difference is a slightly higher level of cash flow availability in the additionality group. Operating profit margin (OPM, a proxy of a firm's relative market power) does not seem to play an important role either. At least at this stage, it is not possible to support the idea that the additionality group includes firms with greater market power than the crowding-out group.

The share of R&D project costs covered by FAR is the same in the two groups, showing that this element also does not contribute to explaining potentially differential advantages of one group over the other. In terms of sector, the two groups do not display appreciable differences. In the crowding-out group, the machinery industry (22%) and chemicals/pharmaceuticals (12%) are the two main sectors in terms of number of observations. The same is true for the additionality group, in which the machinery industry is the largest sector (18%), followed by chemicals/pharmaceuticals (15%). The region does not indicate any relevant differences. Lombardia, Emilia Romagna, Veneto, and Piemonte are the regions with the highest number of observed firms, and they appear in the same order in both samples. Finally, as for the delay between project application and final positive acceptance, no differences are detected: both samples display an average of about 22 months, and the distribution of these variables is very similar in the two groups.

Besides firm size, the most important difference refers to the propensity to patent. The average number of patent applications of the additionality group is about six times that of the crowding-out group (and three times in terms of median). The median investment rate of the additionality group is not significantly different from that of the crowding-out group and is, in both cases, negative. Overall, we can state that financial constraints do not seem to characterise varying degrees of propensity to perform additionality. Indeed, while financial variables affect how a public agency selects firms, they do not result in propensity differences within the group of treated units (performing either additionality or crowding-out).

Firm size is an essential differentiation factor. Larger firms tend to demonstrate additionality more commonly than smaller firms, an aspect which deserves further investigation. A key point is that, while the two groups have similar R&D intensity, their performance in terms of patenting activity displays large variations. These variations seem to be ascribable to the additionality group's greater ability to turn inventive inputs (mainly R&D intensity) into innovative outputs (in our case, the number of patent applications). This identifies a different innovation production function in the two groups, which clearly relies on two essential elements: scale economies (essentially linked to firm size) and strategies (firm choices and objectives). As to the first element, some well-known works (such as Schumpeter's Mark II paradigm of the innovation process) point out the benefits (increasing return to scale) deriving from larger firm size: wider and better internal division of labour (benefits from specialisation), greater capacity of internalising/exploiting network and knowledge spillovers (linked to R&D), greater ability to reach and contact new markets, greater market and non-market (political) power, and so on.

As to the second element (strategies), the additionality group displays greater propensity to protect innovations (and thus profits) by patents, and a significant lower negative growth of investments (−7% against −17%, according to the "investment rate 1" in Tables 15 and 16) in a period characterized by cycle downturn in Italy. This seems rather puzzling, as the latter set of firms start from a much lower size. Probably, this might be ascribed to the specific features of the Italian system of innovation, where SMEs (the great majority of firms) are historically more concerned with short-term returns (profits) than with long-term objectives, such as firm growth. Many studies have implied that Italian SMEs are reluctant to enlarge the scale of their production (through, for example, active financing on the stock market), thus remaining essentially under-capitalised. This is in large part because most firms in Italy are family owned and their owners fear that such strategies might lead them to lose power and strategic control. In conclusion, a different innovation function (linked to different average size) and the scope of the strategies pursued seem to affect the occurrence of crowding-out rather than additionality more than a firm's industrial structure (market power), corporate financing components (leverage, equity, cash flow), or knowledge input capacity (R&D intensity).

**Table 17.** Output additionality (pooled and by technology): only treated units

| Dependent variable: number of filed patents | Pooled | High | Medium | Low |
|---|---|---|---|---|
| Own R&D (NN) | 0.0221 | 0.0199 | 0.0314 | 0.2733** |
| | (0.0181) | (0.0209) | (0.0682) | (0.1228) |
| Subsidy | 0.0871 | –0.0477 | 1.7072*** | –0.0444 |
| | (0.0637) | (0.1019) | (0.3026) | (0.1522) |
| Additionality | 0.0354*** | 0.0261** | 0.0794*** | 0.3135*** |
| | (0.0090) | (0.0104) | (0.0156) | (0.1147) |
| Size | 0.0000 | 0.0006* | –0.0007*** | 0.0053*** |
| | (0.0001) | (0.0003) | (0.0001) | (0.0019) |
| N. of treated | 344 | 114 | 165 | 31 |
| Pseudo $R^2$ | 0.40 | 0.37 | 0.49 | 0.55 |
| ll | –922.4168 | –376.0032 | –331.9480 | –29.7126 |

Notes: Standard errors in parentheses; * $p$<0.1, ** $p$<0.05, *** $p$<0.01.


**Figure 2.** The link between R&D policy, technological and economic outcomes

### Analysis of output additionality: the effect of firm additionality on patents

The above analysis focused on input additionality, on measuring the effect of FAR on the target variable, the own R&D expenditure of firms. If the main objective of FAR is to increase the R&D performance of Italian firms, then own R&D is the most relevant variable. Nevertheless, many authors suggest that an increase in R&D expenditure should be seen only as an intermediate step. Indeed, when implementing its technological policies, a public agency should be concerned with enhancing firm innovativeness, for which an increase in R&D is an essential precondition. R&D activity is certainly the main element (the input) of the innovation production function, but an increase in R&D is not automatically translated into an increase in innovative performance. The same can be said for the link between innovation performance and economic profitability. Figure 2 shows how this chain-effect works: the FAR policy is the upstream point of the link between R&D and economic performance, which is the downstream point. In each of the three steps, different elements contribute to either strengthening or weakening the links.

Here we are concerned with the second link of Figure 2, the effect of FAR on firm innovativeness, measured in terms of number of filed patents, via the effect of FAR on R&D performance. This concept deserves further explanation; it seems incorrect to study the direct effect of an R&D policy on technological output (patents, for example), without first analysing its effect on R&D. More precisely, adopting a two-step approach (from policy to R&D, from R&D to innovation) seems to be a more reliable procedure than the adoption of a one-step method (from policy to innovation). Many authors have chosen the latter, but we prefer the two-step method, since what we need to determine, in order to evaluate the effectiveness of an innovation policy, is its ability to foster innovation via its ability to foster R&D additionality. At this stage, however, we do not assess the third and final step (from innovativeness to economic performance).

Operatively, this approach needs to be translated into a model able to identify the link between FAR and R&D additionality, as well as that between R&D additionality and innovativeness. We apply the following procedure, based on the matching approach.

- *Step 1*. By nearest neighbour matching (NNM), we obtain the own R&D expenditure of firm *i*'s non-supported nearest neighbour. Accordingly, this value is interpreted as the level of R&D the firm would have performed without any public intervention.
- *Step 2*. We split the total R&D expenditure of firm *i* into its three components: (i) the NN-own R&D of step 1; (ii) the level of subsidy received by firm *i*; and (iii) the level of the idiosyncratic additionality performed by firm *i*.

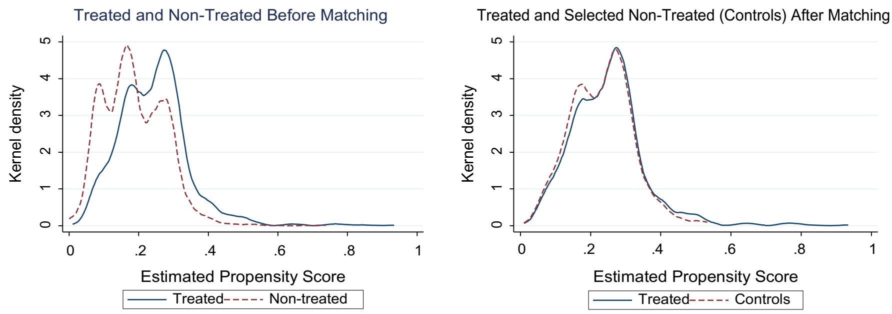


**Figure 3.** Distribution of treated and non-treated units according to the covariates of Table 6

- *Step 3*. We calculate a Poisson regression of the number of patents on those three components plus covariates, only for the sample of supported firms. If the additionality component generates positive and significant results, we can conclude that FAR does have an effect on innovativeness.

Based on Step 1, we implement the NNM, whose results on the goodness of the performed matching can be seen in Figure 3. We can observe that the propensity scores of the supported and non-supported firms after the NNM have a very similar distribution, while in the pre-matching situation they appeared very dissimilar. This confirms the reliability of our matching approach.

After Step 1 and according to Step 2, we can then calculate the own R&D expenditure of firm $i$'s non-supported nearest neighbour, which we indicate as $NN(i)R_j^C$, as well as the level of additionality for firm $i$, $\alpha_i$, obtained as the difference between firm $i$'s own R&D and $NN(i)R_j^C$. We finally indicate with $S_i$ the level of subsidy obtained by firm $i$. Finally, we implement Step 3 by splitting (only for the supported firms, of course) the total R&D expenditure ($R_i$) into its three potential components $(NN(i)R_j^C, S_i, \alpha_i)$, applying a standard Poisson regression of the type:

$$PAT_i = f(NN(i)R_j^C, S_i, \alpha_i, \mathbf{x}_i)$$

where $PAT_i$ is the number of patents filed by firm $i$ and $\mathbf{x}_i$ a set of covariates.[18] We are particularly interested in the effect of $\alpha_i$.

Table 17 shows the results of this Poisson regression. The estimations of the parameters are semi-elasticities. As we can clearly see, the variable additionality ($\alpha_i$) is significant and positive with a value of 0.035, which means that, on average, if additionality increases by 1 million euros (our scale), then the patenting activity increases by 3.5%. This value increases to about 8% and 30% for medium and low technology firms, respectively. Privately-financed R&D is significant and positive only for low technology firms (semi-elasticity: 0.27), while the level of subsidy is significant only for medium technology firms (with a level of 1.7).

These results further support our conclusions on input additionality (own R&D investment). FAR seems to be effective in supporting the ability to activate firm innovativeness. This conclusion was reached by our two-step procedure, even though the limited number of observations makes it impossible to analyse further this aggregate result (which we were able to do for input additionality). A peculiar aspect is worth underlining: both in terms of increased R&D expenditure and in terms of increased number of filed patents, FAR seems to be particularly effective in low technology firms. These are, however, rather large low technology firms belonging to traditional sectors, and they are possibly trying to implement a technological shift from old fashioned to more sophisticated products and processes. They can probably be considered the 'high technology of the low technology' firms working on the technological frontier of their sectors. In any case, the idea that FAR is able to increase the technological underpinnings of these firms is further proof of its success in promoting innovation in those sectors where new technologies are generally less widespread.

## Some results on the economic performance of firms

We consider the following three indicators: labour productivity (simply measured as the ratio of turnover to number of employees), profitability (as operating profit margin), and growth (as turnover growth rate). We calculate these indicators for the crowding-out as well as for the additionality group during the period under investi-

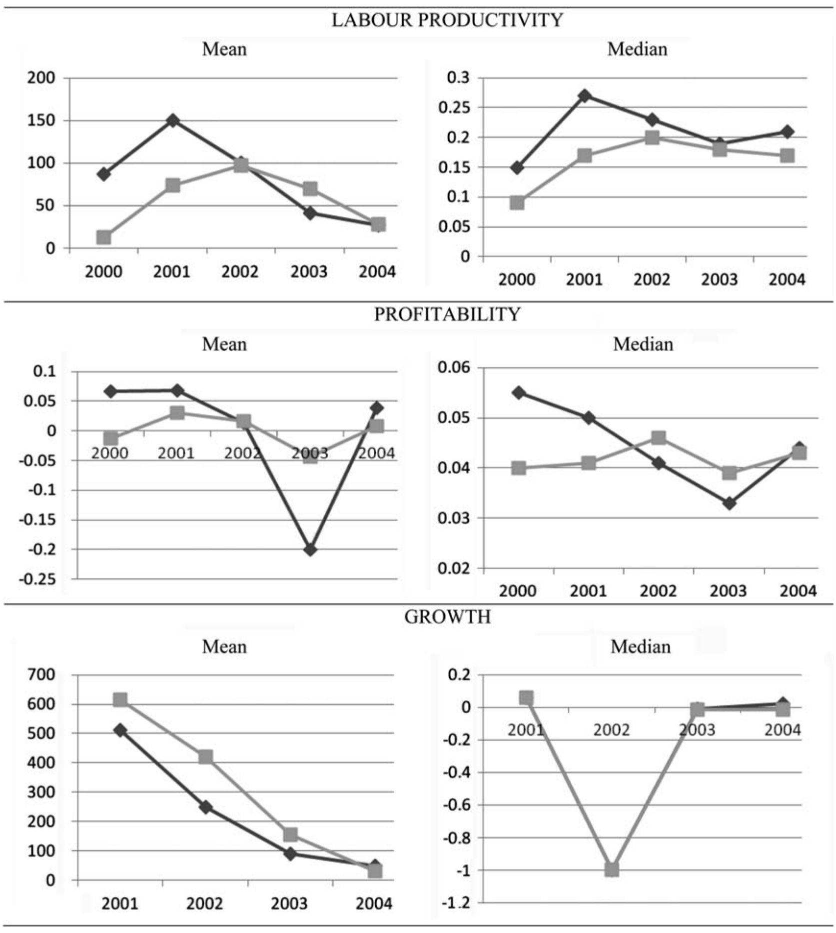


**Figure 4.** Temporal pattern of firm economic performance (productivity, profitability, and growth) in the additionality and crowding-out group. The black line is for the additionality and the grey line is for the crowding-out group

gation (2000–2004). This is not a post-treatment analysis, as we do not have information on accounting variables after 2004, but we believe it to be useful in describing the temporal pattern of the effect of FAR.

Figure 4 sets out the results. It is easy to observe that productivity and profitability display a very similar pattern. The performance of the additionality group is higher in the first two years (2000 and 2001), but decreases in 2003, and again displays an outcome broadly similar to that of the crowding-out group. Overall, these figures show that there is no uniform dominance of the additionality group. Indeed, it emerges that the group's initial advantage (year 2000) decreases during the considered period until no difference is detectable between the two groups.

How can this puzzling pattern be explained? Along with this econometric analysis, the FIRB project also includes a survey of 3,400 firms that received public R&D and innovation support at least once in 1998–2007. The results of this survey – carried out by Confidustria (the Italian association of entrepreneurs) – can shed some light. In particular, we can see that 93% of firms cover their R&D costs through self-financing, more than 60% use public funds, and only 25% resort to self-financing alone. Yet, problems related to delays in the provision of funding and uncertainties regarding the actual availability of public money lead to (further) financial constraints. Most firms actually end up using self-financing to cover the costs of accepted projects for which they have not yet received public funds, and more than 70% of them claim that delays in allocation cause major liquidity problems. This phenomenon has particularly severe repercussions on firms deciding to add incremental projects to those initiated thanks to public incentives (that is, companies showing additionality). The pattern of productivity and profitability can thus be interpreted according to this perspective. Of course, as our dataset does not provide any information for the period after 2004, it is not possible to draw inferences on the long-run post-treatment effects of the subsidy. Hence, we cannot ascertain if the performance of the additionality group improves once the beneficial market returns from additional innovative projects have appeared. The median shows no significant differences in economic growth between the two groups, although the results on the mean seem to indicate that the crowding-out group performs better. Given the high skewness of this variable, however, we prefer to rely on results on the median rather than on those on the mean.

## Conclusions

Based on the analysis provided by our model, FAR seems to have been successful in promoting both input additionality (own R&D performance) and output additionality (patenting performance). The results are: 40% R&D additionality for the average firm (about 800,000 euros of additional own R&D investment), and a 3.5% increase in the number of patents for any 1 million euros of additional firm's own R&D expenditure. Nevertheless, the various subsets of firms display substantial differences. The observed firms that perform additionality are generally larger, more oriented towards patenting and with a lower negative growth of fixed capital accumulation, but similar to the crowding-out group for factors concerning R&D intensity, structure of costs, and corporate financing variables. The interpretation of these results put forth in this paper is based on the role played by scale economies on the one hand, and strategies on the other. Larger firms can benefit from higher scale economies through greater internal division of labour (specialisation), access to wider internal and external networks, ability to generate and absorb spillovers, market/political power, and easier access to credit and equity. Different strategies also seem to be at work, as larger firms appear more forward looking, more interested in achieving long-term objectives. However, most Italian SMEs are historically more concerned with short-term returns (immediate profits). This is attributable, among other things, to the Italian tradition of family ownership of firms and to the related fear of losing power and strategic control.

The above features of the additionality group lead us to reconsider the selection criteria adopted by public agencies in order to make policy interventions more effective in the fields of R&D and innovation. Indeed, it should not come as a surprise that corporate financing variables as well as the structure of costs (in other words, the idiosyncratic financial risk) are not related to additionality or crowding-out outcomes. These aspects are the basic criteria used by public agencies to select good firms/projects and the firms belonging to both groups were indeed successful in being selected for funding. The aspects that actually cause either additionality or crowding-out are much more linked to the behaviour, choices, and objectives of firms, and to their sheer size.

If they are to be more effective, R&D policies should focus on these aspects. The size of the firms being equal, it is their strategies that really matter. Performing R&D without long-term plans for growth, networking, alliances, and/or mergers in an ever-more competitive and globalised market does not seem to be a sustainable strategy. The selection procedures of public agencies should incorporate this message by establishing additional requirements other than the usual balance sheet indicators and project quality. These requirements are, of course, less tangible than the traditional ones, since they are embedded in the way a firm sees itself, the environment it operates in (competitors, imitators, innovation leaders), and the evolution of markets and technologies. Such aspects are often culturally determined and conditioned by socio-political mechanisms. Some indication of the strategic orientation of a firm can be found in its medium-term plan and the reform of FAR seems to be well designed, since it now includes two new preconditions for the selection of large projects: the firms have to demonstrate the additionality character of the requested subsidy and they must also provide a three-year R&D plan.

In summary, FAR seems to be more suited to large firms, in which it can lead to largely positive results. SMEs need more specific and probably targeted (not bottom-up) instruments. Large firms are also natural candidates for top-down programmes but it is difficult to say if satisfactory additionality results can be derived from this type of policy intervention. Besides input and output additionality, it would be interesting to consider other types of effects linked to changes in firm behaviour, such as changing the content of R&D projects or R&D localisation. However, this analysis is probably best developed through surveys.

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## Notes

1. FIRB 2005–2008, code RBNE03ETJY.
2. Martin and Scott (2000) suggest that policy interventions to promote R&D should be targeted and sector-specific rather than widespread and generic. They make use of Pavitt's taxonomy (1984) to identify: (1) main sectoral innovation modes; (2) sources of sectoral innovation failure; and (3) suitable policy instruments.
3. It is worth stressing that, although the main concern of the literature is with input additionality (the direct effect of an R&D support programme on firm R&D expenditure), another two kinds of additionality are relevant: output additionality (referring to the downstream effects of R&D incentives on firm innovativeness, productivity or profitability), and behavioural additionality (referring to structural/strategic changes in the way a firm operates after receiving a subsidy; for example, by becoming a patenting firm, by modifying technological specialisation, and so on). While both input and output additionality are generally measured through quantitative econometric techniques, behavioural additionality is usually detected by qualitative surveys (interviews and questionnaires) as well as case studies [for an in-depth analysis of these aspects, see IPTS (2002)].
4. In particular, they distinguish between contracts and grants as they are different incentive tools on the part of the government. In this paper, we focus on grants, although many of our conclusions can be extended to contracts too.
5. Actually, David *et al*. (2000) maintain that the MCC curve starts flat and rises only after a given threshold. This form of the MCC curve is attributable to the self-financing effect: firms start by using their retained earnings (the flat part) and only when these have run out do they turn to debt and/or equity markets (the upward part). In other words, they embrace the pecking order approach to firm investment financing (see Myers and Majluf, 1984).
6. The distinction among these forms of subsidisation is significant. In particular, the analysis of contracts greatly differs from that of grants. According to Lichtenberg (1987) and David and Hall (2000), two main elements contribute to the occurrence of additionality/crowding-out effects in the case of contracts: the first is based on an increase in research input costs attributable to changes in the labour demand for scientists and engineers brought about by the contract (especially when the total supply of researchers is assumed to be fixed and the government is budget-constrained); the second concerns the spillover effects generated by contracts, especially when they are the basis for future (expected) contracts and/or when firms plan to sell products to the government at the end of an R&D programme. Both causes can bring about additionality as well as crowding-out, even though the former (labour market effect) seems likely to generate crowding-out, whereas the latter (spillover effect) is likely to cause additionality [for a formal model, see David and Hall (2000)].
7. This percentage (13%) does not represent the share of collaborative projects within FAR, but only within our dataset.
8. Here 'oriented' means that more than 75% of R&D activity is devoted to either research or development. In the other cases – the majority – the level is 61%.
9. In what follows, we use the terms 'treated' and 'untreated' as synonyms for 'supported' and 'non-supported'.
10. We work with data on public subsidy commitment and not with subsidy outlays (i.e. subsidy allocation) since the latter are not fully available and are less reliable.
11. Vector $\mathbf{x}_1$ represents the agency's selection criteria, usually including firm/project characteristics as well as welfare objectives. In our case, only the first type of variable is included.
12. Vector $\mathbf{x}_2$ represents variables referring to firm R&D choices/strategies and should include the DHT variables from the previous section.
13. The average own R&D expenditure of the untreated units is about 570,000 euros: $(801–570)/570\approx0.40$.
14. Since benefits from tax credit are calculated on past R&D activities, we have checked for the presence of additionality/crowding-out for this fiscal measure by allowing for one and two-time lags of own R&D expenditure, obtaining the same negative result as in the case of Table 8.

15. The results might be attributable to two factors: not all collaboration projects are included in our dataset (which was created by merging three different initial datasets), and collaboration projects include top-down programmes dominated by large firms.
16. We use the words 'instrument' and 'measure' interchangeably.
17. The introduction of covariates reduces the number of observations because of numerous missing values.
18. Since the NNM already makes use of the covariates used in the regression analysis, in the Poisson regression we use as covariates region, sector, time, and size.

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