A dose response evaluation of regional incentives to R&D

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Abstract

The paper investigates the effects of regional research and development (R&D) incentives granted by the Italian regions in the period 1999-2016 on the performance of the different regional economies. We adopt a continuous treatment model that allows us to analyze the impact of the public support on a series of outcome variables. By studying the shape of the dose response function, i.e. the average treatment effects over all the possible values of the treatment levels, we are able to gauge the impact of public R&D on business performance when the level of the aid intensity changes. By this strategy, we are able to catch differences due a different policy exposure (or "dose") provided at regional level. In fact, the dose-response approach employed in this study is suited when treatment is continuous, and individuals may react heterogeneously to observable confounders. The empirical analysis is carried out on a novel dataset built on purpose, which consists of a panel covering the whole amount of R&D incentives granted by the Italian regions to business activities between 1999 and 2016. We built our database using data sources made available by the Italian Ministry of Economic Development (MISE).

Key words: State aid, evaluation, R&D incentives

Introduction

The intervention of the State in the economy, and more in particular, the question whether the Government may award State aid to companies has long been discussed in the economic and in the public finance literature. The debate is not only on the necessity, but also on the effectiveness and the efficiency of public interventions to the markets for private goods. Different economics schools arrive at very different answers regarding these topics. Recent researches, most of them ex-post evaluations, have reached several conclusions on the effectiveness and the efficiency of public intervention, depending for example in the sector of intervention and on the type aid instrument (i.e. direct aid or tax exemption).

In the ideal world of fully functioning markets and perfect competition, there would be no place for state intervention and no rationale for any type of state aid support. However, it is long recognized that there exist a number of market failures which can have far-reaching negative impact on prosperity and which lead to suboptimal economic equilibria. The crucial role of State aid is hence to promote the better allocation of resources also favoring better societal outcomes.

State aid is the most direct policy instrument by which state can intervene in the markets through subsidies or advantages granted to companies. From strategic perspective, State aid is necessary in areas that are key for growth such as infrastructure, human capital and research and innovation (Aghion & Howitt, 1992; Zachariadis 2004). In particular, in the field of R&D&I, State intervention may correct market failures improving the functioning of markets and, thereby, contributing to smart, sustainable and inclusive growth. In the context of R&D&I, market failures may arise, for instance, because market actors do not normally take into account the (positive) externalities that ensue on other actors in the economy, and therefore engage in a level of R&D&I activities which is too low from the point of view of society. Likewise, R&D&I projects might suffer from insufficient access to finance (due to asymmetric information) or from coordination problems among firms. Therefore, State aid for R&D&I can be compatible with the internal market where it can be expected to allevi ate a market failure in promoting the execution of an important project of common European interest or facilitating the development of certain economic activities, and where the ensuing distortion of competition and trade is not contrary to the common interest

At the same time, efficiency consideration must be taken into account by ensuring that support is only granted when there is a genuine inability to obtain funds from the market and thus there is no risk of crowding out of the private resources. Subsidies earmarked for R&D must serve their designated purpose – i.e. enabling the realization of R&D&I activities that would not be undertaken in the absence of aid – and are not diverted for other purposes such as general operating aid support for instance.

To be efficient and effective, the total economic costs of state aid policies have to be lower than the total economic benefits of such policies. Costs do not only include costs of government bureaucracy but also deadweight losses of taxation to finance government expenditure, potential market distortions, and opportunity costs of spending resources on state aid policies instead of funding other kinds of policies.

Therefore, evaluating state aid programs is crucial for designing and implementing efficient and effective measures. Evaluation of public policies may help to understand which have been the effects of a particular aid program on the economic situation of an interested area. Several studies have tried to measure the *incentive effect* of R&D&I support programmes.

This paper contributes to the evaluation studies literature by studying the impact of regional incentives to Research and development (hereafter SA) in Italy for the period 1999-2016, with a focus on the differences between the North-central regions (North) and the Southern regions (South). In particular, our analysis adopt a continuous treatment model that allows us to analyze the impact of the public support on a series of outcome variables, namely private investments in R&D, number of employees , and patent applications. By studying the shape of the dose response function, i.e. the average treatment effects over all the possible values of the treatment levels, we are able to gauge the impact of public R&D support when the level of the aid intensity changes. By this strategy, we are able to catch differences due a different policy exposure (or “dose”) provided at regional level.

1. Evaluating R&D support, a backward in the economic literature

Research and development, resulting in new goods, new processes and new knowledge, is a major source of technical change and economic growth. However, notwithstanding the economic rationale to support R&D, public support should be carefully granted to stimulate additionality.

In this light, the main purpose of any evaluation analysis is to measure the direct impact of the subsidy, i.e. to understand if a causal relationship exists between the aid and economic outcomes. Key questions include how much additional investment was stimulated by the public intervention and to what extent would the outcomes on firm performance could have been achieved without public support.

Several studies have tried to measure the incentive effect of R&D&I support programmes.

In general, the literature tends to distinguish between two main types of additional activities that can be expected, namely input additionality (i.e. change in the private expenditure that can be attributed to the public support) and output additionality (i.e. R&D&I output increases as a result of public support).

Most studies try to explore the sign and the magnitude of the "net" effect of public aid. Input additionality measures how much RDI expenditures have been triggered by each euro of subsidy.

There is also a broad empirical literature on directly measurable output effects of public R&D support schemes. The empirical results widely support the notion that assisted companies have been successful to enhance their innovation capabilities.

In a study that evaluate the effects of the Austrian scheme on R&D tax incentives in 2009-2010, Falk et al. (2011) found a positive impact on the probability for the beneficiary firms to introduce new to the market products.

However we should take into account as reported by several studies1 there are cases where public funding acted as a substitute for private capitals, suggesting partial or total crowding out effect.

To sum up, the literature highlights significant positive effects of R&D aids on both input and output, but the effects are not univocal, mainly because of the side effect of crowding out of

[1] Among the others David, Hall and Toole (2000), Garcia-Quevedo (2004); Zunica-Vincente et al (2012)

private capitals. Considering this, a comprehensive and systematic strategy for evaluating State aid is needed.

Evaluation studies can also help policy makers to invest in the most profitable R&D activities.

The long-standing evidence in the R&D&I evaluation literature is that subsidies used to finance closer-to-market activities are less effective and with more distortive consequences on competition than aid to more fundamental type of research.

Czarnitzki et al. (2011) combine data on firm innovation expenditures from the Belgian OECD R&D surveys of 1999 to 2007 with data on company research projects from Belgian (Flemish) authorities and company finance data. The authors find that "research" (farther from the market) projects are more subject to financial constraints than "experimental development" (closer to the market) projects.

Similarly, Khan and Luintel (2011) found, for a sample of ten OECD countries, a much greater (x 2,7 times) impact of basic and applied research on total factor productivity than experimental development.

These evidences however do not exclude that in some particular circumstances aid to closer to the markets R&D&I activities can also be effective.

Another relevant issue for an efficient allocation of R&D&I aids is whether to focus on small or large firms.

Czarnitzki and Toivanen (2013), in a study prepared for the European Commission, evaluate R&D&I subsidies to firms in the Belgian region of Flanders and in Germany. The authors find no significantly positive effect of the received support on R&D&I spending for large firms compared to a matched control group consisting of similar firms who have not received public support.

Several studies, analyzing the impact of an R&D&I program on a number of outcome of subsidized firms, have pointed out that the programs analysed have been more effective for smaller firms than for larger ones.2 (González, J. Jamandreu, and C. Pazó (2005), Lokshin and P. Mohnen, (2011) Alecke et al. (2011), Paunov (2012) Mouque (2012) and Criscuolo (2012).

[2] It should be pointed out however that a part of the literature suggests otherwise, among the others Cerulli and Potì (2012) find that the largest output gain is seen for larger firms, more oriented towards patenting and with a lower reduction of fixed capital accumulation.

In recent years, advanced economies have opted for two main instruments for R&D support, namely tax incentives and direct support.

In general tax incentives schemes are not targeted to a specific group of firms or projects, but to all potential R&D performers. They are therefore "region or industry neutral", in the sense that they tend to produce lower allocative distortion than direct subsidies. In addition, if tax incentives are implemented on a long term bases, they can reduce the uncertainty faced by enterprises in their financial planning.

On the other hand, direct support can be the right way to sustain large scale projects and reduces the uncertainty of budget consequences faced by Governments. In some cases, tax incentives might be less effective than project-based support as they allow firms to deduct the tax payment even for R&D activities that would be carried out anyway.

As already stressed in the previous sections, small young firms are important players in radical innovation. But tax incentives may advantage large multinational enterprises. As underlined by OECD (2013) in a recent publication, direct incentives would be more effective to support young firms in need of upfront funding, whereas tax credit would not be helpful for new firms that do not have generated taxable income.3

Given the advantages and disadvantages of both types of instruments, it would be crucial to understand, also considering the different contexts, which is the most effective design.

Even if the evidence on the relative effectiveness of direct support as compared with R&D tax credits is limited, we can try to sum up the main findings coming from the evaluation literature.

Firstly, for a tax credits, it seems particularly relevant the choice of the basis of calculation, i.e. volume based or incremental.

Under incremental tax credits, firms are only eligible for tax reduction for the additional R&D effort they make, compared to an earlier period. Level-based R&D tax incentives apply based on the absolute level of research effort.

Parsons and Phillips (2007) underline that an incremental tax credit (which only applies to R&D expenditures above a baseline) may be more effective than a volume-based tax credit in inducing additional business R&D spending, while a volume-based scheme might be preferred

[3] A similar result is also found by Corchuelo and Martinez-Ros (2009), in analysing reactions to fiscal incentives in Spain. They observe that big firms are significantly more likely to know about the possibility to benefit of tax incentives while smaller firms find obstacles in using them. Nevertheless tax incentives are used by firms that also receive direct support, particularly small and medium-sized enterprises.

if the policy goal is to retain R&D-intensive businesses, especially in a context of high overall corporate tax rates.

Incremental tax credits are a tool to incentivize a continuous improvement in research effort, while a volume based tax scheme would be more appropriate if the objective is to increase the overall R&D in the country.

According to Criscuolo et al. (2009) a combination of volume and incremental tax incentives (hybrid schemes) may be considered an optimal to maintain the level, and reward high growth, of R&D.

The choice of the allocation mechanism also plays a crucial role in the effectiveness of the aid. An interesting finding comes from Colombo, Grilli and Murtinu (2011). The authors consider 247 Italian owner-managed firms that receive subsidies. Subsidies allocated on a competitive basis have a positive effect leading to an increase of 31, 4% in total factor productivity while those assigned automatically do not have a significant effect.

The effectiveness of R&D incentives, both direct and indirect, also depends on the stability and the time horizon of the policy over time. For instance when R&D tax policy changes often, the impact of the R&D tax incentives appears to be much reduced.(Westmore, 2013). Hall and Van Reenen (2000) reach a similar conclusion in a study that shows how responses to R&D tax credits are small initially but increase over time. The authors find that moving average base tax schemes, with the narrowing of the effect as the base reaches certain thresholds, lead to a limited incentive effect. These observations suggest that the stability of the incentive scheme is very relevant as it allows firms to rely on the aid, including it in their longer term plans.

To sum up, the available literature on evaluation shows how crucial is for Member States to carefully assess the design of any R&D incentive in order to boost the effectiveness and efficiency of their R&D policies.

1.1 State aid evaluation studies in Italy.

This section provides an overview of the most influential studies and researches on ex-post evaluation of aid to enterprise that have been conducted in Italy. The aim is to provide a partial picture of what has been done at regional and national level with the aid to enterprise. We can distinguish the literature according to the results and findings in terms of impact on investments, production and productivity, job creation, scale of support, and targets.

Among the most relevant and complete studies in the field we should mention the work of Martini and Bondonio (2012). The authors evaluate enterprise support policies at two distinct geographic levels. At the national level they focus on “Law 488/92”, a large-scale programme that supported investments in physical capital through direct grants assigned through open competitions implemented on a regional basis.

At the regional level, they focus on a single Italian region, Piemonte, and on the evaluation of investment support measures available to SMEs.

The authors using a mix of counterfactual techniques show that on average firms that received direct aid under “Law 488” reduced private investments. According to the authors the direct state support to firms have resulted in a decrease in private investment expenditure, and the leverage effect have fall significantly below 1.4 The cost of 1 Euro extra of investment is 1.86 euro. In addition, the authors underlined that 36% of managers “thought they would have undertaken the investment regardless”, a results that pose serious doubts on the incentive effect of the Law.

D’Aurizio and de Blasio (2008) reach a similar conclusion on the same instrument. The authors underline that the stimulation effect of the law 488 has been modest, because it has induced mainly inter-temporal substitution effect in entrepreneurial decision. Apparently more effective has been law no. 388/2000 (budget law for 2001), also because of its different system for the granting of incentives (an automatic mechanism rather than a competitive procedure). Nevertheless, also in this case the additionally of incentives for investment has been scant.

Bronzini and De Blasio (2006), evaluating the impact of the “488/92” investment grant program, compare subsidized firms with firms whose applications were rejected and using the diff-in-diffs approach they find that financed firms substantially increase their investments in comparison with the pool of rejected application firms.

However, their results suggest the presence of intertemporal substitution effects. Firms appear to have anticipated investment projects originally planned after the post-intervention period to take advantage of the incentives. In fact, beneficiary firms significantly slow down their investment activities in the years following the program.

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4 Leverage effects can be interpreted as the ‘investment induced’. A given source of money (is deemed to stimulate other investments, from different sources (either public co-financing from a Member State/region or private sector money). The leverage effect is calculated as the ratio between “Total money (i.e. the original ‘lever’ money, plus the money induced) Original lever money”

Pellegrini et al (2015) using a multiple Regression discontinuity design (RDD) shows that capital subsidies granted under “low 488/92” positively affect “total factor productivity growth” in the medium long term, and not in the short term. According to the author, the allocative efficiency has a positive effect only after 2-3 years. In addition, the analysis underline that the positive impact on (TFP) comes especially trough technical progress and not through scale impact change. Supported enterprises were much more likely than matched control firms to carry out both product and process innovation

At regional level, Bondonio & Martini (2012), in the already mentioned study, reach different conclusion in the analysis of the SME support in Piemonte, where the leverage effect recorded is 1,7.

The latter case seems to be a success story, but not common, especially in South Italy. At regional level, Piergiovanni et al. (2008) show that, a law for the promotion of new enterprise have been particularly ineffective in all sector, with the only exception of the “Construction” sector.

The same conclusion is reached by Accetturo and de Blasio (2011). Analyzing the “Patti Territoriali”, a key policy instrument for fostering growth in the disadvantaged areas of Italy (1996-2007), the author finds very little support for the effectiveness of the program in attracting plants (new investments) for the period of analysis.

Bronzini and Iachini (2014) evaluate a unique program implemented in Emilia-Romagna aimed at foster investments in R&D activities of firms located in the area (Regional Program for Industrial Research, Innovation and Technological Transfer). The authors use a sharp regression discontinuity design to compare investment spending of subsidized firms with spending of a control group.5 For the sample as whole, the authors do not find any significant increase in investment as a result of the program. However, findings suggest that a differentiation can be made according to the size of the beneficiary firm. On average, the author estimate that small enterprises increased their investments by about the amount of the subsidy they received from the program, whereas for larger firms the subsidies appear to have had no additional effect. At different conclusions arrive Cerulli and Potì (2012) in an evaluation

5 Firms were invited to submit proposals for new projects and only those that scored above a certain threshold received the subsidy. This design allows for the use of “sharp regression discontinuity design” to compare investment spending of subsidized firms just above the cut-off score with spending by firms just below the cut-off.

study of an R&D programe support called "Fondo per le Agevolazioni della Ricerca (FAR)".6 The authors find that FAR seems to have been successful in promoting both input additionality (own R&D performance) and output additionality (patenting performance). The study concluded that the program has induced 40% R&D additionality for the average firm (about 800,000 euro of additional own R&D investment) with a leverage effect of 3,41 euro, and a 3.5% increase in the number of patents for any 1 million euro of additional firm's own R&D expenditure. Anyway, while large firms seem to have been decisive for the success of this policy, small firms present a more marked crowding-out effect. According to the authors, large firms are more interested in achieving long-term objectives, while most of the Italian SMEs are historically more concerned with short-term returns (immediate profits).

De Blasio, Fantino and Pellegrini (2010) using a regression discontinuity design approach (RDD) evaluate a program for R&D business support started in 2004, called FTI7. The FTI had the purpose of "stimulating the applied development of innovations through subsidies to the R&D activity of firms." The results of the study pointed out that there is no evidence of effectiveness of the aid. Compared to the control group, the subsidized firms did not invest more in either tangible or intangible assets. Therefore, according to the authors, the FTI have caused a crowding out of private funding. While the effects of the program on sales, profitability and financial conditions of the firms were also negligible, is however underline a positive impact on the overall size of the balance sheet, which suggests that money saved on R&D was spent on alternative assets.

As we have already stressed State aid can be also used to foster employment.

In most of the studies analyzed, it seems that the level of employment did not change thanks to the measure implemented.

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6 FAR was a sort of 'mini-mix' policy instrument; it contained 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.

[7] The subsidy was a combination of a concessional loan (which covers 60 percent of the subsidy and charges an interest rate that amounts to 1/5 of the market rate) and a grant (for the remaining part). The maximum length of the reimbursement plan of the loan was ten years, plus a grace period during the execution of the project.

Interesting results and observation come from the analysis of the work of Martini and Bondonio (2012), and in particular with the comparison of the ex-post monitoring of “Law 488/92”. The authors found that out of 89.000 new jobs recorded in the ex-post monitoring, only 12.500 were effectively created, at a cost of EUR 232.000 per labor unit. While for the SME’s support in Piemonte, the cost for unit labor was of EURO 33.000.

As we have seen, aid to firms produces different effects depending on the amount of support granted, the size of the firm, the geographical area where it is located and the type of aid pledged.

2. The impact evaluation analysis using dose-response model

In order to reliably establish a causal relationship between regional aid and economic outcomes it is crucial to define a reasonable counterfactual scenario: what would have happened in the absence of aid? How did the aids change the outcome?

To respond to these research questions, we adopt a “continuous treatment framework” that allows to investigate the impact of the public support to firm on a series of outcome variables. However, from a program evaluation perspective we were facing the problem of evaluate the impact of a policy without the existence of “treated” and “untreated” groups that are necessary for the evaluation analysis. Indeed, each unit observed (regions) have granted aid along all the considered time period 1999-2016.

In order to overcome this problem, we consider as untreated the units of observation “regions/year” that are under the 15th percentile of intensity of aid then, for each level of treatment, we compute the expected difference in the outcome between treated and untreated. By studying the shape of the dose response function, i.e. the average treatment effects over all possible values of the treatment levels, we are able to catch the impact of aid to firms, or better, to study whether effects on the outcome variables change when the level of aid changes

With this strategy, we not only explore the difference of the binary treatment status, but also the support exposure (or “dose”) provided by the regions.

Obviously, the model has important limitations. First of all, the short time horizon considered 1999-2016 have not permitted to use temporal lags larger than one-year, as to avoid a serious

reduction of the observations. Secondly, as we have already stressed, we do not have a proper counterfactual group, without treatment. Due to these limitation we are not able to grasps conclusive evidences, but useful indications.
Recent literature on public program evaluation have used a dose-response frame, even if in other policy framework or with a different econometric approaches (Adorno et al., 2007; Marino et al., 2011; Potì, Cerulli, 2014). The dose-response approach employed in this study is suited when: (i) treatment is continuous, (ii) individuals may react heterogeneously to observable confounders.

2.2 The model

As explained above we are interested in estimating the causal effect of the treatment variable t (aid to firm) on a series of potential outcome y within the observed sample, by assuming that treated and untreated units may respond differently both to specific observable confounders and to the "intensity" of the treatment t.
In this context, the dose-response function is shown to be equal to the "Average Treatment Effect, given the level of treatment t" (i.e. ATE(t)).
But also, other causal parameters of interest, such as the unconditional Average Treatment Effect (ATE), the Average Treatment Effect on Treated (ATET), the Average Treatment Effect on Non-Treated (ATENT) are estimated, along with these effects conditional on the vector (x; t).
Here we briefly present the model that we use from the analysis proposed by Cerulli (2014).

We assume that our population (regions) may have two potential outcomes:

$$\{w = 1: y_1 = \mu_1 + g_1(x) + h(t) + e_1$$
$$\{w = 0: y_0 = \mu_0 + g_0(x) + e_0 \qquad (1)$$

Where the h(t) function is different from 0 only in the treated status. Given this, we can also define the casual parameters of interest. Indeed, by defining the treatment effect (TE) as (TE) (y1-y0), we define the casual parameters of interest as the population Average Treatment Effects (ATEs) conditional on x and t, that is:

$$\begin{aligned}&\mathrm{ATE}(\mathbf{x};t)=\mathrm{E}(y_1-y_0\,|\,\mathbf{x},t)\\&\mathrm{ATET}(\mathbf{x};t>0)=\mathrm{E}(y_1-y_0\,|\,\mathbf{x},t>0)\\&\mathrm{ATENT}(\mathbf{x};t=0)=\mathrm{E}(y_1-y_0\,|\,\mathbf{x},t=0)\end{aligned} \quad (2)$$

where: y1 and y0 are the outcome of a generic unit when treated and untreated (under 15th percentile) respectively; x is a row vector of M exogenous and observable characteristics (confounders), t the treatment dose (varying from 0 – no treatment – to 100 – maximum level of treatment).

Let w be the treatment indicator, taking value 1 for treated and 0 for untreated units; N be the number of units involved in the experiment; N1 be the number of treated units; and N0 the number of untreated units with N = N1 + N0.

ATE indicates the overall average treatment effect, ATET the average treatment effect on treated, and ATENT the one on untreated units. By assuming a linear specification of the potential outcomes, the Average Treatment Effect (ATE) conditional on x and t becomes:

$$\mathrm{ATE}(\mathbf{x},t,w)=w\cdot[\mu+\mathbf{x}\boldsymbol{\delta}+h(t)]+(1-w)\cdot[\mu+\mathbf{x}\boldsymbol{\delta}]$$

where μ=(μ1-μ0) and δ=(δ1-δ0). Moreover, under some manipulations, we obtain:

$$\begin{cases}\mathrm{ATE}=p(w=1)(\mu+\bar{\mathbf{x}}_{t>0}\boldsymbol{\delta}+\bar{h}_{t>0})+p(w=0)(\mu+\bar{\mathbf{x}}_{t=0}\boldsymbol{\delta})\\ \mathrm{ATET}=\mu+\bar{\mathbf{x}}_{t>0}\boldsymbol{\delta}+\bar{h}_{t>0}\\ \mathrm{ATENT}=\mu+\bar{\mathbf{x}}_{t=0}\boldsymbol{\delta}\end{cases} \quad (3)$$

where the dose-response function is given by averaging ATE(x, t) over x:

$$\mathrm{ATE}(t)=\begin{cases}\mathrm{ATET}+(h(t)-\bar{h}_{t>0}) & \text{if} \quad t>0\\ \mathrm{ATENT} & \text{if} \quad t=0\end{cases} \quad (4)$$

that is a function of the treatment intensity t.

Under previous definitions and assumptions, the following baseline random-coefficient regression can be obtained (Wooldridge, 1997; 2003):

$$y_i = \mu_0 + w_i \cdot \mathrm{ATE} + \mathbf{x}_i\boldsymbol{\delta}_\mathbf{0} + w_i \cdot (\mathbf{x}_i - \overline{\mathbf{x}})\boldsymbol{\delta} + w_i \cdot (h(t_i) - \overline{h}) + \eta_i$$

where $\eta_i = e_{0i} + w_i \cdot (e_{1i} - e_{0i})$.

Assuming un-confoundedness, which implies that conditional on the knowledge of the true exogenous confounders x, the condition for randomization are restored, and causal parameters become identifiable. Given the set of random variables {y1i, y1i, wi , xi, ti}, we can write the regression line of the response y simply as:

$$\mathrm{E}(y_i \mid w_i, t_i, \mathbf{x}_i) = \mu_0 + w_i \cdot \mathrm{ATE} + \mathbf{x}_i\boldsymbol{\delta}_\mathbf{0} + w_i \cdot (\mathbf{x}_i - \overline{\mathbf{x}})\boldsymbol{\delta} + w_i \cdot (h(t_i) - \overline{h}) \quad (5)$$

and Ordinary Least Squares (OLS) can be used to retrieve consistent estimation of all parameters.

Once a consistent estimation of the parameters in (2) is obtained, we can estimate ATE directly from this regression, and ATET, ATENT and the dose-response function by plugging the estimated basic parameters into formula (4) and (5). To complete the identification of ATEs and the dose-response function, we finally assume a parametric form for h(t):

$$h(t_i) = at_i + bt_i^2 + ct_i^3$$

where a, b, and c are parameters to be estimated in regression (1).

Under CMI, an OLS estimation of equation (1) produces consistent estimates of the parameters, we indicate as $\hat{\mu}_0, \hat{\boldsymbol{\delta}}_\mathbf{0}, \hat{\mathrm{ATE}}, \hat{\boldsymbol{\delta}}, \hat{a}, \hat{b}, \hat{c}.$ With these parameters at hand, we can finally estimate consistently the dose-response function as:

$$\hat{\text{ATE}}(t_i) = w[\hat{\text{ATET}} + \hat{a}(t_i - \frac{1}{N}\sum_{i=1}^{N} t_i) + \hat{b}(t_i^2 - \frac{1}{N}\sum_{i=1}^{N} t_i^2) + \hat{c}(t_i^3 - \frac{1}{N}\sum_{i=1}^{N} t_i^3)] + (1-w)\,\hat{\text{ATENT}}$$

where:

$$\hat{\text{ATET}}(t_i) = \hat{\text{ATE}}(t_i)_{t_i > 0}$$

Moreover, for each level of the dose t, it is also possible to calculate the α-confidence interval around the dose-response curve. Indeed, by defining T1=t-E(t), T2=t2-E(t2) and T3= t3-E(t3), the standard error of the dose-response function is equal to:

$$\hat{\sigma}_{\hat{\text{ATE}}(t)} = \left\{ T_1^2\hat{\sigma}_a^2 + T_2^2\hat{\sigma}_b^2 + T_3^2\hat{\sigma}_c^2 + 2T_1T_2\hat{\sigma}_{a,b} + 2T_1T_3\hat{\sigma}_{a,c} + 2T_2T_3\hat{\sigma}_{b,c} \right\}^{1/2}$$

This means that the α-confidence interval of $\hat{\text{ATE}}(t)$ for each t is then given by

$$\left\{ \hat{\text{ATE}}(t) \pm Z_{\alpha/2} \cdot \hat{\sigma}_{\hat{\text{ATE}}(t)} \right\}$$

that can be usefully plotted along the dose-response curve for detecting visually the statistical significance of the treatment effect along the support of the dose t.

Differently from Hirano and Imbens (2004), this model does not need to specify a generalized propensity score, as we work within a control-function model. Moreover, we are able to take into account both zero-inflation at t=0 and treatment observable endogeneity under reasonable assumptions.

In this application of the model, we also run the model with regional dummies as to have regional fixed effect estimation. This strategy will allow us as to control the robustness of the OLS model and we may further mitigate endogeneity problems

We will study the potential outcome of the treatment on three different variables, all considered at regional level:

- Private investments in R&D from 1999-2016
- Number of R&D Employees
- Patent application

As confounders x we are using the following variables:

- GDP. Regional GDP
- Public expenditure in R&D
- Regional Private investments in percentage of GDP
- Capital Stock: gross fixed investments in percentage of GDP
- Rate of employment

3. The Dataset

The dataset employed in this paper has been built with data taken from the Italian Ministry of the economic development (MISE). Data refer to the R&D incentives to enterprise granted by Italian regions from 1999 to 2016.

In order to better understand the object of the analysis, it is important to clarify the notion of "aid". We are referring to several instruments adopted by regional public authorities, on the basis of different legal or administrative acts [8], that give substance to a form of an economic "aid". In particular, we consider only the subsidies to enterprise that can be considered "Sate aid" granted by regional administrations. According to article 107 of the Treaty of the Functioning market of the European Union (TFUE), State aid is defined as an "*advantage in any form whatsoever conferred on a selective basis to undertakings by national public authorities*."

To be State aid, a measure needs to have these three features. (1) There has been an intervention by the State or through State resources which can take a variety of forms (e.g. grants, interest and tax reliefs, guarantees, government holdings of all or part of a company, or providing goods and services on preferential terms, etc.); (2) The intervention gives the recipient an advantage on a selective basis, for example to specific companies or industry sectors, or to companies located in specific regions competition has been or may be distorted; (3) The intervention is likely to affect trade between Member States.

In sum, the aid must have a State origin (in our case regional administration); be selective, i.e. the State intervention should create an advantage for some specific firm; and be potentially

[8] With our own calculation made on data coming from the "Ragioneria dello Stato" we were able to count 715 different legal or administrative acts (1999 – 2012). The most important National instruments were: the Law 488/92; Credito D'imposta; Contratti di Programma; Patti territoriali; Fondo agevolazione alla ricerca (FAR).

distortive for the internal market. Subsidies granted under general measures open to all enterprises do not constitute State aid (examples include general taxation measures or employment legislation).

In order to have more reliable estimations of the total aid expenditure at regional level, we have considered only the following forms of aids: (1) Capital grants, grants related to income and interest rate subsidies: which consist in a cash flow from the Region to the enterprise and for which there is no obligation to return; (2) Fiscal incentives that may consist in reduction of tax burden (tax credit, rates reduction, fiscal exemption, reduction on social burden); (3) The mix contribution, characterized by the combination of two different form of advantage, direct grants and tax incentives.

We will not include aids under the forms of guarantees[9], capital risk participation[10] and preferential (or direct) financing[11], because it is not easy to exactly define the cost in terms of "net equivalent" for the regional administration, especially in the case in which the aids have been granted in the last years of the observed time period.

Regarding the resources through which State aid measures are financed and implemented, we can distinguish three main financial channels[12]: European structural funds; national funds; and regional resources. The first category is mainly managed by the Regional administrations within the framework of the Regional operation programs (ROP) of the European Regional Development Fund (ERDF) and, to lesser extent, by the ROP of the European Social Fund (ESF). National resources, instead, are planned and managed under the framework of the "Development and Cohesion Fund"[13] (FSC, former FAS) that, starting from 2007, is managed by the different regional administrations with the seven years Regional Implementation Programs

[9] the cases in which the Region (I)forgoes the premium intended to cover the risks of non-payment of the guarantee; (II) the legal form of the enterprise rules out bankruptcy or other insolvency procedures or provides an explicit state guarantee or coverage of losses by the State; (III) the acquisition by a State of a holding in an enterprise if unlimited liability is accepted instead of the usual limited liability

[10] that consist in a financial advantage in so far as the rate of return requested by the Region is lower than the one normally requested by any private investor.

[11] defined as loans, with an obligation of return with rates below the market price

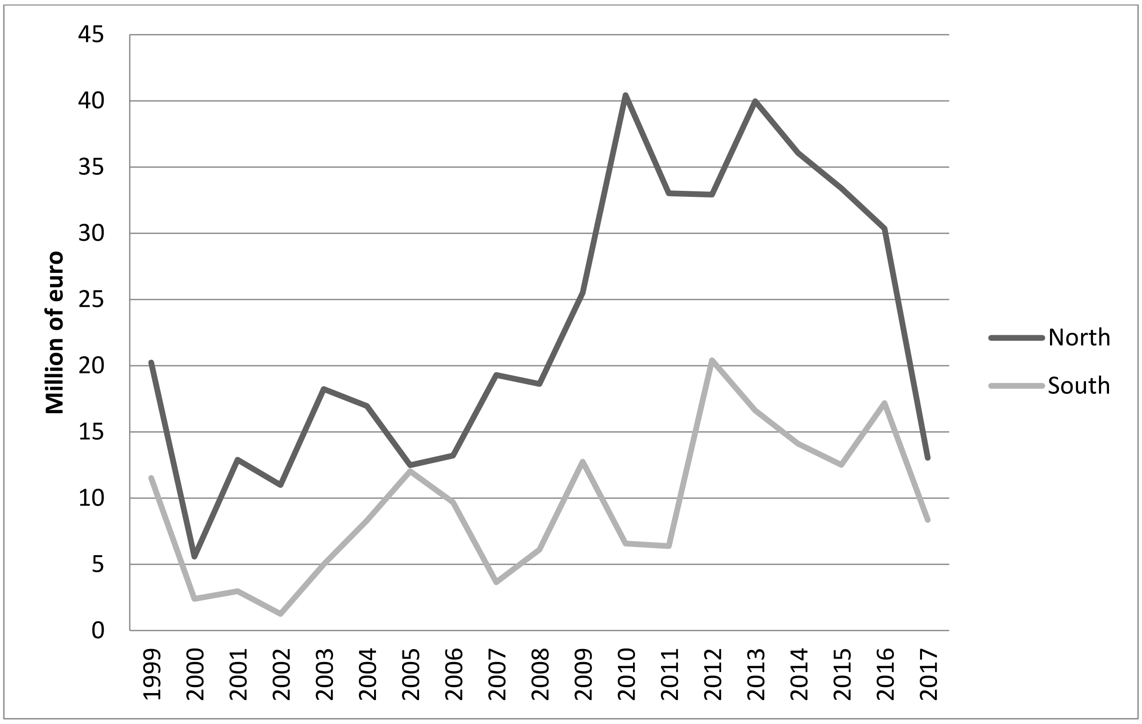
[12] With our estimations made on data coming from the "Ragioneria dello Stato" we were able to count 715 different legal or administrative acts (1999 – 2012). The most important National instruments were: the Law 488/92; Credito D'imposta; Contratti di Programma; Patti territoriali; Fondo agevolazione alla ricerca (FAR).

[13] The 80% of FSC is devoted to Southern regions

(PAR).[14] Finally, regional own resources have also been used to finance aid schemes. Unfortunately, we are not able to understand exactly where the resources came from and what the weight that the weight these channels have had in the total resources allocated to business aid.[15]

The figure (1) shows the broad picture of total aid to R&D activities granted by the Italian regions from 1999 to 2016.

Figure 1. Total aid granted to R&D activities by the Italian regions from 1999 to 2016.



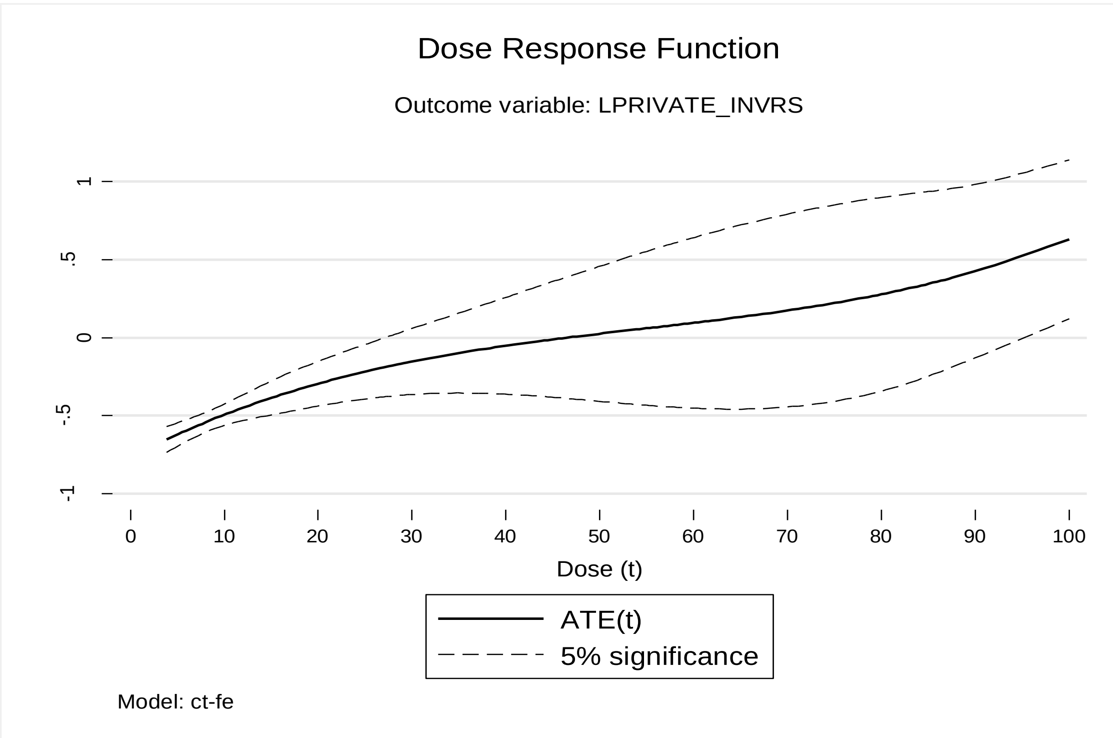
[14] The southern regions (PUGLIA; CALABRIA; CAMPANIA; SICILIA) do not have a regional PAR due to the lag and difficulties found in the implementation of the PAR.

[15] We were not able to understand the budget provision for each regional law on business support. Only thanks to the new provisions of the article 3 of d.lgs. 118/2011, starting from 2016 regional budgets should be public.

4. Result of the analysis

In this section we present the results of the impact evaluation analysis on different outcomes that are traditionally tied with the granting of public incentives to private R&D. In the first section we present the Dose response function (DRF) of the Fixed effect model (FE). OLS estimation confirms the results of the FE model, indicating that results are robust even without idiosyncratic heterogeneity. As we have already explained in the introduction "aid to firm" is the most direct policy instrument by which state can intervene in the markets through subsidies or advantages granted to companies. The most direct and decisive result of a policy implemented should be the increase of private investments that can structurally improve growth through a series of productivity channel as the increasing stock of research and innovation. The leveraging effect of private funds is the crucial element in order to determine the success of every aid scheme. So our first variable of interest is "Private investments in R&D" that accounts for private investments in research and development at regional level from 1999-2016. As all the outcome variables considered in this analysis we add a one-year temporal lag in order to avoid endogeneity problems.

Graph 1. Dose Response function. Outcome variable Private investments in R&D. Italy



Each point of the dose response function is the difference between treated and non-treated expressed as:

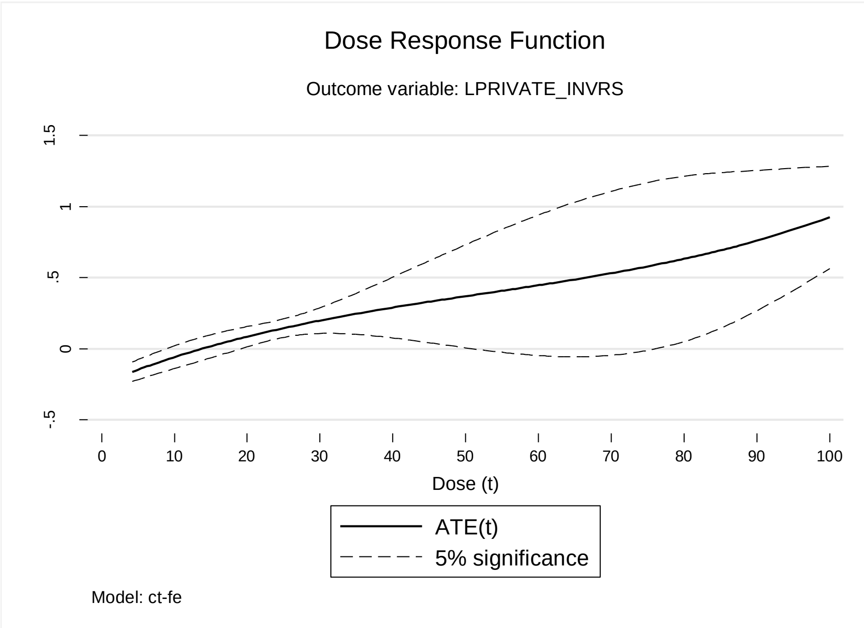
ATE (t) = E(Y(t)) – E (Y(0))

According to the results (see Graph1), the difference between being treated and non-treated (in the specification that we used) is negative until the 45th percentile, and then, even if the values of the DRF start to be positive, "the confidence intervals" indicate a non-significant impact.

The right tail of the dose-function seems to suggest that for higher level of aid intensity (above the 95th percentile) the impact may be slightly positive. However, the sign and the significance of the coefficient "treated-d" (Table 1 in the annex) accounting for the difference between treated and untreated, is negative thus indicating a negative but non-significant impact in the overall sample.

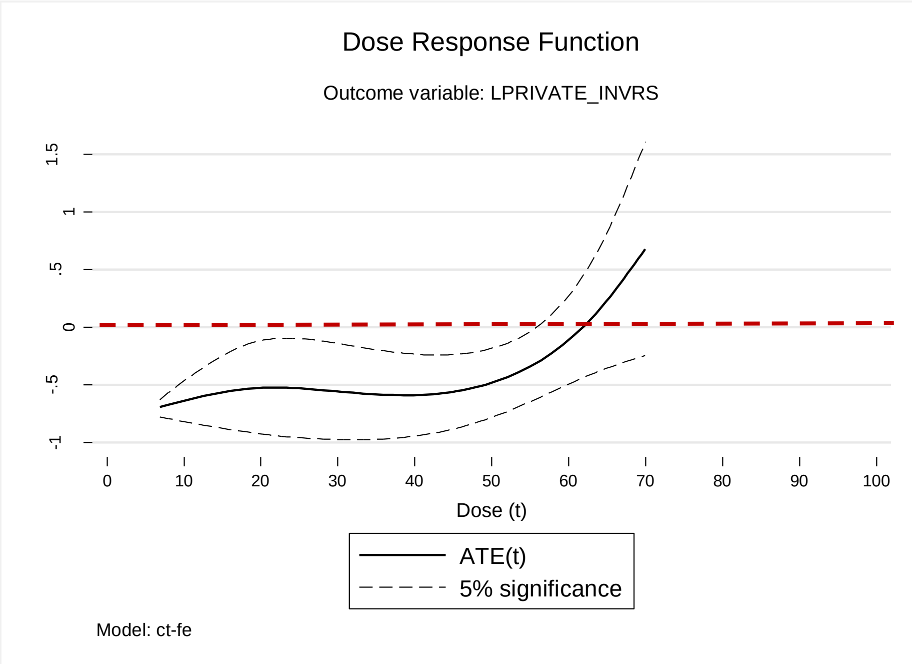
In the second graph we report the DRF for the northern-central regions. In this case we can observe a slightly positive impact of aid, on the outcome variable considered, only after the 80th percentile. The shape of the curve suggests that the impact of the "treatment" increase with the level of aid intensity. However, even if the curve of the DRF starts to be positive around the 20th percentile the larger confidence intervals are a clear indication of a less precise estimation. Indeed, the sign and significance of the variable "treated-d" (table 1 in the annex) confirms the results of the graph.

Graph 2. Dose Response function. Outcome variable Private investments, North



In graph3 is reported the dose response function of Southern regions. Both the values of the DRF and the confidence intervals are below zero until the 60th percentile, indicating a negative impact of aid on private investments in R&D in South Italy. Even if the DRF became positive for higher values of aid intensity, the confidence intervals are between zero, indicating a non-significant effect of the "treatment".

Graph 3. Dose Response function. Outcome variable, Private investments, South



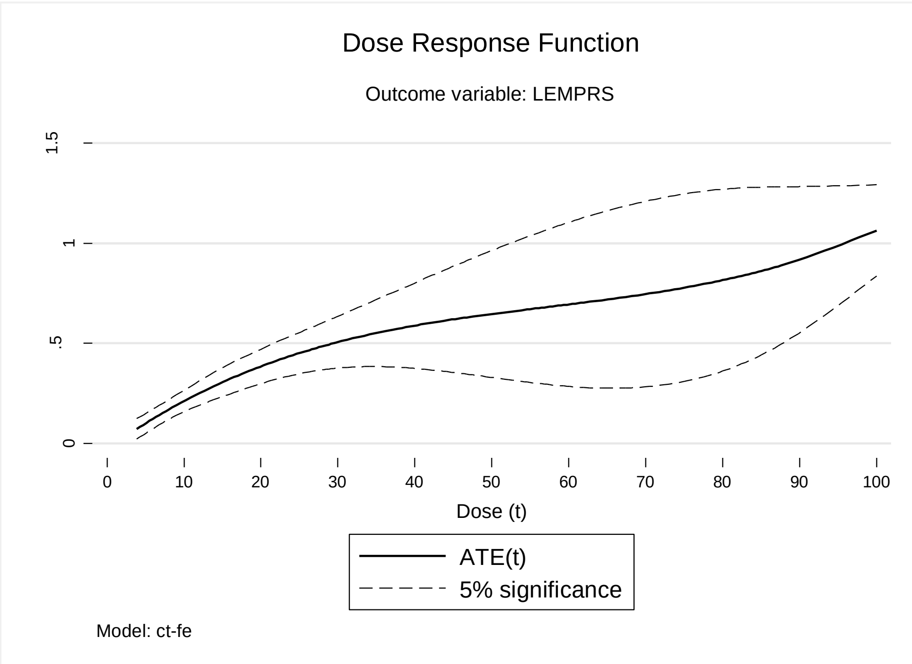
In order to understand the impact of aid on the number of employees in research and development activities, we study the dose response function of the "treatment" on the outcome variable "LEMPRS" that accounts for number of employees in R&D activities of private firms in the Italian regions between 1999 and 2016.

In the firs sample considered (graph 4) the DRF is above zero with a positive slope, indicating a positive relation between the impact and the level of aid intensity. However, larger confidence intervals around the 50th percentile indicate a less precise estimation.

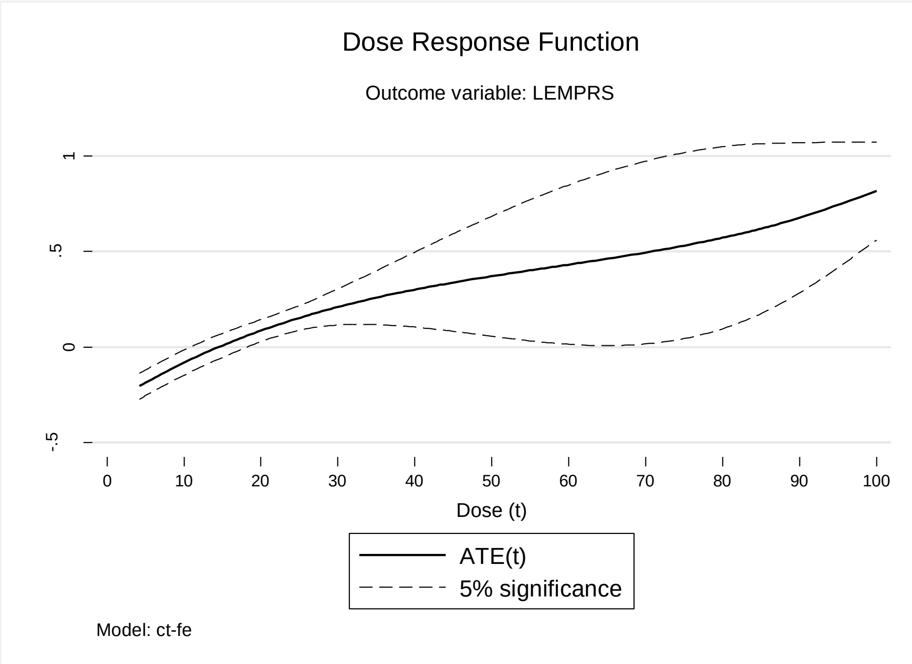
The shape of the DRF of the Norther regions seems to be similar to the one observed in graph 4. However, the impact starts to be positive only after the 20th percentile.

Finally, the last graph indicates that for Southern regions R&D incentives have the highest impact on the number of employees in R&D activities with respect to the other the two groups observed. The slope of the curve increases significantly after the 50th percentile indicating, also in this case, a higher effect of treatment for higher level of aid intensity. The sign and the significance of the coefficients "treated-d" (table II in the annex) confirm the results of the graphs. In particular, the coefficients are positive and significant in the overall sample (Italy) and in the Southern regions, whereas are slightly negative but non-significant in the sample of northern regions.

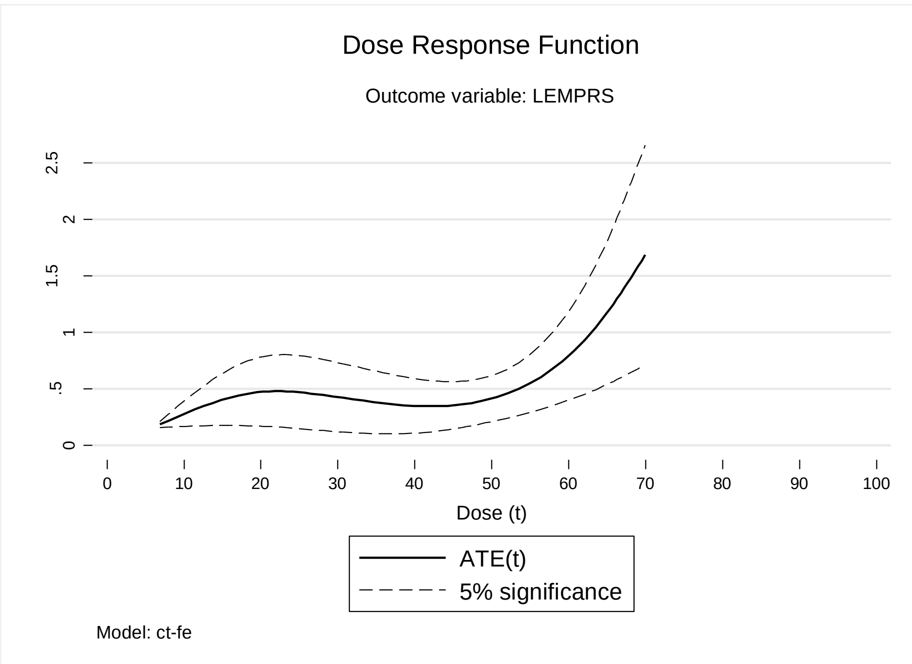
Graph 4. Dose Response function. Outcome variable: Number of employees in R&D activities. Overall sample



Graph 5. Dose Response function. Outcome variable: Number employees in R&D activities. Northern-Central



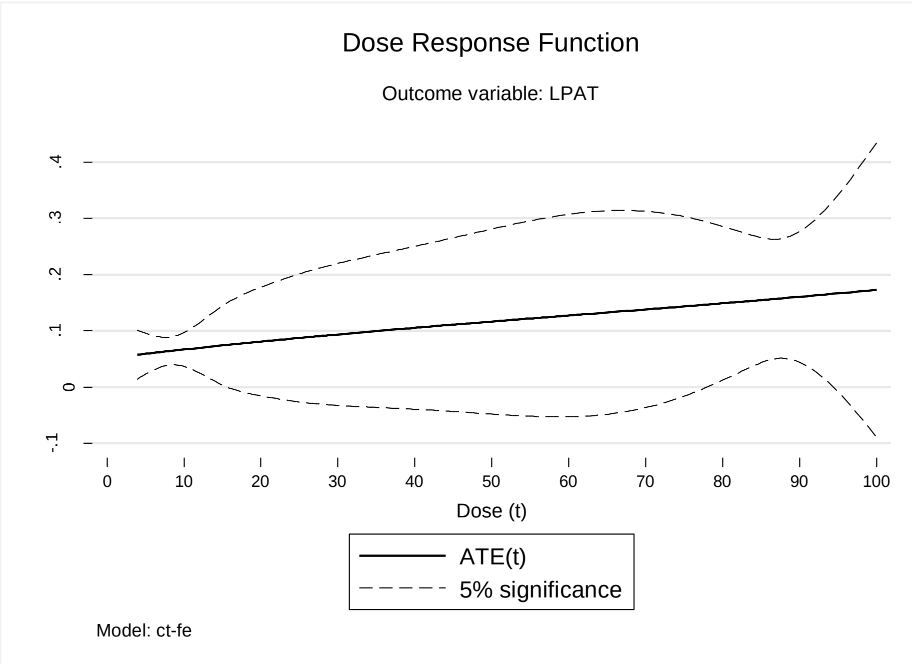
Graph 6. Dose Response function. Outcome variable: Number employees in R&D activities. South



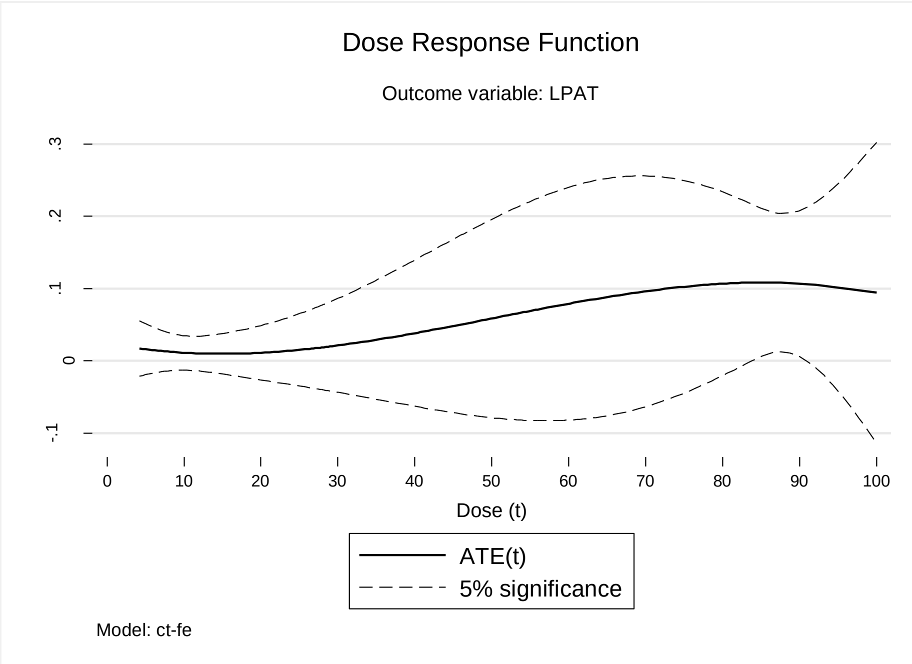
Finally, we observe what has been the impact of aid to R&D on the patenting activities of firms at regional level.

As already done, we run our model for the Overall sample, Northern-central and Southern regions. Results are shown in Graphs 7, 8 and 9. In the first case, the shape and the values of the DRF lead us to conclude that the impact of State Aid on the patent application is slightly positive but not significant. The only exception seems to be recorded for the lowest level of the treatment and between the 80^{th} and 95^{th} percentile. Focusing on Northern regions (graph 8) we can see a similar pattern of the DRF. However, in this case the confidence intervals are straddling the zero line indicating a non-significant effect of the treatment.

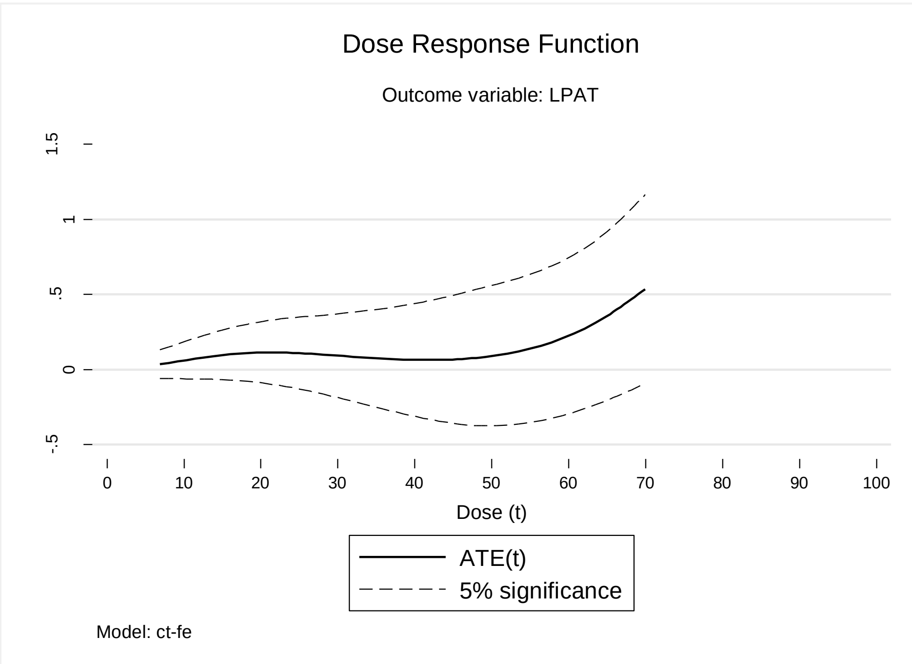
Graph 7. Dose Response function. Outcome variable: Patent. Overall sample



Graph 8. Dose Response function. Outcome variable: Patent. Northern-Central



Graph 9 Dose Response function. Outcome variable: Unemployment. South



The graph above (9) reports the dose response function of southern regions. Also in this case, the treatment seems to have non-significant effect. The DRF has positive values but the confidence intervals contain always zero thus indicating a non-significant impact of R&D aid to patent application.

The results of the regression (table 3 annex I) indicate that in all the three sample the coefficients of the treatment are positive but not significant.

Preliminary Conclusion

The analysis conducted so far has helped us to add some information on the study of public incentives to firms granted by regional authorities.

Even with some important limitations the paper is aimed at understand and describe the impact of regional R&D incentives to firms on a series of economic outcomes that are traditionally tied with "State aid" and which may have an important influence on the growth of the regional economy.

We have observed that regional incentives to firms may have produced a positive, even if modest, impact only on the ***numbers of employees*** engaged in R&D activities in private firms, but only on two of the samples considered, i.e. Southern regions and the Overall sample.

More controversial is the result for ***patent application*** and ***private investments*** in R&D, in which the impact seems to be negative even if non-significant.

Certainly, there are other factors that may have an influence on the efficiency and effectiveness of public transfer to enterprises, such as the continuity of a policy (avoiding of the frequent habit of the "stop and go") and the coherent design of the measure implemented.; however the results obtained in this analysis are showing a low additionality effect of public money and a severe risk of crowding out of private resources.

In the recent "State aid modernization reform" (SAM) the DG Competition has set up a system of rules in order to prevent the waste of public money. In particular, the reform increases transparency and accountability by introducing a new system for collecting data and by establishing compulsory counterfactual evaluation of large schemes.

Annex (I)

Table I. Regression results. Outcome variable: Private investments R&D

Private Investments	(9) Italy	(10) North	(11) South
Treat_d	-0.459	-0.008	-0.653
	(0.472)	(0.034)	(0.627)
GDP_1	0.002**	0.032	0.011
	(0.083)	(0.034)	(0.276)
CAP_STOCK_1	-0.373	-0.081	-0.434*
	(0.273)	(0.077)	(0.198)
PRIVATE_INV_1	0.435	0.108	0.597*
	(0.328)	(0.088)	(0.289)
EMP_1	-0.003*	-0.001	-0.005
	(0.002)	(0.008)	(0.009)
_ws_GDP_1	-0.021	-0.067	-0.854
	(-0.004)	(-0.001)	(-0.300)
_ws_CAP_STOCK_1	0.324	-0.086	0.596*
	(0.298)	(0.068)	(0.285)
_ws_PRIVATE_INV_1	-0.404	0.0431	-0.770*
	(0.353)	(0.086)	(0.359)
_ws_EMP_1	0.002	0.001	0.006
	(0.001)	(0.006)	(0.004)
Tw_1	0.031**	0.020**	0.053
	(0.013)	(0.008)	(0.044)
Tw_2	-0.004	-0.002	-0.019
	(0.000)	(0.000)	(0.001)
Tw_3	0.008	0.098	0.021
	(0.002)	(0.028)	(0.002)
Constant	13.05***	11.21***	9.441**
	(1.014)	(0.466)	(2.881)
Observations	344	230	106
R-squared	0.337	0.521	0.432
Number of id	21	14	7

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table II. Regression results. Outcome variable: Number of R&D employees

	(6)	(7)	(8)
Number of R&D employees	Italy	North	South
Treat_d	0.194*	0.032	0.181**
	(0.192)	(0.040)	(0.257)
GDP_1	0,001**	0,002**	-0,003*
	(0.265)	(0.008)	(0.003)
CAP_STOCK_1	0.016	-0.059	-0.009
	(0.127)	(0.075)	(0.173)
PRIVATE_INV_1	-0.007	0.094	0.061
	(0.149)	(0.085)	(0.199)
EMP_1	-0.008*	-0.002	-0.003
	(0.009)	(0.007)	(0.002)
_ws_GDP_1	0.076	-0.065	-0.076
	(0.004)	(0.000)	(0.006)
_ws_CAP_STOCK_1	-0.108	-0.090	-0.020
	(0.124)	(0.076)	(0.188)
_ws_PRIVATE_INV_1	0.083	0.026	-0.019
	(0.137)	(0.094)	(0.163)
_ws_EMP_1	0.019	0.024	0.001
	(0.005)	(0.002)	(0.012)
Tw_1	0.027***	0.025***	0.080*
	(0.036)	(0.007)	(0.035)
Tw_2	-0.004	-0.003	-0.002**
	(0.029)	(0.002)	(0.001)
Tw_3	0.046	0.089	0.008**
	(0.006)	(0.004)	(0.087)
Constant	7.103***	6.479***	5.316*
	(0.675)	(0.614)	(2.243)
Observations	344	230	106
R-squared	0.370	0.567	0.370
Number of id	21	14	7

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table III. Regression results. Outcome variable: Patent

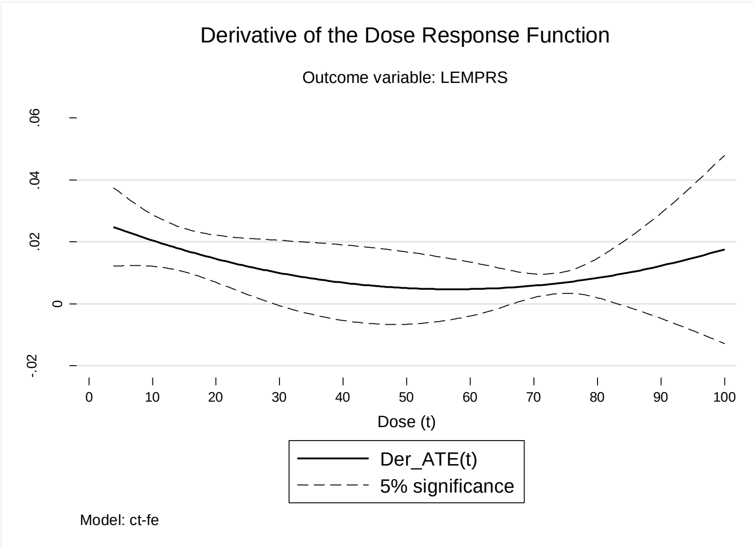
Patent	(2) Italy	(3) North	(4) South
treat_d	0.065	0.023	0.038
	(0.622)	(0.530)	(0.118)
GDP_1	0.001	0.003	0,034
	(0.000)	(0.015)	(0.118)
CAP_STOCK_1	0.056	-0.143	0.116
	(0.0778)	(0.115)	(0.151)
PRIVATE_INV_1	-0.048	0.198	-0.083
	(0.0916)	(0.128)	(0.141)
EMP_1	-0.005	0.043	0.001
	(0.000)	(0.001)	(0.001)
_ws_GDP_1	-0.043	-0.101	-0.087
	(0.001)	(0.003)	(0.004)
_ws_CAP_STOCK_1	-0.040	0.143	-0.167
	(0.090)	(0.116)	(0.124)
_ws_PRIVATE_INV_1	0.044	-0.186	0.122
	(0.105)	(0.135)	(0.135)
_ws_EMP_1	0.001	0.001	0.069
	(0.064)	(0.054)	(0.069)
Tw_1	0.001	-0.002	0.025
	(0.008)	(0.004)	(0.021)
Tw_2	-0.007	0.000	-0.009
	(0.002)	(0.001)	(0.007)
Tw_3	0.507	-0.560	0.000
	(0.113)	(0.001)	(0.117)
Constant	3.833***	3.804***	-1.779
	(0.744)	(0.925)	(1.889)
Observations	336	228	100
R-squared	0.512	0.672	0.771
Number of id	21	14	7

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

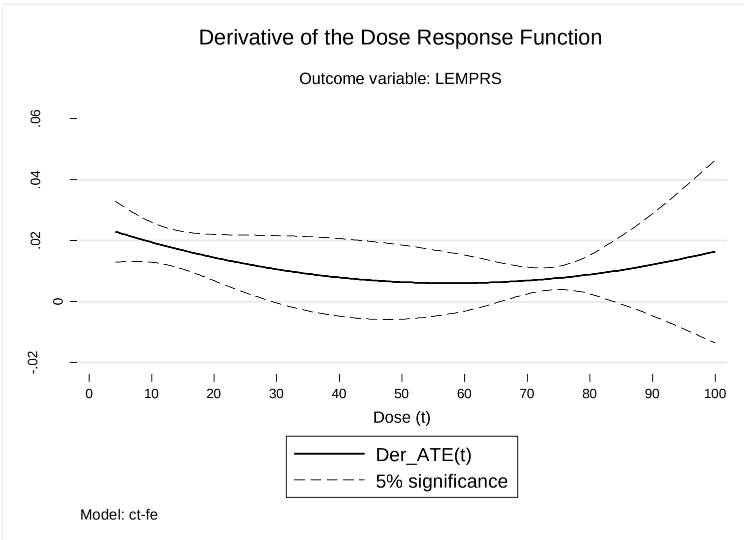
ANNEX (II)

In the graphs below we report the derivatives of the Dose response functions. The shape of the derivative indicates increasing or decreasing returns of the treatment.

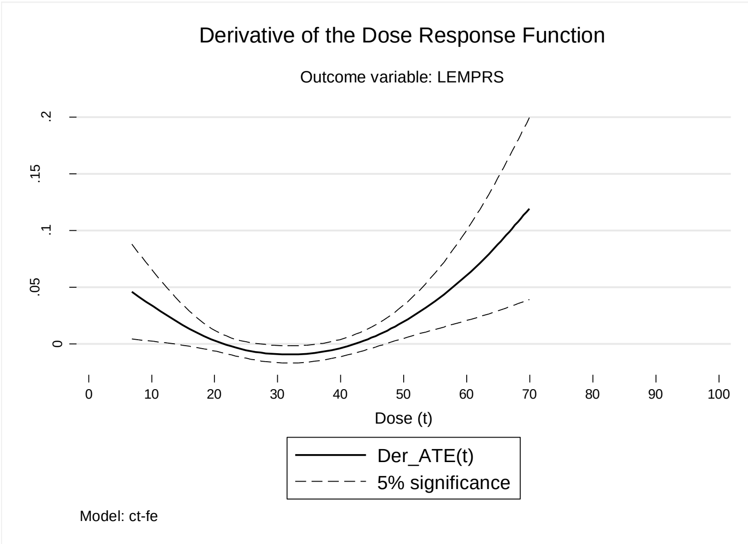
Graph 10 Derivative of DRF Outcome variable: Number of R&D employees. Overall Sample



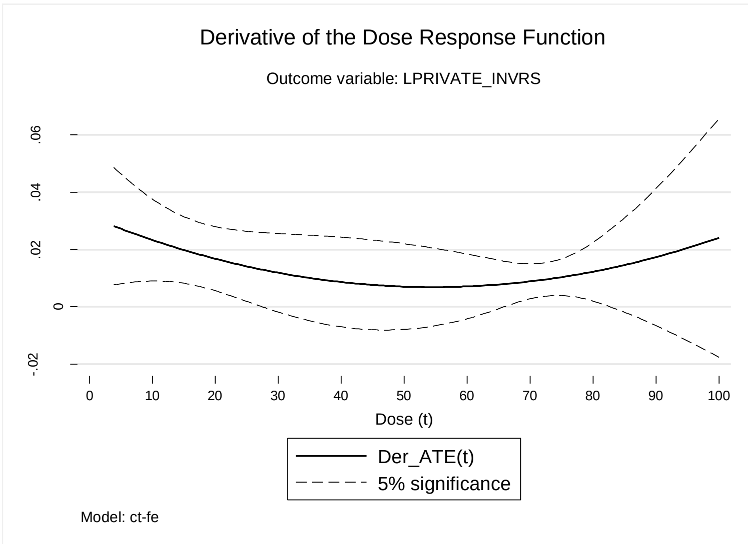
Graph 11 Derivative of DRF Outcome variable: Number of R&D employees. North



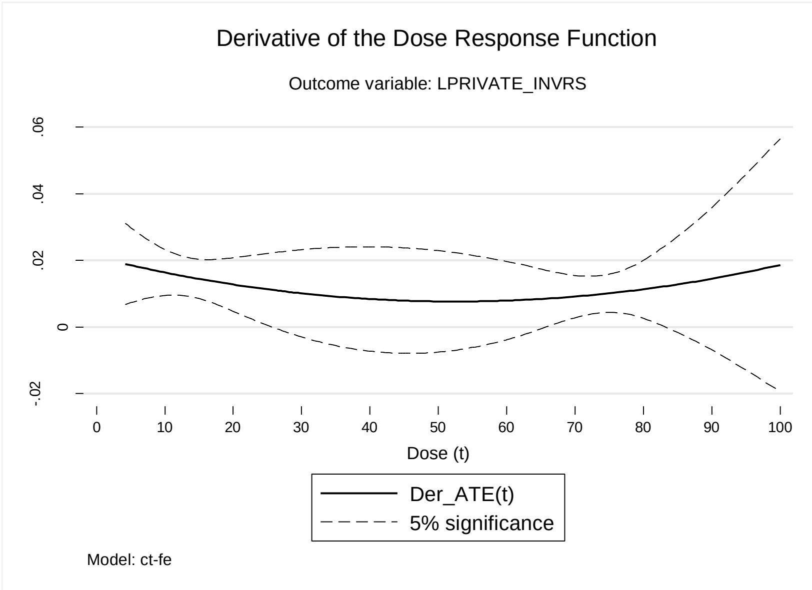
Graph 12 Derivative of DRF Outcome variable: Number of R&D employees. South



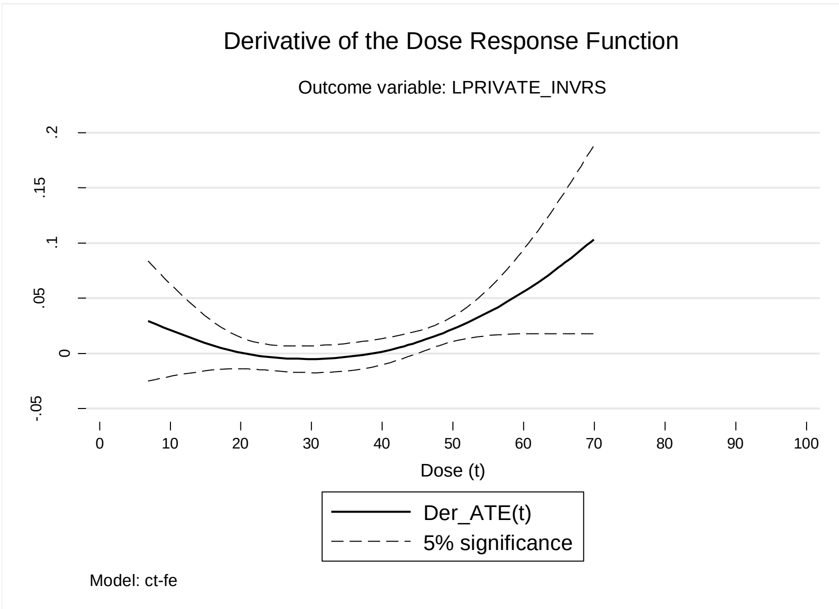
Graph 13 Derivative of DRF Outcome variable: Private investments in R&D. Overall sample



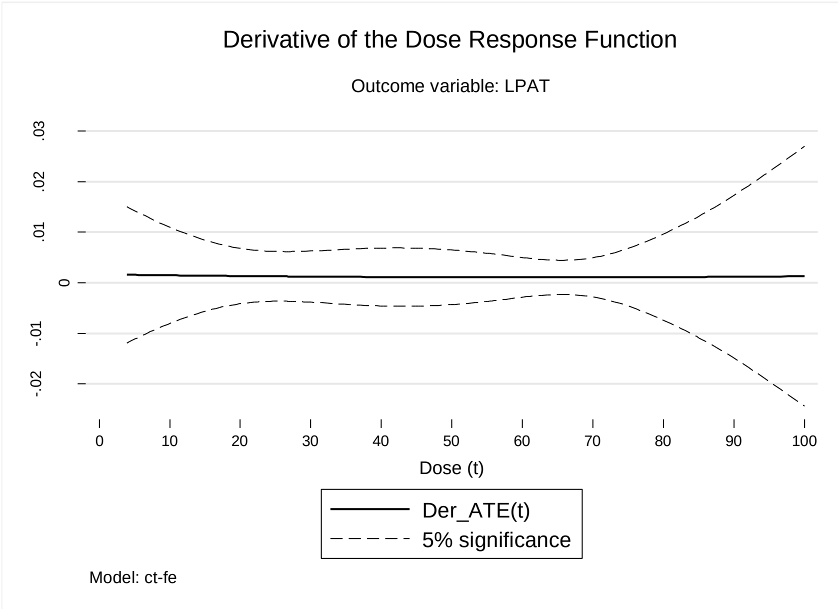
Graph 15 Derivative of DRF Outcome variable: Private investments in R&D. North



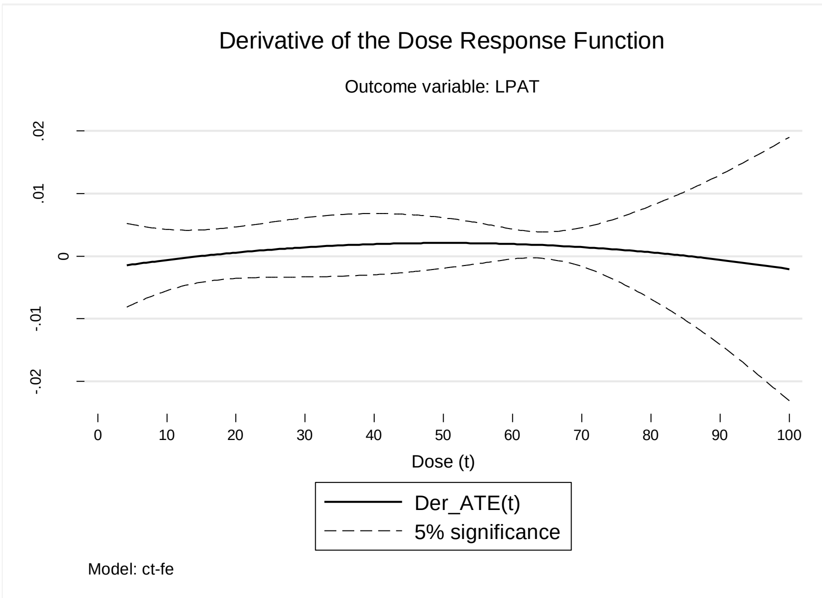
Graph 15 Derivative of DRF Outcome variable: Private investments in R&D. South



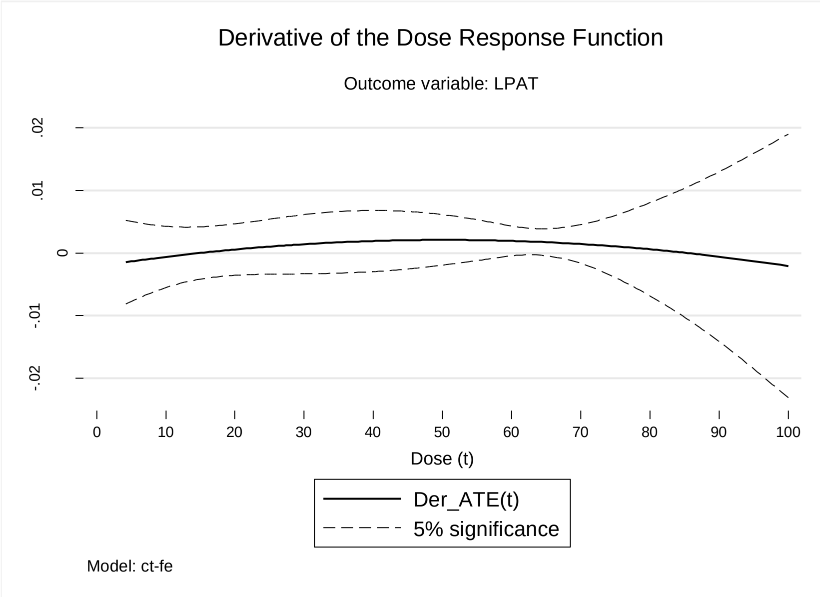
Graph 15 Derivative of DRF Outcome variable: Patent application. Overall sample



Graph 16 Derivative of DRF Outcome variable: Patent application. North



Graph 17 Derivative of DRF Outcome variable: Patent application. South



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