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Evaluating the Additionality of Innovation Policy. An Investigation at Different Levels of Analysis

by

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1
Introduction

Since the mid 90s (European Commission, 1995) and, in particular, with the definition of the Lisbon Strategy in 2000 (European Council, 2000), innovation policy has been definitely set at the core of the regional, national and EU strategies aimed to increase the competitiveness and the growth of the European economic systems. Given that, at the prospected deadline (2010), the EU had not reached the target of becoming the "most competitive and dynamic knowledge-based economy in the world", the support to innovation still remains a focal issue in the European economic policy-making at all the territorial levels it is made: European, national and regional. The new Europe 2020 Strategy (European Commission, 2010) reinforces the support to a "smart growth" based on knowledge and innovation. In particular, within the "Innovation Union" flagship initiative, different kinds of innovation policies are expected to improve the framework conditions for the innovation process to take place. The access to finance for research and innovation, the cooperation among the actors of the knowledge "triangle" (research, innovation and education) are some of the most notable examples. As for the objectives, the setting-up of the R&D intensity target of 3% by 2020 has been followed up by the search (in particular, within the EU DG Research and Innovation) of a broader set of headline indicators that can guide policy actions (e.g. the share of fast growing -or young- and innovative firms in the economy) (High-Level Panel on the Measurement of Innovation, 2010).

The severe economic crisis that invested Europe in 2007, and its latest repercussion on the debt crisis of the Member States of the EU, puts this policy strategy at a stake and implies the need for a very efficient and effective use of the scarce public resources available. With this respect, the need emerges to increase the accuracy with which innovation policies are evaluated. Indeed, not only the evaluation of innovation

programmes is relevant in terms of assessment purpose. Evaluation is also a policy-learning tool (e.g. Arnold, 2004) that can offer lessons to future policy schemes, shedding light on the determinants of the success or failure of the public interventions.

The assessment of the innovation policy effects is the issue at stake in this Thesis. In a system-kind of perspective innovation policy is meant as the set of public interventions that can be implemented to support the innovation process of different organisations and, in a broader perspective, the innovation performances of the systems these are part of. Despite this large definition, however, in the present Thesis particular emphasis will be devoted to the evaluation of the policy support to firms' innovation activities.

To be sure, the evaluation of innovation policy is nowadays a large research field, which crosses the borders of different scientific disciplines in the academia (e.g. economics, statistics and econometrics, sociology, political sciences, environmental studies, etc…) and also reaches the realm of practitioners' analysis. The evaluation of innovation policy can be inspired by a formative and/or a summative purpose: the former is oriented towards discourse, monitoring, programmes improvements and stakeholders' feedbacks; the latter is more oriented towards the judgment of facts and "hard" evidences. When evaluating an innovation policy intervention different impacts can be considered too: scientific, technological, economic, social and environmental (Edler et al., 2010). Several methodologies can be employed, including qualitative, semi-qualitative and quantitative techniques (Piric and Reeve, 1997). Furthermore, different types of evaluation are focused on different stages of the publicly supported projects: ex-ante evaluations occur prior the project is launched; ongoing/*in itinere* assessments concentrate on the results obtained during the implementation of the projects; ex-post evaluations take place once the projects are concluded and the results can be tracked (Capron and van Pottelsberghe de la Potterie, 1997). Although all the approaches have their own rationales and advantages (along with disadvantages), this Thesis focuses on a specific type of ex-post impact assessment, adopting a quantitative approach in its empirical applications. More precisely, focusing on the (techno-)economic impact of the public intervention, the Thesis investigates the additionality effects of the innovation policy. In other terms, it is concerned with the extent to which the policy "supplements" the innovation activities, performances and behaviours of the beneficiaries. This focus is motivated by the capacity of the additionality evaluation to capture the net effects directly generated by the public intervention, comparing the actual situation after the

implementation of the policy with an hypothetical counterfactual condition in which the policy has not been implemented (or it is implemented with a lower support).

The attention on the additionality of the public support to innovation activities dates back to the standard neoclassical theory rooted in the marginalist equilibrium tradition (Colander, 2000). Within this approach, innovation policy is aimed at overcoming the underinvestment in innovation activities generated by the presence of market failures, such as externalities, uncertainty, indivisibilities and increasing returns (Nelson, 1959; Arrow, 1962). In this perspective, the public intervention is justified by its capacity to stimulate an additional private investment in innovation activities in order to reach the social optimum. This idea underpins the evaluation of what has been called the "input additionality". This is focused on the amount of innovation inputs, as the R&D investment, that would not have been allocated without the policy. While the analysis of the input additionality is the most popular, also because of its straightforward consistency with standard neoclassical approach, the present Thesis enriches it by considering that the additionality of the innovation policy is actually manifold and should extend to other two dimensions. The first one, still originated in the neoclassical approach, is called “output additionality” and concerns the amount of innovation outputs or outcomes that would not have been reached without the public support. The second one, the “behavioural additionality”, is focused on the strategic and behavioural changes directly induced by the policy.

Drawing on a recent strand in the literature, developed upon the contribution by Buisseret et al. (1995), particular attention is devoted to this latter dimension. Although the precise definition of behavioural additionality is still somehow fluid, its analysis represents an essential complement to that of the input and the output dimensions. Indeed, looking at the behavioural changes induced by the policy, it is possible to provide an evaluation that takes into account the effects occurring within the “black box” of the beneficiaries and, thus, better understand how additional inputs are used and additional outputs obtained. In particular, in assessing the behavioural additionality the focus is on both the internal organisation of the beneficiaries’ innovation process and on their relations with external sources of knowledge.

As will be illustrated within the Thesis, the multi-dimensional analysis of the additionality and, in particular, the focus on the behavioural dimension represents the most important added value of the research. This allows for an evaluation which is firmly anchored in an evolutionary theoretical background and in the literature on innovation

systems, according to which policy intervention is not simply aimed at overcoming the underinvestment in (and underproduction of) innovation. More precisely, whereas according to the standard neoclassical approach public support has to promote individual innovation events -by reallocating in an efficient way resources to firms-, according to the evolutionary approach and the innovation system perspective policy should enhance innovation capabilities and promote framework conditions in which innovation systems can better self-organise themselves (Metcalfe, 2005). In this sense, the analysis of the behavioural additionality is particularly useful, as it sheds light on the impact of the policy on beneficiaries' learning process, accumulation of new or diverse capabilities and relationships with external actors and sources of knowledge (e.g. Georghiou and Clarysse, 2006; Hall and Maffioli, 2008; Breschi et al., 2009).

In addition to a multi-dimensional analysis of the additionality effects of the innovation policy, the present Thesis provides other original contributions to the existing literature. At first, in terms of level of analysis. More precisely, the Thesis, in its empirical applications devotes particular attention to the level of public intervention. Focusing on Italy and Spain, the Thesis investigates the effects of the multi-level systems of policy and analyse the relation between the impacts generated by the regional and the national public support schemes. Furthermore, the Thesis also directly analyses the effects of the regional innovation policy, focusing on the R&D subsidy implemented in the Emilia-Romagna NUTS 2 region of Italy. Another main originality of the Thesis lies in the methodological approach implemented, which also allows for the analysis of issues that have been scarcely investigated in previous contributions. The likely presence of the selection bias in the econometric estimation of the additionality (i.e. the average treatment effect on the treated) is controlled for, by employing a set of propensity score matching estimations. Moreover, two methodological developments are proposed. First, a tentative investigation of the relation between the average impact of the policy and the dispersion of the effect across the beneficiaries. Second, an application of the generalised propensity score to investigate the effects generated by an increasing amount of subsidy, rather than by the participation in the policy as a such.

The Thesis is a collection of three essays. Although these address specific issues and topics, they are also characterised by interconnected research objectives that will lead to general concluding remarks. The first paper (Chapter 2) provides an updated review of the theoretical and empirical contributions dealing with the additionality of the innovation policy, devoting particular attention to its behavioural dimension. The paper investigates,

at first, whether this dimension, which is not uniquely conceptualised in the literature, can be used to assess innovation policies consistently with the evolutionary theory and the related innovation system perspective. More precisely, the paper analyses the extent to which the concept of behavioural additionality can be used to evaluate the capacity of the policy to mitigate the system failures (e.g. Smith, 2000; Metcalfe, 2005; Malerba, 2009). Moreover, the paper considers some key aspects that should be taken into account when evaluating the behavioural and strategic changes induced by the policy intervention. Particular emphasis is put also on the likely relations that might emerge between the behavioural and the other two dimensions of the additionality (i.e. input and output). As for the review of the empirical contributions, in addition to the presentation of the main behavioural additionality effects that innovation policy interventions can induce, the paper analyses two key issues. On the one hand, what are the econometric methods that are used to deal with the specific methodological problems characterising the evaluation of the innovation policy (e.g. selection bias). On the other hand, how the concept of behavioural additionality is operationalised in the left-hand side of the econometric specifications, i.e. which are the outcome variables used to proxy the behavioural changes induced by the policy. Some very recent empirical contributions employing alternative quantitative approaches, or not directly aimed at evaluating the behavioural additionality are also presented.

The second paper (Chapter 3) proposes the first empirical application provided in the Thesis. Based on data stemming from the 4th wave of the Community Innovation Survey (CIS4, 2002-2004), it aims at investigating the multi-dimensional additionality effects of the public support to firms' innovation activities. To this purpose the paper is focused on the policy interventions, both regional and national, implemented in Italy and Spain. The review of the previous econometric studies supports the need for such an analysis. Prior works employ different methodologies based on different data and sometimes consider different specific policy programmes. Due to this, (even intra-country) comparisons are hardly possible. What is more, none of these previous works provides a comprehensive analysis of the different types of additionality effects that innovation policy can stimulate. In addition to a multi-dimensional approach aimed at analysing the three additionality dimensions, the paper adopts a multi-level perspective. This latter finds its theoretical and empirical anchorage in recent contributions, which consider innovation as a phenomenon that is shaped by institutions and policy interventions initiated at different levels (e.g. Cooke, 2002; Kaiser, 2003). By adopting

this perspective, the paper analyses the relations between regional and national policies, investigating whether the two levels of public support overlap in the additionality effects they produce. This kind of analysis seems to be particularly appropriate in the case of the two countries considered in the paper. Indeed, both in Italy and Spain, national and regional policies are implemented according to different objectives and modalities (Cefis and Evangelista, 2007; Garcia-Quevedo and Afcha-Chávez, 2009; Barbieri et al., 2010; Afcha-Chávez, 2011). The paper tries to address also another issue that is still relatively under-investigated in the literature. Whereas the majority of the contributions are focused on the average impact of the participation in the policy, it is not clear whether a high average level of additionality is associated to a high or low dispersion of the policy effect across the beneficiaries. With a tentative investigation, the paper analyses whether a given average impact is generated by the concentration or, instead, by the polarisation of the effects on the single beneficiaries. As for the econometric strategy, the analysis of the additionality is carried out with a set of propensity score matching estimations of the average treatment effect on the treated (ATT). This methodological approach, developed upon the seminal contribution by Rosenbaum and Rubin (1983), allows for the reduction of the selection bias, by controlling for the selection on the observables. Different matching procedures developed in the literature (e.g. Becker and Ichino, 2004; Cameron and Trivedi, 2005; Smith and Todd, 2005; Caliendo and Kopeinig, 2008) are applied to support the robustness of the results. As for the tentative analysis of the relation between the average additionality impact and the dispersion of the policy effect, this is based on the Spearman's rank correlation coefficients between the rank of the ATTs, calculated for each additionality indicator, and the rank of the corresponding coefficients of variation.

The third paper included in the Thesis (Chapter 4) considers other aspects related to the additionality of the innovation policy and is characterised by another level of analysis. It is focused on the effects of a specific regional R&D subsidy, implemented in the Emilia-Romagna NUTS 2 region of Italy. Using data collected through an *ad hoc* survey and merged with balance sheets information, the paper addresses two main issues. At first, it tests whether the public support to R&D activities stimulates changes in firms' behaviours that might reduce potential system failures occurring (also) at the level of the beneficiaries: problems in learning processes; problems due to missing or inappropriate connections; unbalanced evolutionary trade-offs that can lead to lock-ins. With respect to this latter type of failure, drawing on recent contributions (e.g. Bathelt et al., 2004; Gertler and Levitte, 2005; Boschma and ter Wal, 2007; Uyarra, 2010), the paper

investigates the capacity of the policy to open-up the regional innovation system to the diverse knowledge lying outside the regional borders. In addition to this, the paper focuses on a specific type of effect induced by the policy: the impact on the geographical range of the cooperation with research partners (i.e. universities and research institutes). In doing this, it departs from the standard analyses of the policy effects, as it investigate the impact generated by an additional amount of subsidy rather than by the participation in the policy as a such. Drawing on recent works (Belussi et al., 2010; D'Este and Iammarino, 2010; Laursen et al., 2011), the paper assumes that the more advanced and exploratory is the research that firms are looking for, the narrower is the choice of suitable partners in their proximity. However, in the case of a cooperation with a distant partner the lack of geographical proximity might increase the cost of the interaction. Moving from here, the paper investigates whether an increase in the amount of public support, allowing firms to face the higher cost of a distant cooperation, enhances the propensity to extend the range of the interactions also beyond the regional borders. In addressing these specific objectives, the paper makes use of a twofold econometric strategy. On the one hand, to estimate the different behavioural changes induced by the regional policy, a set of propensity score matching estimations is implemented. On the other hand, to investigate the impact of an increasing amount of subsidy on the cooperation with research organisations a more sophisticated approach is used: the generalized propensity score (Hirano and Imbens, 2004). For each level of subsidy, this estimates the effects induced by an additional amount of public support on three cooperation strategies: no cooperation, cooperation with a regional research organisation, cooperation with an extra-regional research partner.

At the end of the Thesis, a concluding section (Chapter 5) presents the results of the three papers and their main implications. Particular attention is devoted also to the definition of the future lines of research, which this Thesis has not addressed, due the lack of proper data and robust methodologies. These pertains to three relevant aspects which, by now, are still under-investigated in the literature. At first, the empirical analysis of the likely synergies existing among the three additionality dimensions. Second, the effect of the policy on the reduction of the barriers that hamper firms' innovation performance. Third, the analysis of the distribution of the policy effects.

2

Evaluating the additionality of innovation policy: what do we know about the behavioural dimension? A literature review [*]

Abstract

The paper aims at providing a literature review and a critical discussion of the additionality of innovation policy: that is, the net effects of the public support that would not have occurred in its absence. In particular, the paper focuses on the behavioural dimension of the additionality concept, i.e. the strategic and behavioural changes induced by the policy. In the first part, the paper argues that the behavioural dimension, though not yet clearly defined, provides a necessary complement to the input and output ones, in order to assess innovation policies consistently with the evolutionary theory and the related innovation system perspective. In the second part, the paper organises and reviews the recent econometric and quantitative works that have tried to measure the behavioural additionality of the policy in empirical studies. In so doing, it presents some of the main behavioural changes that have been found to be induced by innovation policy interventions, as well as some methodological issues, which characterise the investigation of the behavioural additionality.

1 Introduction

Innovation policy is nowadays at the core of the governmental strategies aimed at increasing the performances of the economic systems, supporting in particular their growth and competitiveness (e.g. Hall and Maffioli, 2008; European Commission, 2010). This relevance, particularly in a time of severe economic crisis and public resources scarcity, increases the importance of assessing whether and to what extent public monies generate significant results. To this aim, an increasing amount of work has been devoted to evaluate innovation policy with different purposes (formative vs. summative), considering different impacts (e.g. economic, social, environmental, scientific), stages of

[*] The paper included in the present Thesis is the result of the PhD candidate's work only. An updated version has been accepted for publication (forthcoming 2012) in the *World Review of Science, Technology and Sustainable Development*. Only the paper submitted for publication has been co-authored by Davide Antonioli (Faculty of Economics, University of Ferrara). A declaration by the co-author, confirming this point, has been presented to the Secretariat of the Doctoral School.

the publicly funded innovation projects (ex-ante, ongoing/*in itinere*, ex-post) and employing different methodologies (i.e. qualitative, semi-qualitative and quantitative) (e.g. Capron and van Pottelsberghe de la Potterie, 1997; Piric and Reeve, 1997; Edler et al., 2010).

This paper contributes to the literature on the evaluation of innovation policy, by focusing on a specific type of ex-post assessment, mainly summative and focused on the (techno-)economic impacts: the analysis of the additionality of the public support. The main advantage of this type of investigation, when compared to the other evaluation approaches, is that of providing an analysis of the net effects generated by the public intervention. In general terms, the analysis of the additionality is aimed at comparing the actual situation emerging after the implementation of the policy with a hypothetical situation in which the policy has not been implemented. Drawing on the seminal contribution by Buisseret et al. (1995), the present work considers the additionality concept as a multi-dimensional notion and provides an updated review of the theoretical and empirical contributions dealing in particular with the behavioural additionality dimension (i.e. the behavioural and strategic changes induced by the policy), rather than with the input and output ones.

This type of work, which at the best of our knowledge has not been provided yet, offers a twofold contribution to the existing literature, which is still characterised by a certain blurriness in the definition of the behavioural dimension of the additionality concept. First, the paper proposes a theoretical guidance to the behavioural additionality evaluation. As it will be argued in the following, this latter, being consistent with the evolutionary and system perspectives provides a necessary complement to the assessment of the input and output additionality dimensions, initially developed upon the standard neoclassical theorising. The analysis of the effects on the R&D investment and on the innovation outputs achievement (i.e. the focus of the input and output additionality dimensions, respectively) do not completely lose their importance when adopting an evolutionary approach and an innovation system perspective. However, these latter call for an evaluation that takes into account a broader range of effects that pertain to the beneficiaries' competencies, capabilities and relationships with external actors. The second aim of the present paper is that of providing a review of the recent empirical works that analyse, with econometric and quantitative methods, the strategic and behavioural changes induced by the policy intervention. With this respect, the paper, dealing also with some relevant methodological issues, presents the main behavioural

additionality effects that can be generated by the public support to innovation. This focus is particularly important for future contributions, because quantitative approaches, so far, have been less extensively used to analyse the behavioural additionality than the input and output dimensions (Georghiou, 2004).

The reminder of the paper is organised as follows. Section 2 introduces the input and output additionality dimensions originated from the standard neoclassical approach. Section 3 begins with an overview of the system failures rationale arising from the evolutionary theory and the related innovation system perspective; then the analysis emphasises that the behavioural dimension of the additionality concept, though sometimes too broadly defined, can be used to evaluate innovation policies according to these heterodox perspectives. At the end of the section some key aspects that should be considered when analysing the behavioural additionality are also presented. Particular attention is devoted to the analysis of possible synergies between the three dimensions of the additionality. Section 4 is focused on the empirical literature. After a brief outline of the main econometric problems in the analysis of the additionality of a policy intervention, the section presents the main results, characteristics and methods of the empirical contributions that employ quantitative approaches to investigate the behavioural additionality. Section 5 concludes.

2 Additionality in a neoclassical perspective: the input and output dimensions

2.1 The market failures framework

The most relevant additionality dimensions in an innovation policy evaluation, as well as the objectives and means of the public intervention, depend on the theoretical background. Following a neoclassical perspective, the focus of the evaluation should be on whether the policy has been able to overcome the underinvestment in, and the underproduction of, innovation. In an additionality perspective the focus is on what have been called, respectively, input and output additionality.

According to Colander (2000) six main attributes characterise the standard neoclassical tradition in economics: the attention on the allocation of resources in a given moment in time; some forms of utilitarianism as playing a central role in understanding the economy; the focus on marginal trade-offs; the farsighted rationality of economic actors; the methodological individualism centred on maximising actors; the presence of a

general equilibrium[1]. Within this general theoretical background, the seminal contributions by Nelson (1959) and Arrow (1962) introduce the innovation policy foundations in a neoclassical perspective. Nelson (1959), stressing that basic research activities are characterised by externalities and uncertainty, claims for a direct intervention of the government in order to overcome the private underinvestment in research. According to Arrow (1962), due to non-perfect appropriability, uncertainty, indivisibility and increasing returns, there is a systematic difference between private and public returns to innovation. The underinvestment in innovation activities resulting from these market failures implies that innovation policy should be aimed at stimulating a certain amount of private investment in R&D in order to reach the social optimum.

In addition to this, another implication emerges when considering the underlying linear relation between innovation inputs and outputs (e.g. Edquist, 1999; Etzkowitz and Leydesdorff, 2000), according to which the upstream phases of the innovation process are unidirectionally linked to the downstream ones. Within this perspective, an underinvestment in R&D, caused by the presence of market failures, leads to an underproduction of innovation. What emerges is that innovation policy is also eventually aimed at increasing the amount of innovation outputs produced by private actors.

The neoclassical rationale has inspired three broad groups of policy interventions (e.g. Dasgupta, 1987, 1988; Swann, 2009): subsidies (or tax credits) to raise private incentive to innovate; institutions that create and enforce propriety rights, government expenditure or procurement to promote innovation activities not carried out by private actors.

2.2 Input and output additionality dimensions

With respect to the first type of intervention defined above, i.e. subsidies or tax credit, the main concern is on the input additionality of the policy: whether the resources provided to the firms are additional to those that would have been allocated also in absence of the intervention. In other terms, the focus is on the amount of innovative inputs (e.g. R&D investment) that would not have been allocated without the policy (Georghiou, 2002, 2004; Clarysse et al., 2004). When the input additionality is the focus of the evaluation, the objective of the analysis is to understand whether the policy has generated additional

[1] These features have evolved over time: the characteristics of the modern mainstream economics sometimes deviate from these six pillars. See Colander (2000) for a detail.

R&D expenditures or whether it has crowded-out the private investment in innovation; in its strict definition, input additionality emerges in cases in which the additional R&D investment activated by the policy is higher than the subsidy received[2] (Cerulli, 2010).

Despite the literature on the input additionality of public support schemes is mainly "empirically-oriented" (David et al., 2000; Cerulli, 2010), at least three contributions (Usher, 1994; David et al., 2000; Hall and Maffioli, 2008) present interesting theoretical insights, which are worth mentioning. Usher (1994) proposes a set of theoretical rules for a test of "ideal incrementality" (Lipsey and Carlaw, 1998, p. 45). Accordingly, the funded project must be the least costly way to undertake the desired level of R&D investment, social benefits must exceed the subsidy (including transaction costs, deadweight losses and other leakages) and discounted benefits must exceed the discounted cost of intervention. David et al. (2000) investigate the effects of the public intervention on the interplay between the marginal rate of return (MRR) on investment in R&D and the marginal cost of capital (MCC), which reflects the opportunity cost of investing in R&D. In the simple case of a direct subsidy, for instance, the shift of the upward sloping MCC curve results in a higher R&D investment, particularly in the case of internal financial constraint. Another theoretical analysis of the input additionality can be found in Hall and Maffioli (2008). In their model, firms face a downward sloping demand for R&D and a supply cost of R&D that is flat until the innovative projects are internally funded, then jumps up to the cost of external funds and increases the more external funds are needed. The implication of the model is that crowding-out is a possibility for firms that rely on internal funds, but it is unlikely for those that are financially constrained.

Although the concept of input additionality is quite straightforward, it presents some limitations and criticalities. Bach and Matt (2005) refer to three cavalier assumptions upon which the estimation of the input additionality is based: the clear link between innovation inputs and outputs; the presence of divisibility and constant returns to scale of the innovation activity; the fact that the nature of the outputs generated by public funds and private funds is the same. However, the main argument against the input additionality evaluation is related to the fact that this is simply concerned with the effects

[2] This perspective can face a practical limitation when the researcher does not have information on the precise amount of the subsidy received by the beneficiaries. In this case, when only a binary treatment status is available, it is possible at most to estimate the amount of resources that would not have been allocated without the policy.

of the policy on the allocation of resources. In other terms, input additionality does not consider at all the impacts on the organisational aspects, the behaviour of the beneficiaries and the improvement of knowledge and capabilities, which are in fact at the core of the behavioural additionality evaluation.

As mentioned at the beginning of the section, due to the linear innovation model characterising the neoclassical approach (e.g. Edquist, 1999; Etzkowitz and Leydesdorff, 2000), market failures are expected to generate also an underproduction of innovation. Hence, policy intervention is eventually aimed at increasing the amount of innovation outputs produced by private actors. In this sense, a second dimension of the additionality concept emerges: the output additionality. This is focused on the proportion of outputs that would not have been achieved without the policy intervention (Georghiou, 2002, 2004; Georghiou and Clarysse, 2006). The fact that output additionality is consistent with the market failures framework is, in a sense, stated also by Lipsey and Carlaw (1998), who refer to the "narrow test of incrementality" (p. 45) as the test that has to be performed according to the neoclassical perspective. This is concerned with the extent to which some technology is actually developed or installed due to the intervention under consideration.

A first problem in the evaluation of the output additionality is related to the definition of what innovation outputs actually are. Indeed, innovation activities can have a number of different results (e.g. Hsu and Hsueh, 2009). As it could be difficult to estimate a direct causal relation between the policy intervention and long-term or macro effects -due to the problems in isolating these impacts from the general economic background "noise"-, Buisseret et al. (1995) claim for an analysis which is focused on the microeconomic effects of the policy intervention. These latter, which are more directly measurable, can be the outputs of the supported projects (e.g. reports, papers, patents, prototypes, business plans) and their outcomes (e.g. improved business performances as resulting from the introduction of new products, processes, services) (Georghiou, 2002).

In addition to this issue, another important limitation emerges. Output additionality relies on the strict assumption of a clear linear link between inputs, allocated with the support of the policy funding, and outputs. This link is much more complex, unpredictable and needs to be investigated in depth, looking also at the internal behaviour of the supported organisations (Georghiou and Clarysse, 2006). In fact, as it will be shown below, this aspect is crucial in the behavioural additionality evaluation.

3 Additionality in the evolutionary and system perspectives. The behavioural dimension

Following an evolutionary perspective to innovation, policy has to reach other objectives and is expected to achieve also other additionality effects. In order to make this point explicit, it is useful to introduce the innovation policy foundations emerging from the evolutionary theory and the related innovation system perspective[3].

3.1 Evolutionary and system foundations: the system failures framework

It is out of the scope of this work to present in detail the main contributions arising from the vast evolutionary theory (see, among the others, the comprehensive review by Fagerberg, 2003). However, some key aspects can be outlined briefly here, with the aim of providing an introduction to the system failures rationale for the innovation policy. First, in the evolutionary approach, economic actors are seen as heterogeneous and routine-based "behavioural innovators" that behave differently according to their specific competencies and to their particular strategic, cognitive and organisational aspects (Metcalfe, 1995). The root of this idea can be found in the seminal work by Nelson and Winter (1982). Criticizing the idea of perfect rationality, they argue that firms base their decisions on the, so-called, bounded rationality; firms behave following rules (i.e. routines), which are heritable, selectable and which represent the organisational memory of the economic agents. Another key element that characterise the evolutionary approach is the analogy with biology (e.g. Dosi and Nelson, 1994): neo-Schumpeterian evolutionary theory devotes particular attention to the mechanism that determine the selection process of genotypic elements (e.g. technologies, organisational routines), and the mechanism that determines the mutation in the population of the same genotypes. The relation between these two mechanisms is dynamic, two-way and characterised by positive and negative feedbacks (Metcalfe, 1994). The resulting process of innovation, which in an evolutionary perspective is characterised by trials and errors and radical uncertainty (e.g. Metcalfe, 1995) is represented at the micro-level by a chain model (Kline and Rosenberg, 1986). Accordingly, different phases, both internal and external to

[3] In the system perspective, innovation is characterised as an evolutionary process (Edquist, 2005). Malerba (2009) points out that the system perspective is complementary to the evolutionary approach, linking the relevance of learning, competencies and heterogeneity of actors to the importance of the relations and interactions among them.

the firms, are complementary and interconnected through positive and negative feedbacks.

Stemming from the evolutionary micro-foundations, the innovation system perspective (e.g. Freeman, 1987; Lundvall, 1992; Nelson, 1993) has further enriched the analysis of the innovation process, devoting particular attention to the institutional setting and the framework conditions that support firms' innovation activities. Accordingly, firms do not innovate in isolation, but interacting and collaborating with other actors, both public and private. More precisely, the constituents of an innovation system are, on the one hand, the components (i.e. organisations and institutions) and, on the other hand, the interactions among these (Edquist, 2005).

The emergence of the evolutionary approach and the innovation system perspective has led to rethink the role of the policy intervention, providing a comprehensive analysis of the policy rationale. Whereas according to the neoclassical framework public support has to promote individual innovation events by allocating in an efficient way resources to firms, according to the evolutionary and system perspectives policy should enhance innovation capabilities and promote framework conditions in which innovation systems can better self-organise themselves (Metcalfe, 2005). In this perspective, innovation policy is not simply justified by an under-supply -and underproduction- of knowledge and innovation, but by the presence of "areas of systematically weak performances" (i.e. system failures) (Smith, 2000, p. 94).

Two macro-categories of failures can be identified in the literature. The first one pertains to failures in the creation of knowledge and in the evolutionary process of innovation. At first, the innovation performance of a system can be hampered by problems in learning processes and in the accumulation of capabilities (Malerba, 2009). These can be due to an insufficient level of human capital and R&D -here considered also as a mean to enhance the capacity to absorb external knowledge (e.g. Cohen and Levinthal, 1989)-, or to the lack of technical and market knowledge among the population of firms. Furthermore, systems can fail in case of unbalanced evolutionary trade-offs between exploration and exploitation or variety and selection. In a situation in which low exploration is associated to high exploitation, firms tend to concentrate on what they know best, disregarding new alternatives. In this case, existing core capabilities (i.e. the knowledge set that distinguishes and provides the firms with a competitive advantage) essentially act as rigidities (Leonard-Barton, 1992). Hence, there emerges a limited capacity to adapt to technological changes, particularly if these are radical and

discontinuous (Smith, 2000; Malerba, 2009). The trade-off between exploration and exploitation is linked to the more general tension between variety and selection that characterises the evolutionary process of innovation (Nelson and Winter, 1982; Metcalfe, 1994). The main risk is that tough selection is associated to low variety. This can result in lock-in positions into inferior technologies, which can be extremely difficult to be reversed due to the path-dependence generated by network externalities and by the fact that technologies are embedded in the overall social and economic environment (Smith, 2000).

Moving to the second category of failures, which pertains to the structure and the configuration of the system as a whole, it is possible, at first, to define the institutional failures (Smith, 2000). These pertain to the weak functioning of both formal institutions (e.g. regulations, standards, laws, etc...) and informal institutions (e.g. social norms and values, cultural aspects, trust, willingness to cooperate, etc...)[4] (Smith, 2000; Woolthuis et al., 2005). As the innovation system perspective is based upon the idea that a number of components are crucial actors in the innovation process, system can fail also because of missing or inappropriate components. The lack of (appropriate) components is none other than the unavailability of knowledgeable individuals and minds within both firms and research organisations (Metcalfe, 2005). When components are inappropriate or missing, systems may be trapped in vicious cycles of low interactions and learning, instead of developing dynamic complementarities (Malerba, 2009). As noted by Edquist (2005), interactions and relations among components represent a crucial constituent of innovation systems. Hence, systems may fail also because of missing or inappropriate connections (Metcalfe, 2005; Malerba, 2009). On the one hand, weak interactions limit interactive learning, the possibility to create a shared vision of future technological developments and the coordination of efforts among formally independent actors (Carlsson and Jacobsson, 1997). However, system failures may emerge also because of too strong networks, which can generate inertia, myopia, internal orientation, thus enhancing the risk of being locked into existing trajectories (Woolthius et al. 2005). Finally, drawing on Smith (2000) it should be taken into consideration that other failures may emerge in case of problems related to infrastructural investment and provision; these are generated by specific technical features characterising the investment in infrastructures (e.g. long term

[4] It is beyond the scope of this paper to present a complete and comprehensive analysis of the definition of institution. See, for a more complete discussion, Hodgson (2006).

horizons of the operations, large scale, indivisibilities, inability to produce adequate returns within ROI appraisal techniques).

3.2 Defining behavioural additionality

The main advantage of the behavioural additionality evaluation pertains to the possibility to analyse profound effects on the beneficiaries' behaviours that cannot be captured by the input and output additionality assessments. As it will be clarified below, the behavioural additionality evaluation allows for assessing the presence of changes in the beneficiaries' innovation process that are extremely relevant according to the system failures rationale. Nevertheless, the advantage coming from this theoretical anchorage is not fully exploited: in absence of clear-cut definition of behavioural additionality, its link with the evolutionary approach and the innovation system perspective is not always made explicit in the literature.

For instance, a first and simplistic way of dealing with the behavioural additionality is that of extending the linear and strict nature of the input additionality (Gök and Edler, 2010). This is done by analysing the effects on the scale and the scope of the funded R&D projects (e.g. Luukkonen, 2000) or considering also the acceleration of the beneficiaries' innovation activities (e.g. Falk, 2007). The evaluation in these cases is concerned, respectively, with whether the funded project has: increased the scale of the R&D activity of the beneficiaries in the chosen area; expanded the coverage of their R&D activity to a wider range of applications and markets; brought forward in time their R&D activity (Georghiou, 2002, 2004; Georghiou and Clarysse, 2006). As noted by Gök and Edler (2010), this simple version of the behavioural additionality mainly pertains to effects that are limited in time, occur only during the funded project and in its immediate vicinity. What is more, the use of the behavioural additionality to extend the input dimension is not fully consistent with the evolutionary and system perspectives, as it still fails to take into account the impact of the policy on beneficiaries' competencies, capabilities and interactions with external actors.

However, the concept of behavioural additionality can be used far beyond the extension of the input dimension and can be employed to assess more profound changes in the behaviours of the agents supported by the policy intervention. In other terms, looking at the behavioural changes induced by the policy it is possible to consider the way in which the public intervention re-shapes the characteristics of the beneficiaries'

innovation process. For example, with respect to R&D, this is clear in the seminal contribution by Buisseret et al. (1995, p.590) that coined the concept of behavioural additionality as "the change in a company's way of undertaking R&D which can be attributed to policy actions". More in general, Georghiou (2004, p.7) defines behavioural additionality as "the difference in firm's behaviour resulting from the intervention". By focusing on the behaviours of the beneficiaries it is possible to overcome a limitation which is implicit in the evaluations based on the measurement of the input and output additionality: the fact that economic actors are considered as "black-boxes". In this sense, one of the aim of the behavioural additionality evaluation is that of opening these "black-boxes" (Clarysse et al., 2006; Hall and Maffioli, 2008) to look at the micro-effects occurring within the beneficiaries' innovation process.

It is evident that this kind of definition is quite flexible and can encompass a number of relevant behavioural changes induced by the policy. These can pertain to the acquisition and improvement of knowledge, capabilities, organisational routines and strategies (Georghiou and Clarysse, 2006; Breschi et al., 2009). Furthermore, as noted by Geroghiou (2004) and Georghiou and Clarysse (2006), focusing on the behavioural changes related to the acquisition of competences in new or extended technologies and market areas, it is also possible to assess whether a given policy intervention has been able to reduce lock-ins. Similarly, Bach and Matt (2005) stress the importance of focusing on the ability of the policy to create cognitive capacity additionality, which pertains to the creation of novelty and capacity to adapt to future situations that cannot be envisaged. Another important set of effects that can be analysed using the concept of behavioural additionality is that related to the networking, interactions and connections between beneficiaries and other economic actors. Drawing on the evaluation framework proposed by Hall and Maffioli (2008), behavioural additionality evaluation, in addition to effects that occur in the internal organisation, can capture also changes that pertain to external relations. In this sense, it is possible to assess whether the policy has helped to build networks or coordinate systemic innovations (Georghiou, 2004; Georghiou and Clarysse, 2006), creating new partnerships -which involve not only firms but also research organisations- and favouring the persistence of these interactions (Fier et al., 2006). Breschi et al. (2009) stress the great importance of assessing the effects of the policy on partnerships and networking. According to the authors, large part of the behavioural additionality is realised through interactions, as these can provide access to external knowledge, while valorising internal competencies and expanding learning

capabilities. This emphasis is in line with the emerging relevance of the open innovation paradigm as opposed to the closed innovation models, which are characterised by the internal and vertical integration of R&D activities. In the open innovation modes firms acquire competencies from external sources and use inflows and outflows of knowledge to increase their innovation (and business) performances (Chesbrough, 2003, 2006; OECD, 2008).

However, as the concept of behavioural additionality is quite flexible, evaluators may take into consideration a range of behavioural changes that can be even too wide. As noted by Gök and Edler (2010), the concept can be used also to evaluate effects that are not strictly or directly related to innovation activities, but to the more general conduct of the beneficiaries. This is quite evident looking at the list, provided by Georghiou (2004) and Georghiou and Clarysse (2006) of six possible effects that can be taken into consideration in the behavioural additionality evaluation. These pertain to: (i) knowledge acquisition (e.g. R&D organisation and networking), (ii) human resources (e.g. hiring of researchers and acquisition of management skills), (iii) capital investment strategy (e.g. acquisition of equipment and location of companies' facilities), (iv) market positioning[5] (e.g. introduction to new market or customers and acquisition of leadership positions), (v) strategies for manufacturing or service provision (e.g. changes in the production or service delivery methods), (vi) corporate responsibility and environmental sustainability. With respect to this list, it seems relevant to mention a possible problem. The inclusion of a broad range of behavioural and strategic changes, which can be not directly related to the innovation activities of the beneficiaries, leads to the potential risk of considering effects that are not immediate objectives of the innovation policy. This possibility is quite evident for evaluations focused on the effects pertaining to the capital investment strategy, to the strategies for manufacturing and service provision, to the corporate responsibility and environmental sustainability.

The point here is then: what are the changes which are worth being assessed when evaluating the behavioural additionality? In other terms: what should be considered as a relevant behavioural change? Answering to these questions not only allows for a clear-cut definition of the behavioural additionality, but also for its anchorage to the evolutionary theory and the innovation system perspective. Indeed, to answer to these questions one should necessarily consider the policy objectives arising from the economic

[5] This type of effect seems to be more related to the output dimension of the additionality.

rationale. In this sense, as the aim of the public interventions is to deal with the system failures, behavioural additionality evaluation should be focused on the changes that help to mitigate these failures.

The use of the behavioural additionality to evaluate the capacity of the policy to mitigate the system failures is not a novelty in the literature. In opposition to the "ideal" and "narrow" incrementality tests, which are consistent with the neoclassical approach, Lipsey and Carlaw (1998, p. 45) claim for the use of the "weak test of incrementality" to evaluate the innovation policy within an evolutionary perspective. This test, with no attempt of optimality, should be focused on the evaluation of structural changes and the enhancement of beneficiaries' capabilities (Georghiou, 2002, 2004; Georghiou and Clarysse, 2006). Bach and Matt (2005) state that the cognitive capacity additionality - which I prefer to consider as a sort of further specification of the behavioural additionality- is able to assess the policy intervention in an evolutionary approach. More explicitly, Georghiou (2002) states that, to an extent, the behavioural additionality can be used to assess whether the policy has been able to deal with the system failures. However, according to him, the fact that the natural operational level of the additionality test is the firm implies a limitation. On the one hand, there are failures that do not pertain at all to firms, but occur only at the system level; on the other hand, there are failures that occur both at the level of the firm and of the system. This limitation can be partially reassessed, as in a system perspective it is necessary and possible to consider the behavioural changes induced by the policy on all the systemic organisations targeted by the public intervention, not only the firms but also the other beneficiaries (e.g. research institutes, innovation centres, universities, etc.). Nevertheless, even with this broader definition of the unit of analysis, the use of the behavioural additionality to assess the ability of the policy to deal with the system failures is not so unproblematic. First, some system failures still occur both at the organisation and system levels, as the failures pertaining to learning processes and accumulation of capabilities, to missing or inappropriate connections and to unbalanced evolutionary trade-offs. With respect to these failures, behavioural additionality evaluation can be employed but, as this is focused on the effects on the beneficiaries, it is possible at the most to evaluate the sum of the single additionality effects. However, this latter, due to synergies and interactions, might differ from the effect on the whole system. A second problem emerges for the failures pertaining to weak institutional performances, missing components and infrastructural investment. In this case, it seems that the behavioural additionality cannot be properly employed, as it is very

complicated to assess whether the policy has been able to solve these failures by looking at the behavioural and strategic changes of the beneficiaries. The operational level of the evaluation, in other terms, cannot be the supported organisation but needs to be the system.

When considering this limitation a question emerges: can the behavioural additionality still be considered a useful instrument to evaluate innovation policy according to the evolutionary and system perspectives? The answer is yes. Behavioural additionality can be used to capture the capacity of the policy to induce relevant changes related to the upgrading of competencies, the acquisition of new or diverse knowledge and the interactions with external actors. These behavioural changes induced by the policy can be seen as a way to reduce the system failures that occur (also) at the level of the supported organisations. What cannot be achieved with the behavioural additionality evaluation is the complete assessment of the policy capacity to deal with all the different system failures. With this respect, the analysis of the behavioural additionality is only one of the evaluation tools that can be employed. Indeed, the analysis of the policy effects on the single beneficiaries needs to be integrated by analysis of the impacts on the system as a whole (Bellandi and Caloffi, 2010). In general terms, as noted by Arnold (2004), when the aim is to assess the overall capacity of the policy to deal with all the different system failures, the evaluation should be carried out with different methods and taking into account different levels of analysis, from the micro to the system one.

However, another important aspect has to be taken into account when providing a behavioural additionality evaluation which is consistent with the evolutionary and system perspectives. In a surrounding changing and evolving environment, characterised by a number of micro-complexities (Malerba, 2009), the behavioural additionality evaluation cannot aim at providing an optimality assessment of the policy intervention, simply because a stable and optimal equilibrium to be used as ideal benchmark does not exist (Chaminade and Edquist, 2006). This implies, as stressed by Georghiou (2004) and Georghiou and Clarysse (2006), that some behavioural changes in the long-run might even result to have induced beneficiaries to move towards the wrong direction. This implication is not confined to the behavioural additionality only. In general terms, when adopting an evolutionary approach, all the kinds of evaluation cannot be aimed at assessing the capacity of the policy to solve, in an optimal and stable way, the system failures (Arnold, 2004).

3.3 Other issues at stake in the behavioural additionality evaluation

So far, this section has been mainly focused on the definition of the behavioural dimension of the additionality concept, stressing in particular its consistency with the system failures framework emerging from the evolutionary theory and the innovation system perspective. However, other key aspects are worth being considered to increase the quality and the comprehensiveness of the behavioural additionality evaluation.

The first point concerns the difficulty in isolating the effect of the policy. As stressed by Buisseret et al. (1995) and Georghiou (2002), the funded project should not be seen in isolation but within a portfolio of other innovation activities: a wider programme that is likely to be started before the funded project, continues even after the end of the public support and integrates also privately financed activities. This limits the possibility to isolate the effect of the single funded projects, but not the usefulness of the behavioural additionality evaluation as a such, whose contribution still remains valid when analysing the effect of the policy on the overall innovation strategy of the beneficiaries (Buisseret et al., 1995). A similar conclusion can be reached considering the displacement phenomenon (Davenport et al., 1998). Given the investment portfolio perspective and assuming that applicants tend to present the projects that are more likely to be funded (i.e. more promising and well planned), then it might be that beneficiaries are funded for a given project, but use the money to finance other activities, maybe of higher risk but just as strategically important.

Another aspect that should be taken into account, when evaluating the behavioural additionality, concerns the fact that in some cases the policy intervention can affect even non funded companies and organisations. First of all, even the application phase of a support scheme[6] can induce behavioural changes in the potential beneficiaries. These might be stimulated to present projects and set the stage for activities to be carried out according to the policy requirements (Georghiou, 2004). The result is the presence of some additionality effects also on non beneficiaries that have presented projects then rejected in the selection process. A similar outcome can emerge considering the spillovers taking place between funded organisations and non beneficiaries. Though not directly referring to the behavioural additionality, the review provided by Klette et al. (2000) points out that non beneficiaries may be affected by the policy due to the spillover effects, especially if the technological and cognitive distance with the supported organisations is

[6] Georghiou (2004) refers in particular to grants.

not too high. Indeed, spillovers effects are quite likely to occur. On the one hand, in many cases policy-makers implement public support schemes that aim at enhancing cooperation and networking among organisations. On the other hand, funded organisations embracing open innovation modes (Chesbrough, 2003, 2006; OECD, 2008) can collaborate with non beneficiaries. Unfortunately, when the behavioural additionality evaluation is carried out with econometric methods, the presence of additionality effects on the non beneficiaries implies some drawbacks in the creation of a suitable counterfactual group of non supported units[7].

A final aspect is related to the fact that behavioural additionality cannot be expected to be a homogeneous phenomenon. Georghiou (2004) proposes to differentiate the evaluation according to the different types (e.g. in terms of size and knowledge-intensity) of beneficiaries, as the additionality effects on these are supposed to be different. This reasoning is supported by some empirical evidences. Hsu et al. (2009), with respect to R&D programmes in Taiwan, point out the existence of some different patterns of behavioural additionality in different sectors and innovation categories. Different behavioural additionality effects in different types of beneficiaries, especially in terms of size, emerge also from the analysis of the Austrian FFF R&D support scheme provided by Falk (2007). Apart from the empirical evidences, it is relevant to stress that heterogeneous patterns of behavioural additionality are also theoretically justified. As the economic actors are heterogeneous and behave differently according to their particular strategic, cognitive and organisational aspects (Metcalfe, 1995), it is quite unlikely that their response to the policy support is similar[8].

[7] For instance, the presence of spillover effects implies that the stable unit-treatment value assumption (SUTVA) might not hold (see Section 3.1 of the third Chapter included in the Thesis). Unfortunately, this assumption, which is at the basis of the impact assessment econometric methods, cannot be directly tested with the available methodologies.

[8] To deal with the heterogeneity of the behavioural additionality effects one could: exploit *ad hoc* information on the idiosyncratic level of additionality for each beneficiary, as in Falk (2007) or Hsu et al. (2009); estimate the average impact of the policy in different groups of beneficiaries; employ a quantile treatment effect method (e.g. Battistin and Fort, 2008; Angrist and Pischke, 2008) to investigate the distribution of the policy effects on the population of beneficiaries. In the present Thesis, the lack of proper and precise data has impeded the use of these methodological approaches. However, the heterogeneity of the policy impact has been partially analysed with a tentative investigation of the relation between the average additionality impact and the dispersion of the effect across the beneficiaries (see the third Chapter of this Thesis).

3.4 Behavioural additionality in-between input and output ones: a multi-dimensional evaluation

The last point considered in this part of the paper concerns the fact that the behavioural additionality evaluation can be included in a multi-dimensional investigation that analyses also the input and output additionality effects. As stated by Bach and Matt (2005), only analysing together the different additionality dimensions it is possible to have a complete and better understanding of the policy impact. One might argue that this joint analysis is incorrect from a theoretical point of view, given the contrast between the neoclassical approach, from which the input and output additionality dimensions arise, and the evolutionary theory, which claim for the analysis of the behavioural changes induced by the policy. This argument is only partially acceptable. On the one hand, the contrast between the theoretical approaches is evident and strong. On the other hand, whereas from a neoclassical standpoint the impact on the beneficiaries' innovation behaviour is simply not worthy of consideration, when adopting the evolutionary and system perspectives, the input and output additionality dimensions cannot be considered as totally pointless. Indeed, the aim of the evolutionary theory and of the related innovation system perspective is essentially that of analysing the complexity of the whole process of innovation. In this sense, the information on the input and output additionality effects can complement the fundamental investigation of the behavioural changes induced by the policy, shedding light on whether the public support has affected the attitude towards the R&D investment (also considered as a way to enhance the innovation capabilities) and the capacity to reach higher innovation performances (both in quantitative and qualitative terms).

In addition to this, it is also useful to consider the synergic relationships that might exist between the three additionality dimensions. A first one can emerge between input and output additionality. In line with the standard linear view of the innovation process, the more the policy stimulates the investment in R&D, the more this is expected to result in a higher level of innovation output (e.g. Czarnitzki and Hussinger, 2004; Czarnitzki and Licht, 2006; Cerulli and Potì, 2010). Departing from this linear perspective, at first, an inverse relation between output and input additionality cannot be excluded: the more the policy has favoured the achievement of innovation outputs and economic outcomes, the more these could result in higher resources and incentives to invest in R&D. Nevertheless, it is possible also to consider relations involving the

behavioural additionality. The first one is related to the effect of the behavioural changes on the output additionality. According to Davenport et al. (1998), sustained changes in the R&D management induced by the public support can be seen as a sort of latent ability of the policy to influence the possibility to achieve more outputs. Another type of behavioural change induced by the policy can positively affect the output dimension of the additionality. In particular, innovation outputs can be increased by the adoption of open innovation modes (Chesbrough, 2003; 2006) enhanced by the public intervention. In this sense, Magro et al. (2010) point to the positive effect that the increased cooperation of the beneficiaries can have on the capacity to achieve higher innovation performances. Indeed, public support schemes leading to a higher collaborative attitude improve beneficiaries' innovation process, by enhancing interorganisational learning, as well as the access to complementary knowledge, technological and financial assets (Fier et al., 2006; Autio et al. 2008; Clarysse et al., 2009). Also an inverse relation between output and behavioural additionality, although not directly investigated by previous contributions, cannot be excluded. In particular, a positive relation can emerge in case the policy has stimulated the beneficiaries to introduce patented innovations. Indeed, considering the knowledge protection/sharing dilemma (e.g. Olander et al., 2009), patenting implies a lower risk of knowledge leakages and, thus, might result in a higher cooperation with external actors. A similar outcome can emerge because of the positive effect that patenting, through the related process of environment scanning aimed at identifying other pieces of codified knowledge, exerts on absorptive capacity (e.g. Franco et al., 2011). Moving to the relation between input and behavioural additionality, some contributions are worth of mentioning. Autio et al. (2008) consider the positive effect that a policy-induced increase in the R&D investment, enhancing technological search, can have on learning outcomes. Similarly, according to Clarysse et al. (2009), a higher engagement in R&D induced by the policy is positively related to learning and improvements in the management of the innovation process[9]. However, the relation between these two dimensions is quite complex and the other causality direction, going from the behavioural to the input additionality, cannot be excluded. One can think at two examples. The first is a case in which the policy intervention has favoured the collaboration with external partners. In this circumstance, beneficiaries may need to

[9] Autio et al. (2008) use a slightly different terminology. Instead of input and behavioural additionality they refer to first-order additionality and learning outcomes. Clarysse et al. (2009), due to a data constraint, cannot provide a causality test.

invest more in R&D in order to increase their absorptive capacity (Cohen and Levintal, 1989; Franco et al., 2011). Another example is a situation in which beneficiaries, due to the competencies' enhancement induced by the participation in policy, are more willing and able to invest in R&D. All in all, considering the non-linear nature of the innovation process, the potentially complex interdependencies and interactions between its different internal and external phases (e.g. Kline and Rosenberg, 1986; Edquist, 1999), one should bear in mind the complex set of relations which involves also the three dimensions of the additionality. When considering together these relations, virtuous circles and synergies might emerge. Of course, this hypothesis should be further investigated and properly tested, by making use of methods (e.g. system of simultaneous equations) which take into account the simultaneity and the mutual causation characterising the three additionality dimensions.

4 The quantitative evaluation of the behavioural additionality

4.1 General empirical issues

Coming to the empirical aspects related to the evaluation of the additionality and of its behavioural dimension in particular, at first it is necessary to provide a brief introduction to the general empirical issues in the (ex-post) assessment of innovation policy [10]. These are essentially related to the problems that characterise the estimation of the causal relation between the policy support and the impacts of interest.

The general methodological framework is the following. The policy intervention is considered as a treatment (t), the firms[11] are the units of analysis and the additionality indicator (e.g. R&D expenditure in case of input additionality) is the outcome variable. Accordingly, the net effect (i.e. the additionality of the policy) can be defined as the difference between the actual outcome reached by treated units and the outcome that would have been reached even without the treatment, i.e. the counterfactual. However, this latter cannot be observed for the treated individuals once the treatment has been implemented. For this reason, the fundamental problem faced in the process of assessing causality can be considered as a missing data problem. Drawing on Holland (1986, p.947), to solve the fundamental problem of causal inference it is necessary to replace the

[10] See, for more details, Section 3.1 of the third Chapter of the present Thesis.
[11] Or other organisations that could be targeted by the policy.

"impossible-to-observe causal effect of *t* on a specific unit with the possible-to-estimate average causal effect of *t* over a population of units".

In addition to this first problem, another serious issue emerges when trying to estimate a causal relation between the policy intervention and its effects. As innovation policies are unlikely to be randomly assigned to a population of potential beneficiaries, it would be incorrect to estimate the impact of the intervention by comparing the outcome of the group of treated individuals and that of the group of non participant units. In fact, in such a situation the estimation would be affected by a selection bias. On the one hand, this might be due by the self-selection of certain types of units into the treatment. On the other hand, selection bias may also arise because the assignment is ruled by specific strategies followed by the policy-maker. Indeed, the public support might be granted according to 'picking the winner' or 'aiding the poor' strategies. In the first case, a potential upward bias emerges in estimating the effect of the policy, if appropriate econometric techniques are not employed. On the contrary, a potential downward bias emerges if the government strategy is of the second kind (Cerulli, 2010).

Following the debate in the literature on the ex-post impact assessment (e.g. Heckman, 2005a, 2005b; Sobel, 2005; Heckman, 2008; Heckman and Vytacil, 2007) two broad classes of methods that allow for dealing with the selection bias can be identified: structural and matching models[12]. The first class of methods is constructed on the basis of explicit assumptions derived from the theory, thus allowing for a more insightful interpretation from an economic point of view. Structural models are more "explicit about how counterfactuals are generated and how interventions are assigned (the rules of assigning 'treatment')" (Heckman, 2005b, p.6). On the contrary matching methods, originated in the statistical literature, are more "data-driven": matching estimators are essentially aimed at pairing treated units with similar non treated ones, so that the difference in the outcome of the two groups is only due to the policy intervention[13].

[12] See, among the others, Cerulli (2010) for a more complete review of the different methods that can be employed in the ex-post evaluation of the innovation policy interventions.

[13] On this point, it is worth stressing the important role, in the empirical literature, of the propensity score matching (Rosenbaum and Rubin, 1983). This latter, instead of pairing treated and non treated units on the basis of each single observable characteristic, reduces the dimension of conditioning by matching treated units with non treated ones that have a similar probability of being treated (given a set of observable characteristics). For a more detailed presentation of the matching approach and, in particular, of the propensity score matching, see Section 3.1 of the third Chapter included in the present Thesis.

This brief introduction to the issues characterising the ex-post impact evaluation constitutes a functional step to frame the following review of the empirical contributions focused on the behavioural additionality of the innovation policy.

4.2 Operationalising the behavioural additionality: a review of the empirical literature

In addition to the problems raised in the ex-post evaluation literature, which call for the use of appropriate econometric methods, behavioural additionality assessment needs to cope with a non homogeneous transition from the conceptual theorising to the empirical specification. A relevant problem in the operationalisation of the behavioural additionality evaluation lies in the left-hand side (LHS) of the econometric specification, i.e. the definition of the outcome variables. More precisely, a common way of capturing the behavioural changes induced by the policy is still missing. For these reasons, in addition to the main results arising from the different contributions, the remaining part of the paper will also report the methodologies that can employed in analysing the behavioural additionality and the types of behavioural change that are taken into consideration.

The following review, whose main insights are presented in Tab. A1 in the Appendix, is divided in two parts. The first is focused on those works which directly evaluate, with econometric methods, the behavioural and strategic changes induced by the policy (Falk, 2006; Fier et al., 2006; Busom and Fernández-Ribas, 2008; Hall and Maffioli, 2008; Magro et al., 2010; Marino and Parrotta, 2010; Afcha-Chávez, 2011). The second set of contributions is characterised by the use of alternative approaches to the study of the behavioural additionality (e.g. network analysis), or by a focus on its determinants and relations with other additionality dimensions (Falk, 2007; Autio et al., 2008; Breschi et al., 2009; Hsu et al., 2009; Clarysse et al., 2009).

As for the direct evaluations employing econometric methods, two sub-categories can be further distinguished. The first group is made of contributions (Fier et al., 2006; Hall and Maffioli, 2008; Magro et al., 2010; Marino and Parrotta, 2010) employing (only) matching models, while the second group of analyses make use (also) of other econometric techniques[14] (Falk, 2006; Busom and Fernández-Ribas, 2008; Afcha-Chávez, 2011).

[14] Both Busom and Fernández-Ribas (2008) and Afcha-Chávez (2011) jointly use a structural model and a matching approach.

Fier et al. (2006) base the empirical analysis on data stemming from the German Community Innovation Survey (CIS) and from an *ad hoc* survey. Their analysis aims at assessing whether public funding induces a change in firms' propensity to cooperate with both other companies and research organisations. Furthermore, they investigate whether the change in the cooperation strategy is persistent and lasts even after the end of the public support. To this purpose, Fier et al. (2006) apply at first a matching procedure to estimate the impact of the policy on the firms' cooperation attitude and then a bivariate probit to verify the impact of the policy on the continuation of the collaborations. The general results point to a positive effect on the creation of new collaborations between firms and scientific institutes. However, when compared to the collaborations already existing at the beginning of the public support, newly established cooperation agreements with scientific organisations are less likely to continue.

The second study here considered is the one by Magro et al. (2010), who focus their analysis on a regional policy programme implemented in the Basque Country of Spain. The authors aim to verify whether the public funding increases firms' propensity to engage in collaborative innovation activities, raises firms' capacity to participate in international R&D programmes, leads to a systematic and persistent R&D behaviour in the supported companies. The results, emerging from a matching technique, point to a positive effect of the intervention on the three aspects of the behavioural additionality analysed.

Marino and Parrotta (2010) focus their analysis on Danish firms to evaluate the impact of the policy on the endowment of human resources devoted to formal innovation activities. The increase in the share of R&D workers is used as a proxy for the change in the management of innovation strategies. Whereas previously reviewed contributions analyse the effect of the participation in the policy by using a binary treatment variable, Marino and Parrotta (2010) adopt a continuous treatment approach, i.e. the genearlised propensity score method (Hirano and Imbens, 2004)[15], which can be seen as an extension of the "traditional" propensity score matching. The emerging evidence points to a positive effect of the amount of subsidy on the share of R&D workers. This effect is found to be significant up to a certain threshold of public funding (i.e. 1.8 million of DKK).

The contribution by Hall and Maffioli (2008), is a survey of evaluations conducted in several countries in Latin America. All the three additionality dimensions

[15] An application of the generalised propensity score is provided in the fourth Chapter of this Thesis.

are considered: input, output and behavioural. As for this latter, the analyses are carried out with a matching approach. The findings reveal the capacity of the policies implemented in Chile and Panama to stimulate the cooperation of supported firms with external sources of knowledge and finance.

As for the studies that do not (exclusively) adopt a matching approach, here below are reported those by Falk (2006), Busom and Fernández-Ribas (2008) and Afcha-Chávez (2011). These two latter are, at our best knowledge, the only ones that (try to) employ a structural model to test for the behavioural additionality.

The first work (Falk, 2006), considers the Austrian federal R&D support scheme (FFF). The econometric analysis is carried out by exploiting the panel structure of the data, which allows for the implementation of both a fixed effects model with time-invariant variables and a dynamic panel model (partial adjustment model). The behavioural additionality evaluation is aimed at estimating the effect of the policy scheme on the endowment of R&D personnel. This is expected to facilitate "an increased awareness of R&D opportunities, the establishment of informational network" and to "improve the firm's absorptive capacity with respect to new knowledge" (Falk, 2006, p.67). As for the results, the FFF scheme is found to have a positive, even if quite marginal, impact on the demand of skilled R&D personnel.

The work by Busom and Fernández-Ribas (2008), focused on Spain, analyses the impact of the policy on the cooperation attitude of the funded firms, as many other contributions here reviewed. The econometric approach is based, at first, on the specification of a structural model: the decision to participate in the policy programme is modelled as well as the equations of partner selection (i.e. on the one hand customers and suppliers and, on the other hand, public research organisations). However, to deal with the endogeneity of the policy intervention, Busom and Fernández-Ribas (2008), adopt also a matching approach. The results point to a positive effect of the policy on the cooperation agreements between funded firms and public research organisations and, to a lesser extent, on the interactions between supported companies and other business partners.

A similar econometric exercise is carried out by Afcha-Chávez (2011), who investigates the effect of the Spanish national and regional policies on the cooperation strategy of supported firms. As in Busom and Fernández-Ribas (2008), Afcha-Chávez (2011) tries at first to adopt a structural model, but then moves to a matching approach due to the endogeneity of the policy support. The emerging evidence points to a positive

impact of the regional and national policies on the likelihood to establish cooperation with a university or a technological centre. However, both the levels of interventions are found to be ineffective in stimulating collaborations with customers or suppliers.

The last set of works here reported is the less homogeneous in terms of behavioural changes considered, methodologies applied and objectives. These latter do not specifically pertain to the policy causal effect, but to a broader range of aspects related to the behavioural additionality.

Focusing on the Austrian FFF R&D support scheme, Falk (2007) employs a series of ordered probit regressions to investigate the drivers of additionality. Two types of determinants are considered. On the one hand, firm's characteristics (i.e. size, sector, age, obstacles to innovation); on the other hand, the number of support schemes in which the firm has been enrolled. Different forms of additionality are taken into account. As for the behavioural dimension, the considered effects pertain to the scale, the acceleration and the scope (in terms of more cooperation, more risk, more basic research and more applied research) of the supported innovation activities. The main findings reveal that large firms are more prone to realise various forms of additionality. Furthermore, multiple policy interventions are found to be a necessary condition to stimulate firms to engage in cooperation and to undertake risky basic research.

Hsu et al. (2009), in their contribution focused on Taiwan, propose an interesting device to reduce the potential high number of strategic and behavioural changes to be taken into account when analysing the behavioural additionality. With a factor analysis, from 19 items, they identify four sub-dimensions of the behavioural additionality: project enlargement behaviour, strategy formulation behaviour, cost-effectiveness behaviour and commercialisation behaviour. Furthermore, Hsu et al. (2009) investigate, with a Scheffe's multivariate comparison and with a cluster analysis, the additionality differences within sectors and for different types of innovation categories, as well as the presence of different patterns of additionality.

In the analysis provided by Autio et al. (2008), the behavioural changes enhanced by Finnish collaborative R&D programmes are proxied with four types of learning: direct technological learning, technological distinctiveness, market learning and internationalisation learning. Among the other interesting issues, the authors analyse one aspect which has been pointed out in the theoretical part of the present work: the possible relation between input and behavioural additionality. The emerging evidence points to a

positive and significant impact of the input additionality on the direct technological learning and the internationalisation learning.

Another contribution that analyses the relation between input and behavioural additionality is the one of Clarysse et al. (2009). Even if the cross-sectional nature of the data does not allow them to provide a rigorous causality test, the results obtained with a Heckman model, support the hypothesis according to which input and behavioural additionality are strongly related.

The last work presented here, by Breschi et al. (2009), applies an alternative approach to investigate the existence of behavioural changes somehow enhanced by the policy intervention: the social network analysis. The authors consider the impact of the Information Society Research, Technological Development and Demonstration (IST-RTD) programmes included the Sixth Research Framework Programme. The analysis shows the positive influence of the public support on the: attraction of key actors to the European IST knowledge networks; creation and strengthening of relations among partners; effective diffusion of new knowledge. This type of analysis offers a systemic perspective and an insightful representation of the linkages between different actors. The methodology employed, i.e. the social network analysis, taking the system rather than the beneficiary as the unit of investigation, emerges as a tool that may complement the more "traditional" econometric investigations of the additionality.

5 Concluding remarks

The paper has been focused on the additionality evaluation of innovation policies. Particular attention has been devoted to the behavioural dimension of the additionality, which is focused on the behavioural and strategic changes induced by the public intervention. The first part of the paper has stressed the capacity of the behavioural additionality to provide a fundamental complement to the standard input and output dimensions. Consistently with the evolutionary theory and the related innovation system perspective, by evaluating the behavioural additionality it is possible to focus on the effects that occur within the "black box" of the beneficiaries. More precisely, the impacts on beneficiaries' competencies, capabilities and relations with external sources of knowledge. However, as the concept of behavioural additionality is quite flexible, its definition risks to be too broad. As in Georghiou (2004) or Georghiou and Clarysse (2006) this might lead to consider a set of effects which are not directly related to the

objectives of the innovation policy. To reduce the potential vagueness of the behavioural additionality definition, the paper has suggested to focus on those changes in the beneficiaries' behaviours that can help to mitigate the system failures that occur (also) at the level of the beneficiaries (i.e. problems in learning processes and in the accumulation of capabilities, missing or inappropriate connections, unbalanced evolutionary trade-offs). The first part of the paper has also stressed some other crucial aspects: the problems in isolating the effect of single funded project and the consequent need to focus on the overall strategy of the beneficiaries, the possible presence of indirect effects on the non funded organisations, the heterogeneous nature of the additionality effects. A main open question for future research has been raised at the end of the first part of the paper. This pertains to the relations that can exist among the three dimensions of the additionality. In particular, input, output and behavioural additionality should not be seen as separate results of the policy intervention, but as parts of a framework of synergies, in which each dimension can affect the others. A first step towards a clearer understanding of this point is to review the strands of literature, not necessarily related to the evaluation of innovation policy, that can shed some light on the relations among the R&D investment, the outputs/outcomes of the innovation process and the changes in firm's behaviours and strategies.

The review of the empirical contributions has been introduced by a short presentation of the main problems in the ex-post impact evaluation, which calls for the use of proper econometric methods when assessing the behavioural additionality of a policy intervention. The review of the empirical literature on the behavioural additionality has shown a specific criticality in the crucial passage between theory and empirics has been stressed. Due to the flexibility of the behavioural additionality concept, it is not possible to determine an univocal way of capturing the behavioural changes induced by the public intervention. All the surveyed empirical works assess the presence of specific behavioural changes, with many contributions being focused on the effect of the policy on the cooperation with external actors. Nevertheless, the insights emerging from the review of the empirical literature largely support the need to evaluate the behavioural changes induced by the policy intervention. Indeed, almost all the works report the presence of relevant policy effects that cannot be captured with the simple input and output additionality assessments. In particular, these impacts pertain to the increased cooperation with external actors, both firms and research organisations, and to the upgrading of internal innovation capabilities. As for the empirical aspects concerning the

evaluation of the behavioural additionality, three suggestions for future research can be advanced in these concluding remarks. The first one concerns a strategy to define proper outcome variables capable of capturing relevant behavioural changes. To improve the comprehensiveness and, at the same time, the parsimony of the analysis, an idea could be that of collecting information on the various indicators of behavioural change and then applying multivariate statistical techniques, such as the factor analysis, which reduce the initial vector of potential outcome variables in a smaller one. Another point pertains to the necessity to complement the investigations of the effects on the beneficiaries with methods that take the innovation system as the unit of analysis. This would provide a more effective picture of the ability of the policy to mitigate the system failures. The use of the social network analysis represents a promising development in this direction. Finally, a third suggestion for future researches concerns the empirical method to analyse the framework of synergies that might exist among the three additionality dimensions. A first step in this direction is to check whether a system of simultaneous equations can be applied to this purpose.

Appendix

Tab.A1 Operationalisation, methods and results in behavioural additionality studies

Authors	Methodology	Policy intervention variable	Outcome variables/ Behavioural additionality indicators (effects of the direct evaluations[16])
Econometric evaluations of the behavioural additionality			
Matching methods			
Fier, Aschhoff and Löhlein (2006)	Matching estimation with Mahalanobis metric / Bivariate probit	Subsidy dummy / dummy indicating whether the cooperation was established by the policy	Collaborations with other firms (NS), with scientific organisations (+), both with other firms and scientific organisations (NS). Persistence of established cooperation with scientific organisation (-) and other firms (NS)
Magro, Aranguren and Navarro (2010)	Propensity score matching	Subsidy dummy	Internationalisation of R&D activities (+), systematisation of R&D activities (+), long-lasting collaborative agreements (+)
Marino and Parrotta (2010)	Generalised propensity score	Amount of subsidy (continuous treatment)	Share of R&D personnel to proxy change in the management of innovation strategies (+, up to 1.8 mil DKK)
Hall and Maffioli (2008)[17]	Propensity score matching	Subsidy dummy	Access to external sources of knowledge (+) and financing (+), training and organisational activities (NS).
Other econometric techniques			
Falk (2006)	Fixed effect model with time invariant variables / Dynamic panel specification	Log R&D subsidies / Δlog subsidies (t), Δlog R&D subsidies (t-1)	R&D personnel to proxy R&D opportunities and absorptive capacity (+)
Busom and Fernández-Ribas (2008)	Structural model (and matching)	Binary participation status (subsidy dummy)	Cooperation with: suppliers and customers (+); public research organisations (+)
Afcha-Chávez (2011)	Structural model (and matching)	Binary participation status (subsidy dummy), distinguishing regional and national policies	Cooperation with: university and technological centres (+, both the levels of policy); suppliers and customers (NS, both levels of policy)

[16] For sake of simplicity it is only reported the sign or NS in case the effect is found to be non significant.

[17] This work is a meta-analysis of evaluation studies.

Alternative quantitative analyses of the behavioural additionality			
Falk (2007)	Ordered probit regressions	Policy dummies for support coming from one, two or three programmes respectively	Changes in the scale, scope (in terms of more cooperation, more risk, more basic research and more applied research) and acceleration of funded projects
Hsu, Horng and Hsueh (2009)	Factor analysis, cluster analysis, Scheffe's comparison to test differences in additionalities	Not directly used (the analysis is based on government sponsored R&D project)	Project enlargement, strategy formulation, cost-effectiveness, and commercialisation behaviours
Autio, Kanninen and Gustafsson (2008)	Factor analysis, OLS regressions	Dummy for participation in policy programmes	Direct technological learning, technological distinctiveness, market learning and internationalisation learning
Clarysse, Wright and Mustar (2009)	Heckman selection model	Subsidy dummy (used in the selection equation)	Single factor capturing the extent to which: innovation management process is more formalised; innovation management capabilities are increased; the research path is changed.
Breschi, Cassi, Malerba and Vonortas (2008)	Social Network Analysis	Not directly used (the analysis is focused on the networks of the participants in the policy programme)	Creation of knowledge linkages and connectivity, nurturing of key actors and knowledge leaders.

3

Multi-level innovation policy in two EU countries. An additionality evaluation of the Italian and Spanish public interventions*

Abstract

The paper aims at proposing and applying a new multi-level and multi-dimensional evaluation of the additionality effects of innovation policy. The impacts of national and regional support schemes are jointly investigated (multi-level), by simultaneously analysing their input, output and behavioural additionality effects (multi-dimension). By making use of the 4th wave of the Community Innovation Survey, an empirical application of this evaluation is provided for two EU countries, namely Italy and Spain, through a propensity score matching estimation of the average treatment effect on the treated (ATT). The picture of the results is quite complex. In both countries, only national policies increase R&D investment. On the other hand, their regional and national interventions induce additional innovation performances and innovation behaviours of different nature. The proposed methodology is integrated with an original, although somehow tentative, analysis of the relation between the average additionality effects of the policies and the dispersion of their impacts. With the exception of Italian regional policies, the higher is the average additionality level, the lower is the polarisation of the policy effect.

1 Introduction

Two contrasting forces characterise innovation policy in EU countries. Whereas the support to innovation activities is a necessary condition to reach the objectives of the Europe 2020 strategy (European Commission, 2010), the ongoing economic crisis is pressuring governments to reduce their direct intervention in support of the economic systems, or at least to increase the effectiveness and the efficiency of the policy actions. In this framework, the contribution to the policy-learning process coming from the evaluation of innovation policies is of particular importance, as it allows for a better shaping of future interventions.

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The present paper contributes to the empirical literature on the impact of innovation policy interventions, by focusing on two EU countries, namely Italy and Spain. Its first aim is to investigate the additionality effects of the public support to firms' innovation activities. In doing this, the paper adopts a multi-dimensional approach to disentangle the different effects that the policy can have. On the one hand, the present work analyses the standard input and output additionality dimensions. These latter, initially originated from the standard neoclassical rationale (e.g. Arrow, 1962), are respectively concerned with whether the policy intervention affects firms' investment in R&D and the capacity to achieve higher innovation outputs. On the other hand, an analysis of the behavioural additionality is also provided. This latter, introduced in the literature by Buisseret et al. (1995), is focused on the strategic and behavioural changes induced by the public intervention and is consistent with the system failures rationale (e.g. Smith, 2000; Metcalfe, 2005; Malerba, 2009), developed upon the evolutionary and system perspectives. In assessing the additionality of the innovation policy interventions, due to the relevant interplay between the regional and the national support schemes (e.g. Cooke, 2002; Kaiser, 2003; European Commission, 2001, 2010), this paper adopts a multi-level perspective. This aims to investigate the impacts of the regional and national policies and the consistency in the effects generated by the two levels of public support.

The second aim of this work is to provide a tentative analysis of an issue which has been scarcely investigated in the literature on the evaluation of innovation policy. Indeed, whereas the majority of the empirical contributions deals with the average effect of the public intervention (i.e. the average treatment effect on the treated, ATT), it is quite unclear whether a higher average effect is associated to a higher or lower dispersion of the impact across the beneficiaries. The paper tries to make a step ahead in this direction, investigating whether the policy impact is evenly distributed or rather polarised. In this sense, the paper analyses the extent to which the average level of additionality is correlated to the concentration or the dispersion of the impact across the funded firms.

The quantitative analysis provided in this work is based on microdata on manufacturing firms coming from the fourth wave (2002-2004) of the Community Innovation Survey. The cross-sectional nature of the data limits the possibility to overcome (completely) the potential endogeneity of the policy. On the one hand, lagged variables for the public support cannot be employed. On the other hand, in absence of panel data, it is not possible to control for the potential bias arising from unobservable characteristics (e.g. Cameron and Trivedi, 2005; Angrist and Pischke, 2009). However, to

control for the likely presence of selection bias on the observables, the additionality evaluation is carried out with a set of propensity score matching estimations. As for the analysis of the relation between the average additionality effect and the dispersion of the policy impact, this is based upon the Spearman's rank correlation between the ATTs, calculated for each additionality indicator considered, and the corresponding coefficients of variation.

The reminder of the paper is organised as follows. After this brief introduction, Section 2 deals with the theoretical and empirical background: it reviews the additionality concept, introduces the multi-level perspective in innovation policy-making and presents the main characteristics of previous empirical works that have analysed the impact of the Italian and Spanish innovation policies. Section 3 presents the econometric approach, the characteristics of the dataset and the variables used. Section 4 reports the results emerging from the analysis of the regional and national policies implemented in Italy and Spain. Section 5 concludes.

2 Theoretical and empirical background

2.1 The additionality of innovation policy

To introduce the different dimensions of the additionality that are going to be analysed in the paper, it is useful to present the main theoretical foundations these originate from[18]. Within the standard neoclassical approach (Arrow, 1962), the policy is called to correct the underinvestment in innovation generated by the market failures: public intervention is essentially aimed at stimulating an additional investment in R&D to reach the social optimum. However, due to the assumed strict linear relation between inputs and outputs (e.g. Edquist, 1999; Etzkowitz and Leydesdorff, 2000), the same underinvestment in R&D is expected to generate an underproduction of innovation. Hence, policy interventions are eventually aimed also at increasing the amount of innovation outputs produced by private actors. A different, and more complete policy rationale, emerges from the evolutionary theory and the related innovation system perspective. Accordingly, the public support should deal with different failures that concern the creation of knowledge and the evolutionary process of innovation, as well as the structure and the configuration of the innovation system (e.g. Smith, 2000; Metcalfe, 2005; Malerba, 2009).

[18] See the second Chapter of the present Thesis for a more detailed analysis.

Two additionality dimensions are developed upon the neoclassical approach. The first one is the input dimension. This is concerned with the additional amount of resources and innovative inputs (e.g. R&D investment) that would not have been allocated without the policy (Georghiou, 2004; Clarysse et al. 2004; Cerulli, 2010). The second one is the output additionality, which is concerned with the amount of outputs that would not have been achieved without the public support (Georghiou and Clarysse, 2006). These outputs can be immediate results of the innovation projects supported by the public intervention (e.g. new products or processes and patents) and their economic outcomes (e.g. improved business performances as resulting from the introduction of new products or processes) (Georghiou, 2002).

Although quite straightforward, the evaluations of the input and output additionality are affected by a main limitation. In particular, considering the beneficiary as a "black-box", they fail to take into account the complexity of the innovation process, as well as the organisational, behavioural and strategic impacts of the public support (Georghiou and Clarysse, 2006). To overcome this limit, and to make the evaluation of the innovation policy consistent with the evolutionary and system perspectives, a necessary complement comes from the analysis of the behavioural additionality. This is defined by Buisseret et al. (1995) as "the change in a company's way of undertaking R&D which can be attributed to policy actions" (p. 590). Behavioural additionality evaluation is concerned with whether the policy intervention induces relevant changes both in the internal organisation of the beneficiaries' innovation process and in their relations with external sources of knowledge. More precisely, the focus can be on: the improvement of capabilities, the enhancement of beneficiaries' networking and interactions with other organisations; the acquisition of new and diverse knowledge that can mitigate lock-in positions into non-preferable technologies[19] (e.g. Georghiou and Clarysse, 2006; Hall and Maffioli, 2008; Breschi et al., 2009).

2.2 The multi-level system of policy

In addition to a multi-dimensional analysis of the additionality effects, the paper also considers the innovation policy in a multi-level perspective. This latter finds its theoretical and empirical support in recent contributions dealing with the regional

[19] Given the lack of proper data this third type of effect is not considered in the following analysis. For an investigation of the capacity of the policy to stimulate the acquisition of diverse competencies see the fourth Chapter of the Thesis.

innovation policy. In the early literature on regional innovation systems, the regional policy-maker has been considered to be in the best position to implement innovation strategies and to promote network-type instruments (Uyarra, 2010). Such an increasing attention on the regional level of policy has been justified by the idea that public intervention has to be "context-specific and sensitive to local path-dependency" (Amin, 1999, p. 368). However, this viewpoint fails to take into account the necessary inter-connections between the different levels of public support. As noted by Laranja et al. (2008), evolutionary processes of selection, generation of novelty and path-dependency occur at multiple geographical scales; hence, there is not a unique optimal level in which innovation policy should be designed and delivered. Furthermore, innovation is a phenomenon that is shaped by institutional aspects pertaining to different scales: from the regional to the supra-national one (Howells, 1999; Boschma, 2005b). Hence, public interventions should be seen as part of a multi-level system of policy or governance (Cooke, 2002; Kaiser, 2003), in which different support schemes are initiated at different levels.

By adopting a multi-level perspective it is possible to investigate the fundamental interplay between policy actions initiated at different levels. This paper, focusing on the additionality of the public support to firms' innovation activities, examines whether regional and national interventions overlap in the effects they produce. In other terms, whether the two levels of policy are capable of inducing firms to "move towards the same direction", in terms of additionality effects. To carry out this analysis, the Italian and Spanish cases seem to be particularly interesting and appropriate. Indeed, both the countries are characterised by regional policies that are implemented following different targets and means with respect to the national ones. Italian policies initiated at the sub-national levels, with respect to national interventions, are generally characterised by a lower public contribution, being largely targeted to SMEs and aimed to support less formalised innovation activities (Cefis and Evangelista, 2007; Barbieri et al., 2010). Similarly, Spanish regional policies, when compared to the national interventions, are characterised by a smaller scale, scope and by a higher attention to less formalised innovation activities (Garcia-Quevedo and Afcha-Chávez, 2009; Afcha-Chávez, 2011).

2.3 Empirical literature on the additionality of Italian and Spanish policies

Several studies investigate the additionality of the Italian and Spanish policies aimed at supporting firms' innovation activities.

Although somehow indirectly, a first contribution that captures the effects of the Italian policies aimed at reducing the cost of R&D is the one by Parisi and Sembenelli (2003). Employing Mediocredito Centrale data for the period 1992-1997 and applying a censored panel-data regression model with random effects, their evidence points to a positive effect of the policy incentives on the R&D spending.

More directly, Cefis and Evangelista (2007) estimate the impacts of different levels of policy (i.e. local or regional, national and European) supporting Italian firms' innovation activities. Adopting a simple OLS control function approach on CIS3 (1998-2000) data, their findings point to the presence of positive input additionality effects generated by the regional, the national policies and the European Framework Programme. Some output additionality impacts also emerges for the interventions included in the European Framework Programme and, to a lesser extent, for sub-national policies. To reduce potential endogeneity problems, Cefis and Evangelista (2007), merging CIS2 (1994-1996) and CIS3, analyse the effect of a lagged policy support (considering together the different levels of intervention). There emerges a significant input additionality effect; however, this is not confirmed when using as outcome variables the variation rate of the additionality indicators considered[20].

A more recent contribution is the one by Cerulli and Potì (2008). Merging the Italian CIS3 with balance sheets data, they investigate the input additionality of the public support to firms' innovation activities, not distinguishing though among the different levels of intervention. The results, obtained from OLS regressions, a set of propensity score estimations and a Heckman selection model, generally support the presence of input additionality (in terms of R&D expenditure, R&D intensity on the turnover and R&D per employee). Some more mixed evidences emerge when considering the output additionality, captured by effect on the turnover due to product innovations. Interestingly,

[20] Variables capturing the cooperation attitude are also included. Cefis and Evangelista (2007) also provide a comparison with the impact of regional, national and European policies supporting Dutch firms' innovation activities.

Cerulli and Potì (2008) further disaggregate their analysis by macro-region, sector[21] and firm's size. Their results point to a total crowding-out effect only in low knowledge-intensive services sector, very small firms (10-19 employees) and auto-vehicle sector.

Italian policy has been further investigated by works that analyse the impact of specific policy mechanisms and funding schemes.

Some evidence on the effect of specific types of policy instrument comes from Carboni (2011), who employs a propensity score matching approach over Capitalia data for the period 2001-2003. Public support is found to have, in general terms, a positive effect on private R&D investment. Nevertheless, when distinguishing between tax incentives and direct grants, the results point to a much larger and more significant impact of the former type of intervention.

As for the contributions aimed at assessing specific Italian funding schemes, a first work to mention is the one by Barbieri et al. (2010), who investigate the impact of the law 46/82. This consists of two parts, establishing the Fund for Applied Research (FSRA) (which converged in 2001 in the Fund for Research Support (FAR)) and the Fund for Technological Innovation (FIT). In brief, the former is aimed at supporting firms' investment in applied research activities including the collaborations with research partners. The latter is focused on applied innovations and on the development phase of firms' R&D activities. The analysis carried out by Barbieri et al. (2010) is based on a panel created upon three waves of the Capitalia (MedioCredito Centrale) surveys (1995-1997, 1998-2000, 2001-2003). The results, emerging from a difference-in-difference approach, point to an ambiguous evidence on the input additionality of the law 46/82. The only positive and significant effects are those emerging from the difference between the second and the first waves analysed. More precisely, it is noticeable a positive and significant impact of the first part of the law (FSRA/FAR) on the R&D expenditure and of the second part of the law (FIT) on the R&D personnel. To control for the concurring effects of other incentive schemes, Barbieri et al. (2010) employ a difference-in-difference-in-difference method. The results point to a lack of effectiveness of the law when interacted with other policy schemes.

Merito et al. (2010) investigate FAR's predecessor, the Fund for Applied Research (FSRA), focusing on the last two years of its activity (i.e. 1999-2000). FSRA

[21] Sectors considered are: high-tech, medium-high tech, medium-low tech manufacturing sectors; knowledge intensive and low-knowledge intensive services. In addition to these, three specific manufacturing sectors are considered: i.e. auto-vehicle, mechanics, chemicals.

effectiveness is evaluated through a matching approach applied over Amadeus (Bureau van Dijk) data merged with information on firms' patenting activity stemming from the Delphion dataset. The focus of the work is mainly on the output additionality effects of the FSRA, two (2002) and four years after the public support (2004). More precisely, the analysis aims at capturing the impact on the market success, labour productivity, patenting activity, labour force composition and employment growth. The only significant effects (i.e. a positive impact on the patent applications and a negative one on the composition of the workforce) are registered in the short-run (2002). However, the effect of the intervention seems to be dependent on the type of beneficiaries. When the analysis is limited to the SMEs, FSRA is found to be positively affecting the composition of the workforce, the patenting activity (both in the short- and medium-long run) and the employment growth (in the medium-long run).

A more recent study dealing with the evaluation of the FAR is the one by Cerulli and Potì (2010), who employ a panel covering the period 2002-2004, created upon data collected by the Ministry of Research (MIUR) and the Italian National Institute of Statistics (ISTAT). The comprehensive econometric analysis provided sheds, at first, some light on the input additionality effects. The evidence emerging from a structural model, in its reduced form regression equation, points to a positive effect on private R&D spending. Cerulli and Potì (2010) also analyse the heterogeneity of the effects, investigating the presence of input additionality in different subgroups of firms. Input additionality is found to characterise large and very large companies, low-tech, high and medium-high tech firms, as well as companies located in the North and the Centre of Italy. Another interesting insight from Cerulli and Potì (2010) is the analysis of the effect of the input additionality on the level of output additionality, captured by the number of patents. Through a matching technique, for each firm, an idiosyncratic level of additionality and the "own R&D expenditure" are estimated and used as predictors, together with the amount of subsidy, in a poisson regression. The coefficient of the idiosyncratic additionality term turns out to be positive and significant, meaning that the input additionality effect of the policy induces a higher innovation performance in terms of patent applications[22].

[22] Cerulli and Potì (2010) provide other interesting insights. First, an analysis of the differences in the effects resulting from various sub-types of intervention within the FAR. Second, an investigation of the structural differences, concerning also the different economic performances

As for the FIT, this is evaluated by De Blasio et al. (2011) with a regression discontinuity design approach, which exploits a cut-off in the programme due to the unexpected shortage of funding in March 2002. The evidence, based on data from the Ministry of Economic Development and the Cerved dataset of financial statements, points to a substantial lack of effectiveness: subsidised firms do not invest more in either tangible or intangible assets.

A relevant complement to the findings emerging from the contributions reviewed above arises from works that are explicitly focused on specific types of beneficiaries.

As for SMEs, some evidence on the effectiveness of the policy interventions on the investment in innovation can be found in Hall et al. (2009). Employing a CDM model[23] (Crépon et al., 1998) on three waves of the Mediocredito Centrale (Capitalia) data (referring to the periods 1995–1997, 1998–2000, 2001–2003), they investigate the impact of innovation on productivity. The results emerging from the first part of their analysis point to a positive effect of receiving a subsidy on SMEs' investment in R&D.

Another relevant contribution is the one by Colombo et al. (2011). Focusing on new technology-based firms (NTBFs), they investigate the output additionality of R&D subsidies. The authors estimate the effect of the public funding on the increase in the total factor productivity (TFP), by employing data coming from the RITA (Research on Entrepreneurship in Advanced Technologies) dataset. The results, emerging from a GMM-system estimator, which accounts for the endogeneity of the policy support and whose consistency is increased by exogenous instruments, point to the positive effect of selective supportive schemes, while the impact of automatic ones is not significant.

In addition to the works reviewed above, at the best of our knowledge, the contribution by Bronzini and Iachini (2011) is the only one that analyses a specific Italian regional innovation policy, namely the Emilia-Romagna regional R&D subsidy[24]. Bronzini and Iachini (2011) assess the input additionality of the subsidy using balance sheets data and employing a regression discontinuity design approach. This is based on

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(i.e. productivity, profitability and turnover's growth rate), between firms performing crowding-out and firms performing additionality.

[23] This consists of three building blocks. The first concerns with the decision on whether to engage in (and the amount of resources devoted to) R&D. The second one consists of a two-equation knowledge production function (one for process and one for product innovation) in which R&D is one of the inputs. The third consists of a simple extended production function in which process and product innovation are considered as inputs (Hall et al., 2009).

[24] See the fourth Chapter of this Thesis for an investigation focused on the same regional subsidy.

the cut-off generated by a threshold score in the projects' evaluation process. In general terms, the public support is not found to have significant effects; however, when the analysis is carried out by firm's size, there emerges a positive impact on the private investment of small companies.

Moving to the empirical contributions aimed at evaluating innovation policies in Spain, a first work to be mentioned is the early contribution by Busom (2000). She investigates the input additionality of a programme implemented by the Centre for Technological and Industrial Development (CDTI), an agency of the Spanish Ministry of Industry. Through OLS regressions, the mean fitted values of the R&D expenditure and the R&D personnel for participants and non participants are obtained. By comparing these values, Busom (2000) concludes that the policy positively affects both the additionality indicators considered.

A more recent empirical contribution is the one by González and Pazó (2008), who investigate the input additionality of Spanish policies in the period 1990-1999, without distinguishing among the different levels of intervention. They employ a matching technique over panel data coming from the Spanish Survey on Firm Strategy. The evidence points to the absence of crowding-out between public and private spending. Furthermore, public funding is found to be a necessary condition for some types of firms (small and operating in low technology sectors) to engage in R&D activities.

Exploiting the same dataset for the period 1998-2005, Garcia-Quevedo and Afcha-Chávez (2009) analyse the input additionality of the Spanish national and regional policy interventions. Support schemes initiated at the national level positively affect the intensity of R&D investment; however, a similar result is not found for the regional interventions, for which the policy impact is not significant.

The last four contributions here reviewed (Busom and Fernández-Ribas, 2008; Fernández-Ribas and Shapira, 2009; Magro et al., 2010; Afcha-Chávez, 2011) introduce some new insights in the literature, as they are focused also on the behavioural additionality of innovation policy. The work by Busom and Fernández-Ribas (2008) is focused on the cooperation dimension of the behavioural additionality. To evaluate the impact of the national funding, the work employs data coming from the Spanish Innovation Survey (period 1996-1998). At first, the authors adopt a structural model, in which the decision to participate in the policy is modelled, as well as the equations of partners selection. However, after having estimated a reduced form equation of their structural model, Busom and Fernández-Ribas (2008) turn to a matching approach to deal

with the endogeneity of the policy support. The results of the empirical analyses show that the policy support has a positive impact on the cooperation between funded firms and public research organisations and, to a lesser extent, on the interactions between supported companies and private partners.

Afcha-Chávez (2011) considers the impact of national and regional policies on firms' cooperation with business and research partners. The analysis is carried out on the basis of data coming from the Spanish Survey on Firm Strategy (period 1998-2005). As in Busom and Fernández-Ribas (2008), Afcha-Chávez (2011) tries to employ a structural approach, but then moves to a propensity score matching estimation given the endogeneity of the public support. The results point to a positive impact of both regional and national policies on the propensity to cooperate with universities or technological centres. Nevertheless, both regional and national programmes have no significant effects on the cooperation with business partners (i.e. customers and suppliers).

On a similar vein, Fernández-Ribas and Shapira (2009) analyse the effect of national and regional innovation policies on firms' cooperation, but focusing on the interactions with foreign partners. Results, emerging from propensity score matching estimations implemented over data arising from the Spanish version of the Third Community Innovation Survey (1998-2000), point to a generally positive impact of the public support schemes investigated.

The last work here reviewed is the one by Magro et al. (2010). At the best of our knowledge, this is the only contribution focused on a specific Spanish regional policy. The authors analyse a R&D programme implemented in the Basque Country and investigate whether public funding raises the propensity to collaborate, increases the participation in international R&D programmes and leads to a systematic R&D behaviour within the firms. The evidence, emerging from a matching estimation, point to a positive effect on all the three aspects of the behavioural additionality.

The large amount of evidence provided does not lead to an unambiguous conclusion on the additionality profiles of the public interventions implemented in Italy and Spain. What is more, proper comparisons -even among the studies that are focused on the same country/programme- are not allowed, due to the differences in the effects and time-spans considered, as well as in the data and methodologies employed. Some tentative insights can only be drawn about the input additionality of the overall systems of policy of the two countries. The evidence points to the general presence of positive effects (Parisi and Sembenelli, 2003; Cefis and Evangelista, 2007; Cerulli and Potì, 2008;

González and Pazó, 2008; Garcia-Quevedo and Afcha-Chávez, 2009; Hall et al. 2009), even if with some differences. In Italy the evaluations of the specific types of instruments (i.e. direct grants and tax incentives) and funding schemes (i.e. FAR/FSRA and FIT) lead to mixed results (Barbieri et al., 2010; Cerulli and Potì, 2010; De Blasio et al., 2011; Carboni, 2011). In Spain regional policies are found to be ineffective in stimulating private investment in R&D (Garcia-Quevedo and Afcha-Chávez, 2009).

As for the other additionality dimensions, instead, a comparison between Italian and Spanish public interventions is hardly possible. Some evidence on the output additionality, although mixed, is available for the Italian policies only (Cefis and Evangelista, 2007; Cerulli and Potì, 2008, 2010; Merito et al. 2010; Colombo et al., 2011). As for the behavioural additionality, the only available investigations are mainly focused on the capacity of Spanish policy programmes to stimulate funded firms' interactions with other companies and research organisations (Busom and Fernández-Ribas, 2008; Fernández-Ribas and Shapira, 2009; Magro et al., 2010; Afcha-Chávez, 2011).

All in all, the picture emerging from the review of the previous empirical contributions identifies two main limitations that the present paper aims to address. At first, as said, a hardly possible comparability of the results, both within and between the countries. For this reason it seems necessary to systematise the analysis, considering together the three additionality dimensions and using the same methodology and data. Only in this way it will be possible to compare the effectiveness of the regional and the national interventions implemented in Italy and Spain. Second, almost all the contributions (with the partial exception of Cerulli and Potì, 2010) analyse the average effect of the participation in the policy, without considering whether this latter is generated by the concentration or by the polarisation of the effects on the single beneficiaries. This is another aspect that the present paper aims to address.

3 Empirical application

3.1 Econometric strategy

In evaluating the additionality of innovation policies the focus is basically on the net effect of the public intervention. More precisely, in econometric terms, the objective is to estimate the impact that is directly caused by a treatment, which in this case is the participation in the policy and the consequent public funding. This impact can be seen as

the difference between the outcome (e.g. the R&D investment in the case of the input additionality) observable after the treatment and the outcome that would have been observed without the treatment, i.e. the counterfactual. Denoting by Y_{i1} the outcome in case of treatment and by Y_{i0} the outcome in case of non treatment, the effect on a single unit (i.e. the firm) is $\Delta_i = Y_{i1} - Y_{i0}$. As noted by Holland (1986), the possibility to use this kind of approach is limited by the fundamental problem of causal inference: it is not possible to observe both the outcome in presence and in absence of the treatment on the same unit. The statistical solution to this problem is based on the concept of average causal effect, and the parameter of interest becomes the average treatment effect on the treated (ATT):

$$ATT = E(\Delta \mid D = 1) = (Y_1 - Y_0 \mid D = 1) = E(Y_1 \mid D = 1) - E(Y_0 \mid D = 1), \qquad (1)$$

where D denotes the binary treatment status.

In our case, $E(Y_1 \mid D=1)$ can be estimated by the mean outcome of treated firms. However, $E(Y_0|D=1)$ (i.e. the potential outcome in absence of treatment) cannot be observed: for treated firms, it is not possible to detect the outcome that would have been reached in absence of the public funding. In a situation in which firms were randomly assigned to the public support, $E(Y_0|D=1)$ could be estimated by $E(Y_0|D=0)$, because on average participants and non participants would not differ, so that $E(Y_0|D=1)=E(Y_0|D=0)$. Nevertheless, random assignments are very unlikely in innovation policy, as in most of the economic policies. On the one hand, some beneficiaries can self-select themselves. On the other hand, policy-makers can deliberately select recipients with certain characteristics, with either a "picking the winner" or a "aiding the poor" strategy (Cerulli, 2010). The result is that treated and non treated firms can be systematically different; thus, estimating the counterfactual with the mean outcome of the non participants is a source of bias, namely the selection bias. This can be generated, by the omission of observable and/or unobservable variables that determine both the treatment status and the outcome (Cameron and Trivedi, 2005). In the following, to control for the selection on the observables a matching approach is used. This is essentially aimed at pairing treated firms with “twin” non treated ones, so that the difference in the outcome is only due to the treatment.

At the basis of matching estimation there is the conditional independence assumption[25]:

$$Y_0, Y_1 \perp D \mid X. \quad (2)$$

Accordingly, outcomes are assumed to be independent of programme participation conditional on a set of observables characteristics *X*. Conditioning on *X* is like assuming that the assignment is randomised and that unobservables are not relevant for the participation (Dehejia and Wahba, 2002). In order to have a consistent matching procedure another assumption is needed: the so-called "stable unit-treatment value assumption" or SUTVA (Rubin, 1986). SUTVA implies that the outcome for firm *i* must be independent to the treatment given to firm *j*[26]. In addition to these assumptions, for a correct matching estimation of the ATT, the common support condition is also necessary[27]:

$$0 < \Pr(D = 1 \mid X) < 1. \quad (3)$$

Indeed, if (3) is not satisfied there are only treated or non treated firms for certain values of *X*, thus making the matching impossible.

Given (2), SUTVA and (3) it is possible to overcome the inability to observe the potential outcome in absence of treatment for participant firms. The unobservable term $E(Y_0|D=1, X)$, can be recovered from $E(Y_0|\ D=0, X)$ and the ATT can be formalised as follows:

$$ATT = E_{X|D=1}[E(Y_1 \mid D = 1, X) - E(Y_0 \mid D = 0, X)]. \quad (4)$$

Intuitively, matching methods are based on the idea that the effect of the treatment is estimated through the average difference between the outcome of the treated units and the outcome of the non treated ones that have the same set of observable characteristics *X*. In principle, in order to have an unbiased estimation of the treatment effect, each treated firm should be matched with a non treated one that has exactly the same vector of *X*.

[25] A weaker version of (2), i.e. $Y_0 \perp D \mid X$, can suffice (e.g. Cameron and Trivedi, 2005; Caliendo and Kopeinig, 2008).

[26] This is a strong assumption in the evaluation of innovation policy due to the likely interactions among firms. See the Section 3.3 of the second Chapter included in the present Thesis for a discussion of how spillovers might generate additionality effects on non beneficiaries.

[27] As the interest is on the treatment effect on treated, the common support condition can be relaxed and written as Pr (D=1|X) <1. This guarantees the presence of suitable counterfactual firms for each treated (Smith and Todd, 2005; Caliendo and Kopeinig, 2008).

However, if the vector has a high dimension it can be difficult, if not impossible, to find appropriate matches for all the treated firms. Rosenbaum and Rubin (1983), in their seminal contribution, propose a device which helps to reduce the dimension of conditioning: the propensity score. Propensity score is the conditional probability of receiving the treatment given *X*:

$$P(X) = \Pr(D = 1 \mid X). \tag{5}$$

Drawing on Rosenbaum and Rubin (1983), when (2) holds,

$$Y_0, Y_1 \perp D \mid P(X): \tag{6}$$

when outcomes are independent of treatment conditional on *X*, they are also independent of treatment conditional on the propensity score. The aim of the propensity score matching is to reduce the dimension of conditioning by pairing treated and non treated firms which have the same (or very similar) values of *P*(*X*), though possible different values of the single *X*. In this sense:

$$ATT = E_{P(X)|D=1}\{E[Y_1 \mid D = 1, P(X)] - E[Y_0 \mid D = 0, P(X)]\}. \tag{7}$$

To operationalise the propensity score matching estimation of the ATT, in the following empirical application a multi-step protocol is applied (Caliendo and Kopeinig, 2008). At first, the propensity score is estimated with a probit model that includes as covariates all the variables that are expected to affect the outcome and the treatment status.

Then, as a second step, a set of different matching algorithms is chosen. These basically differ in the way non treated firms to be used as matches are selected and weighted. In the following empirical application the use of more matching procedures provides information on the stability and reliability of the emerging evidences. In particular three types of algorithms developed in the literature (e.g. Becker and Ichino, 2004; Cameron and Trivedi, 2005; Smith and Todd, 2005; Caliendo and Kopeinig, 2008) are implemented: 5 nearest neighbours (5NN), caliper and kernel. To provide a better explanation of the different algorithms it is useful to introduce the following general notation (Smith and Todd, 2005) for the propensity score matching estimator of the ATT:

$$ATT = \frac{1}{N_1} \sum_{i \in I_1 \cap Sp} [Y_{1i} - \hat{E}(Y_{0i} \mid D = 1, P_i)], \tag{8}$$

with the counterfactual being defined as

$$\hat{E}(Y_{0i} \mid D=1, P_i) = \sum_{j \in I_0} W(i,j) Y_{0j}. \quad (9)$$

I_1 denotes the set of treated firms, I_0 the set of non treated firms, *Sp* the region of common support[28] and $P(X)$ for simplicity is P. The match for each $i \in I_1 \cap Sp$, is constructed as a weighted average over the outcomes of non treated firms, where the weights $W(i, j)$ depend on the distance between P_i and P_j. 5NN matching is a variant of the single nearest neighbour matching, where $C(P_i)$, the set of controls j selected as matches for each treated i, is such that:

$$C(P_i) = \min_j \left\| P_i - P_j \right\|. \quad (10)$$

More precisely, in the 5NN matching, the counterfactual for each treated firm is calculated as the mean outcome of the five non treated firms with the closest propensity score. With respect to the single nearest neighbour procedure, 5NN implies a trade-off between lower variance (more information is used to create the counterfactual) and an increased bias in the estimation (some dissimilar non treated firms can be used as matches) (e.g. Caliendo and Kopeinig, 2008). Caliper matching reduces this potential bias by imposing a maximum tolerance, ε (i.e. 0.02 in the following application), to the distance in the propensity score values between treated and non treated firms:

$$C(P_i) = \{P_j \mid \left\| P_i - P_j \right\| < \varepsilon\}. \quad . \quad (11)$$

To increase the possibility of finding good matches, in both the 5NN and caliper algorithms, the replacement is allowed: non treated firms can be matched with more than one treated firm. The last algorithm employed is the kernel matching:

$$ATT = \frac{1}{N_1} \sum_{i \in I_1} \left[Y_{1i} - \frac{\sum_{j \in I_0} Y_{0j} G\left(\frac{P_j - P_i}{a_n} \right)}{\sum_{k \in I_0} G\left(\frac{P_k - P_i}{a_n} \right)} \right], \quad (12)$$

where $G(\cdot)$ is a kernel function (i.e. Epanechnikov) and a_n a bandwith parameter (i.e. 0.06). With respect to the other two procedures, which use a limited number of controls

[28] See below for how this region is created by imposing the common support condition.

for each treated firm, kernel matching creates the counterfactual for each participant using the information from (nearly) the entire set of non treated, thus involving a trade-off between lower variance (more information is used) and higher bias (on average the similarity between treated and controls is expected to be lower) (e.g. Caliendo and Kopeinig, 2008).

The third step of the estimation protocol consists of imposing the common support condition to the matching algorithms. In what follows a "minima-maxima comparison" is applied. Following the *psmatch2* STATA procedure (Leuven and Sianesi, 2003), treated observations whose propensity score is higher than the maximum or less than the minimum propensity score of the controls are dropped. In addition to this, a 5% "trim" is also imposed to the 5NN algorithm; this results in dropping treated observations at which the propensity score density of the controls is the lowest.

The last step consists of assessing the quality of the matching. The basic idea is to compare the situation after and before the matching to check that treated firms and matched controls are correctly aligned with respect to the vector of covariates *X*. To this purpose, four tests are employed. The first is a regression-based t-test on differences in the covariates means, for which it is expected that after the matching all the covariates are not able to significantly predict the treatment status. The second is a loglikelihood ratio test. In this case, after the matching, the covariates included in the specification of the probit model for the propensity score estimation are expected to be jointly non significant. The third is a pseudo R^2 test. In this case, the goodness of fit of the probit model is expected to collapse after the matching. The fourth is a test on the standardised bias[29], which is passed if after the matching the standardised bias is reduced below 3%-5% (Caliendo and Kopeinig, 2008)[30].

Propensity score matching is also at the basis of the tentative analysis of the relation between the average impact of the policy and the dispersion of the effects on the

[29] Standardised bias is calculated both after and before the matching as: $SB_{before} = 100 \cdot \frac{(\overline{X}_1 - \overline{X}_0)}{\sqrt{0.5 \cdot (V_1(X) + V_0(X))}}$, $SB_{after} = 100 \cdot \frac{(\overline{X}_{1M} - \overline{X}_{0M})}{\sqrt{0.5 \cdot (V_{1M}(X) + V_{0M}(X))}}$, where $\overline{X}$ is the mean of the covariates, $V(X)$ their variance, and $_M$ denotes the matched samples.

[30] The results of the tests, which are not reported in the following pages -but available upon request-, largely support the quality of all the employed matching procedures. The only slightly non satisfactory test is the one on the standardised bias. Through all the sixteen matching procedures only for five covariates the SB_{after} this is found to be slightly higher (6.1% at the most) than the threshold indicated by Caliendo and Kopeinig (2008).

individual beneficiaries. With this respect, the idea is to provide a preliminary investigation of whether the average additionality level of the policy is driven by the concentration of the effects around the mean impact or by the presence of individual effects which are located well below or above the average impact. More precisely, the aim is to measure the extent to which the ATT is correlated to the dispersion/concentration of the impact across the beneficiaries. To this purpose, at first, "*i-th* firm's" effects are calculated by subtracting from the value of the outcome variable of each supported firm *i* the average outcome of its counterfactual, obtained with a 5NN procedure[31]. Then, for each additionality indicator (i.e. outcome variable) considered (see Section 3.3), a coefficient of variation of the *i-th* effects is calculated. Furthermore, to have comparable ATTs across the different additionality indicators, each ATT is divided by the overall average counterfactual outcome, estimated with the 5NN matching. Finally, a Spearman's rank correlation coefficient is calculated between the (rescaled) ATTs and the corresponding coefficients of variation. This captures the extent to which the rank of the (rescaled) ATTs, calculated for each additionality indicator, is related to the rank of the corresponding coefficients of variation.

3.2 The Community Innovation Survey

The following empirical application is carried out by employing data coming from the fourth wave of the Community Innovation Survey (CIS4). As all the CIS waves, this is based on a harmonized questionnaire which is the same for all the European countries, thus allowing for comparable analyses. In addition to firm's characteristics, the CIS4 dataset includes information on: (i) product and process innovations; (ii) innovative inputs and expenditures; (iii) public funding; (iv) sources of information; (v) cooperation agreements; (vi) effects of innovation; (vii) hampering factors; (viii) intellectual propriety rights; (ix) organisational and marketing innovation; (x) effects of organisational innovation. The information gathered through the harmonised questionnaire of the CIS4 refers generally to the period 2002-2004, however some of the variables capture

[31] A very similar approach to obtain the "*i-th* firm's effect" is implemented by Czarnitzki and Licht (2006) and Cerulli and Potì (2010).

particular aspects in the last year of the reference period[32] or both in the first and last year[33].

Eurostat offers the possibility to access to a CIS4 dataset containing anonymised microdata[34]. The anonymisation of the data eliminates formal identifiers such as the name or exact address of the enterprises. Furthermore, some firm's characteristics (i.e. country of the head-office, sector, size) are recoded into less punctual variables. In addition to this, Eurostat micro-aggregates the data. The resulting database consists of the same number of units as kept in the original database: artificial units are created by replacing original values by the mean (for quantitative variables) or mode value (for qualitative variables) within clusters of three observations[35] formed of individuals of "maximum similarity" (i.e. with the nearest value). The variables in the original dataset are micro-aggregated independently of each other (i.e. clusters are established separately for each specific variable). This process, as mentioned, does not reduce the number of observations, which is actually quite high. More precisely, the two working datasets used in the following empirical application originally consisted of 18,946 observations for Spain and 21,854 for Italy. Nevertheless, in order to provide a proper additionality evaluation of the regional and national policy interventions the size of the working datasets is reduced[36]. That because of three main reasons. At first, the analysis is limited to manufacturing firms. Second, in order to have the complete range of variables for all the observations, firms with unexpected missing values and firms that had not to fill the entire questionnaire[37] are dropped. Finally, to provide a proper additionality evaluation of the regional (national) policies, the working datasets are limited to have among treated units only firms that obtained a regional (national) funding, while among the control units only firms that did not receive any type of public support.

[32] Turnover due to product innovations new to the firm or to the market; expenditure for intramural and extramural R&D; expenditure for machinery, equipment and software; expenditure for external knowledge and total expenditure for innovative activities.

[33] Turnover and size

[34] For 16 European countries (i.e. Belgium, Bulgaria, Czech Republic, Germany, Estonia, Spain, Greece, Hungary, Italy, Latvia, Lithuania, Norway, Portugal, Romania, Slovakia, Slovenia).

[35] In some cases 4 if the number of observations is not a multiple of 3.

[36] See Section 4 for the actual number of observations used.

[37] Those companies that in the period 2002-2004 did not introduce any product or process innovation and did not carry out any innovation activities.

3.3 Variables

To operationalise the econometric approach presented above, at first, dummy variables for the firm's treatment status are needed. To this purpose four dummies are used. These reflect whether the firm received some funding by the regional or local (FUNLOC), the national (FUNGMT) or the European (FUNEU) levels of government and whether the European support was granted within the 5th or 6th European Framework Programme for Research and Technical Development (FUNRTD). These dummy variables allows for the identification of the firms supported by regional or national funding schemes, but also of the firms that were not funded by any type of policy. This, in turn, permits the identification of treated and control groups for the additionality evaluation of the regional and national policies through the propensity score matching estimation.

In addition to the treatment variables, it is necessary to define suitable covariates X[38]. Drawing on recent studies that evaluate the additionality of innovation policy interventions by adopting a propensity score matching approach (e.g. Czarnitki and Licht, 2006; Aerts and Shmidt, 2008; Busom and Fernández-Ribas, 2008), a set of firm's characteristics are identified and included in the propensity score specification (See Tab. A1 in the Appendix) [39]. First of all, firms' size is controlled for, by including three dummies (i.e. SMALL, MEDIUM and LARGE) and the logarithm of the turnover (ln_TURN02). Participation and innovation strategies, however, could be affected also by the sector in which the firm operates. On the one hand, policy intervention might be targeted to specific and strategic industries. On the other hand, firms belonging to more advanced sectors could be more able and willing to apply for the public support with well-promising projects. A series of dummies (SEC_DA-SEC_DN) capturing the manufacturing sector in which the firm operates are thus included[40]. Furthermore, aspects

[38] Considering the characteristics and the rationale of the econometric method here employed (see Section 3.1), the covariates used to estimate the propensity score essentially represent the observable characteristics we control for. Hence, these can be considered, in a sense, as analogous to the control variables included in the specification of a standard parametric regression model.

[39] Given the differences in the policies analysed, some of the relations (assumed below) between the covariates and the propensity to participate in the policy support do not find an empirical support. As FUNLOC and FUNGMT refer to the 2002-2004 period, to avoid endogeneity problems, whenever possible, the propensity scores specification includes variables referred to the first year of the period (2002). This can be done for ln_TURN02, SMALL, MEDIUM and LARGE.

[40] Italian firms belonging to NACE rev. 1.1 19 (i.e. secDC in the CIS4 sectoral classification), 20 (belonging to sec20-21) and 23 (belonging to secDF-DG) are dropped from the working sample:

pertaining to the governance and ownership of the firm are controlled for with the inclusion of two dummies. These indicates, respectively, whether the firm belongs to a group (GP) and whether the firm is an affiliate of a multinational (MNC) corporation (MNCGROUP). Through network channels, firms belonging to a group might have more information on existent policy schemes and, thus, a higher probability of participating in policy programmes. On the contrary, being a MNC-affiliate might reduce the participation in support schemes, as parent companies might be more willing to file subsidy applications in the home country. Another firm's characteristic that can be expected to affect the probability to participate in the policy programmes and the innovation strategy pertains to the engagement in foreign markets (EXPORT). Firms engaged in the international competition are supposed to be more aware of the need to innovate and, thus, probably more willing to apply for policy programmes that support their innovative activities. Another extremely important aspect that should be taken into account in the propensity score estimation concerns firm's engagement in R&D. With this respect, two dummies are included: RDENG and RDCONT. The first captures whether the firm is engaged in R&D, the second whether this engagement is continuous. In principle, both of them should have a positive effect on the participation in support schemes: firms that are committed to formal R&D activities are expected to be more willing and able to apply, successfully, for the public funding. Another factor that might influence the innovation strategy and the participation status is the firm's financial constraint. Two set of dummy variables are thus included in the probit estimations of the propensity score. The first one (i.e. HFENT1, HFENT2, HFENT3) captures whether the firm faces a "nil or low", "medium" or "high" lack of internal funding. Similarly HFOUT1, HFOUT2, HFOUT3, captures whether the firm faces a "nil or low", "medium" or "high" problem in accessing to external funding. In this case, it is expected that, at least up to a certain point, the more the firm faces a lack of internal or external funding, the more it might wish to be supported by the policy in order to compensate for the financial constraint. Differently from previous studies, this research takes into consideration also some informational aspects for the estimation of the propensity score. Three dummies (SMGT1, SGMT2, SGMT3) indicate the relevance ("nil or low",

for these sectors the anonymisation process, carried out by the Italian National Statistical Institute, resulted in the aggregation of medium and large firms into a unique dimensional class. Firms belonging to NACE rev. 1.1 30 (belonging to secDL) are drooped too, as for these the anonymisation process resulted in the aggregation of small, medium and large firms into a unique dimensional class.

"medium", "high") of the governmental sources of information for the firm's innovative activities. Obviously, this type of information is supposed to positively affect the knowledge about possible support schemes, the probability to participate in the policy programmes and to shape the innovation activities consistently with the desired policy objectives. Similarly, other three dummies indicate the relevance of the information coming from professionals and industry associations (SPRO1, SPRO2, SPRO3). Indeed, professionals and industry associations can play a crucial role in supporting firms to gather information about possible public interventions, to file applications for support schemes and to fulfil policy requirements in terms of objectives to be achieved[41].

Finally, by using the CIS4 database, it is possible to use and create a number of additionality indicators (i.e. outcome variables)[42] that capture input, output and behavioural additionality. As for the input additionality these are: (i) the expenditure in intramural R&D, in year 2004 (RDEXP); (ii) the intensity of the intramural R&D investment (RDINT) on the turnover, in year 2004. As for the output dimension the considered outcome variables are: (i) a dummy for product innovation (PRODINNO); (ii) a dummy for process innovation (PROCINNO); (iii) the percentage of turnover in year 2004 due to product innovations introduced in 2002-2004 that were new to the market (TURNMAR); (iv) the percentage of turnover in year 2004 due to product innovations introduced in 2002-2004 that were new to the firm (TURNIN); (v) the sum of TURNIN and TURNMAR (i.e. TURNINNO)[43]; (vi) a dummy for patent application (PROPAT). Concerning the behavioural dimension, two types of impact are considered: the effect of the policy interventions on the acquisition of competencies and on the interactions with external actors. To capture the former type of effect, the main outcome variable is a dummy for the engagement in formal training programmes (TRAINENG). This variable proxies a change that can be argued to be a possible complementary consequence of the public support. More precisely, whether, in order to carry the publicly funded innovation activities, firms are induced to upgrade employees' competencies through formal training programmes. As for the effects on interactions and networking activities two types of outcome variables can be used. First, two dummies capture the cooperation with firms

[41] LARGE, HFENT1, HFOUT1, SGMT1, SPRO1, SEC27 (i.e. NACE rev 1.1 sector 27) are used as reference terms in the probit estimation of the propensity score.
[42] Unless differently reported the variables defined below are referred to period 2002-2004.
[43] TURNMAR TURNIN and TURNINNO are rescaled from 0 to 1.

(COOPFIRM) and research organisations (COOPORG)[44]. Second, two dummies identify the acquisition of relevant information from other firms (INFOFIRM) and from universities or private research institutes (INFOORG)[45]. These outcome variables capture whether policy interventions, through an explicit support and/or by allowing firms to face the cost of collaborating with external actors, enhance beneficiaries' networking and effective interactions with both other firms and research organisations.

4 Results

4.1 Italian regional policies

The additionality evaluation of the Italian regional policies is carried out on a sample of 2,006 manufacturing firms (599 supported and 1,407 potential controls). Considering a hypothetical benchmark situation in which the policy intervention is able to induce positive and significant effects with respect to all the additionality indicators considered, regional policies in Italy, during the analysed period, are characterised by a low level of effectiveness. Indeed, as it emerges from Tab. 1, Italian regional programmes have a number of non significant and also negative impacts.

At first, it is possible to notice the absence of input additionality. An explanation for this result can be found in the low scale of the regional interventions and their focus on less formalised innovation activities (Cefis and Evangelista, 2007; Barbieri et al. 2010). The greater attention on small scale, less formalised, and neither particularly

[44] COOPFIRM is "exploded" in different dummies, capturing cooperation agreements with national (COOPGPNAT) and foreign firms belonging to the same group (COOPGPFOR); national (COOPSUPNAT) and foreign suppliers (COOPSUPFOR); national (COOPCUSNAT) and foreign customers (COOPCUSFOR); national (COOPCOMNAT) and foreign competitors (COOPCOMFOR). Similarly COOPORG is further specified to capture the cooperation with: national (COOPINSNAT) and foreign private R&D institutes and commercial labs (COOPINSFOR); national (COOPUNINAT) and foreign universities (COOPUNIFOR); national (COOPPUBNAT) and foreign governmental agencies or public research institutes (COOPPUBFOR). ATT estimations for these specific types of cooperation are provided in the Appendix.

[45] These dummies are created from the four-point likert scales, included in the CIS4 dataset, that indicate the importance of different sources of information for the firm's innovation activities. The dummies take value 1 if the relevance of the information is "medium" or "high". INFOFIRM captures information coming from suppliers (INFOSUP), customers (INFOCUS) and competitors (INFOCOM). INFOORG includes information sourcing from universities (INFOUNI) and private research institutes (INFOINS). ATT estimations for these specific types of information sourcing are provided in the Appendix.

disruptive nor exploratory innovation projects seems to affect the overall additionality profile of the Italian regional support schemes.

Tab. 1 Additionality of the regional policies in Italy

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
Input add.								
RDEXP	42295.320	67483.270	43382.720	67180.760	23791.990	47706.630	45794.740	71086.020
RDINT	0.003	0.002	0.003	0.002	0.002	0.002	0.003	0.002
Output add.								
PRODINNO	-0.047 *	0.028	-0.058 **	0.029	-0.050 **	0.023	-0.063 **	0.031
PROCINNO	0.122 ***	0.031	0.118 ***	0.029	0.111 ***	0.023	0.133 ***	0.033
TURNMAR	0.002	0.013	-0.003	0.012	-0.002	0.010	0.002	0.013
TURNIN	-0.021 **	0.010	-0.025 **	0.010	-0.016 *	0.009	-0.022 *	0.012
TURNINO	-0.019	0.017	-0.028 *	0.016	-0.017	0.013	-0.019	0.015
PROPAT	-0.023	0.026	-0.019	0.025	-0.007	0.020	-0.021	0.025
Behavioural add.								
TRAINENG	-0.046 *	0.025	-0.046 *	0.027	-0.043 *	0.022	-0.052 *	0.027
COOPFIRM	-0.028	0.020	-0.028	0.018	-0.015	0.013	-0.040 **	0.019
COOPORG	-0.019	0.016	-0.019	0.016	-0.012	0.013	-0.028 *	0.017
INFOFIRM	-0.059 ***	0.022	-0.065 ***	0.024	-0.043 **	0.020	-0.065 ***	0.023
INFOORG	0.097 ***	0.029	0.101 ***	0.028	0.097 ***	0.027	0.095 ***	0.031
N treat. on support	598		598		598		570	
N treated total	599		599		599		599	
N non treated	1407		1407		1407		1407	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

As for the output additionality, regional policies give the impression of inducing a sort of shift in the type of innovations introduced. With respect to similar non supported firms, funded companies are more likely (from +11.1% to +13.3%) to achieve a process innovation, but less likely to introduce a new or improved product (from -4.7% to -6.3%). This lower propensity is also reflected in the proportion of turnover due to incremental product innovations, which is found to be negatively affected by the public support (from -1.6% to -2.5%).

The evidence emerging from the behavioural additionality evaluation confirms the general low performance of the regional innovation policies in Italy. Public interventions initiated by regional governments are unable to sustain firms' formalised learning process. The likelihood of being engaged in training programmes is lower for

supported firms than for similar non funded companies (from -4.3% to -5.2%). Looking at the impact on the networking activities and considering the engagement in cooperation agreements, funded firms are generally not statistically different from non funded ones[46]. Coming to the capacity of the policy interventions to stimulate firms' external knowledge sourcing it is possible to notice, on the one hand, a positive effect on the propensity to acquire relevant information from research organisations (from +9.5% to +10.1%). On the other hand, funded firms are less engaged in information sourcing from other companies (form -4.3% to -6.5%)[47].

As it emerges from Tab. A6 in the Appendix, Italian regional policies are not characterised by a significant correlation between the average impacts of the interventions and the dispersion of the effects. The Spearman's rank correlation coefficient, even if negative, is not significant. Hence, the magnitude of the ATTs is not related to the polarisation of the impacts across the beneficiaries.

4.2 Italian national policies

Tab. 2 reports the results concerning the impact of the interventions initiated by the central government in Italy. The evaluation, based on a sample of 1,845 firms (438 supported and 1,407 potential controls), points to an additionality profile which is largely different from that of the regional policies.

At first, it is possible to notice that, differently from the regional interventions, Italian national policies are characterised by input additionality effects. The larger public support devoted to formal innovation activities (Cefis and Evangelista, 2007; Barbieri et al. 2010) stimulates an additional private investment in R&D. The effect on the single supported firms ranges from + 427,914.1 Euros to + 447,613.6 Euros; this is reflected in the increased intensity of firms' R&D investment (from +0.6% to +0.7%).

However, the higher investment in formal innovation activities does not result in an increased capacity to introduce product and patentable innovations. Even if funded firms, with respect to similar non supported ones, have a higher propensity to introduce

[46] Funded companies are less likely to be engaged in collaboration with national competitors (see Tab. A2 in the Appendix).

[47] Looking at the different types of information sourcing (see Tab. A2 in the Appendix) it is possible to notice the higher propensity of funded firms to acquire relevant knowledge from private R&D institutes. On the contrary, supported companies are less likely to obtain relevant information from universities and suppliers.

new or improved processes (from +8.3% to + 9.6%), no significant effect is found for the other output additionality indicators.

Tab. 2 Additionality of the national policies in Italy

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
Input add.								
RDEXP	429066.1 *	238670.7	427914.1 *	228623.0	447613.6 **	218544.8	313001	261069.2
RDINT	0.007 **	0.003	0.007 **	0.003	0.006 **	0.003	0.007 **	0.003
Output add.								
PRODINNO	0.004	0.034	0.005	0.034	0.006	0.025	0.000	0.033
PROCINNO	0.086 **	0.036	0.086 **	0.035	0.096 ***	0.027	0.083 **	0.037
TURNMAR	-0.002	0.013	-0.001	0.015	-0.005	0.010	-0.002	0.013
TURNIN	0.016	0.012	0.016	0.014	0.013	0.011	0.015	0.012
TURNINO	0.014	0.018	0.014	0.017	0.007	0.014	0.013	0.018
PROPAT	0.047	0.030	0.048	0.031	0.061 ***	0.024	0.041	0.030
Behavioural add.								
TRAINENG	0.007	0.032	0.005	0.033	0.010	0.029	-0.002	0.032
COOPFIRM	0.051 **	0.026	0.050 *	0.026	0.052 ***	0.019	0.049 **	0.023
COOPORG	0.104 ***	0.027	0.103 ***	0.025	0.116 ***	0.022	0.108 ***	0.024
INFOFIRM	-0.010	0.025	-0.009	0.027	-0.015	0.022	-0.014	0.026
INFOORG	0.113 ***	0.035	0.112 ***	0.036	0.108 ***	0.027	0.111 ***	0.038
N treat. on support	433		433		433		417	
N treated total	438		438		438		438	
N non treated	1407		1407		1407		1407	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

Some further effects on the capacity of funded firms' to achieve more radical innovation outputs might emerge in a longer-term, especially considering the changes on firms' innovation behaviour that are induced by the public interventions. In particular, Italian national policies are found to increase funded firms' propensity to engage in R&D cooperation with both other firms (from +4.9% to +5.2%) and, to a larger extent, with research partners (from +10.3% to 11.6%)[48]. This positive effect is also reflected in an increased information sourcing from universities and private R&D institutes (from

[48] As it emerges from Tab. A3 in the Appendix, Italian national policies enhances the propensity to cooperate with national and global suppliers, national private R&D institutes and national universities.

+10.8% to +11.3%)[49]. In general terms, with respect to the capacity to enhance funded firms' interactions, national policies are found to be significantly more effective than the regional ones. This might be due to two possible factors. On the one hand, a higher support, which can also take the form of explicit requirement, to collaborate with research organisations or (also through temporary consortia) with other firms. On the other hand, the larger scale, scope and aim of the projects funded by the Italian national policies (Cefis and Evangelista, 2007; Barbieri et al. 2010) might induce firms to look for necessary assets, both tangible and intangible, which are located outside their boundaries.

All in all, the joint analysis of the additionality effects induced by the national and the regional interventions also allows for a general consideration about the consistency of the Italian multi-level system of policy. The emerging picture is that of a largely dissonant relation between the national policies, which appear as the only capable of inducing a broad set of significant positive effects, and the regional programmes, whose contribution is basically none and in some case a negative.

Finally, the results emerging from the additionality evaluation of the Italian national policies are associated to an interesting relation between the average impacts and their dispersion. A Spearman's rank's correlation coefficient of -0.8462 (See Tab. A6 in the Appendix), reflects a situation in which the ATTs are negatively related to the corresponding coefficients of variation. In other terms, the highest average additionality effects are characterised by the lowest polarisations.

4.3 Spanish regional policies

Tab. 3 reports the results pertaining to the additionality evaluation of the regional policies implemented in Spain. This is carried out on a sample of 4,110 firms (879 supported and 3,231 potential controls).

As far as the input additionality is concerned, like in the case of the Italian policies initiated at the regional level, no significant effect is found to be in place. This is probably due to the low scale of the contributions granted by the regional governments and the greater focus on less formalised innovation activities (Garcia-Quevedo and Afcha-Chávez, 2009; Afcha-Chávez, 2011).

However, considering the output and the behavioural additionality effects, the results point to a higher effectiveness of the Spanish regional interventions when

[49] See Tab. A3 in the Appendix for a detail.

compared to the Italian ones. Despite the absence of impacts on the allocation of formal innovation inputs, Spanish regional support schemes enhance the probability to introduce product innovations (from +3.8% to +3.9%), in particular radical and commercially valuable ones. Indeed, supported firms, with respect to similar non funded companies, are characterised by a higher percentage of turnover due to radical product innovations (from +1.5% to +1.8%). This higher innovation performance is coupled with a higher propensity to file patent applications (from +6.0% to +7.2%).

As for the behavioural additionality, Spanish regional policies are found to induce a large set of changes in the supported companies. On the one hand, regional policy schemes enhance beneficiaries' learning process, increasing supported firms' propensity to implement formal training programmes (from +4.8% to +6.1%). On the other hand, Spanish regional policies stimulate effective interactions with external sources of knowledge. In particular, policy programmes enhance firms' attitude to cooperate with both other firms (from +7.3% to +7.5%) and research organisations (from +9.6% to +10.3%)[50]. Furthermore, it is noticeable an increase in the propensity of funded firms to acquire relevant knowledge from research partners (from +10.5% to 12.1%)[51].

The comparison between the results concerning the Spanish regional policies and the additionality profile of the regional interventions implemented in Italy points to an interesting difference. As said before, in both the countries regional interventions are characterised by a small scale and a greater support to less formalised innovation inputs. Due to this, both in Italy and Spain, regional policies are unable to stimulate an additional investment in R&D. Nevertheless, in Spain this does not affect the capacity to realise other forms of additionality. With this respect, it seems plausible that Spanish regional policies, by targeting (with success) the achievement of important behavioural changes, overcome the lack of input additionality and increase the capacity of funded firms to obtain more radical product innovations and patents. Hence, at least with respect to this specific case, it seems that the lack of input additionality, *per se*, does not completely hamper the effect of the public support on the outputs of the innovation process, especially when significant behavioural changes are stimulated by the policy.

[50] In particular, Spanish regional interventions increase funded firms' propensity to cooperate with a broad range of national partners (i.e. firms belonging to the same group, suppliers, competitors, private R&D institutes, universities and public research organisations) (See Tab. A4 in Appendix).
[51] From both private R&D institutes and universities (See Tab. A4 in the Appendix).

Tab. 3 Additionality of the regional policies in Spain

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
Input add.								
RDEXP	-5305.556	34001.730	-5352.441	34923.640	17351.620	20613.090	-7059.569	35644.120
RDINT	0.154	0.151	0.154	0.147	0.156	0.139	0.161	0.147
Output add.								
PRODINNO	0.038 *	0.022	0.039 *	0.023	0.039 *	0.021	0.038	0.025
PROCINNO	0.022	0.023	0.023	0.025	0.042 **	0.019	0.023	0.026
TURNMAR	0.017 *	0.009	0.017 *	0.009	0.015 **	0.007	0.018 **	0.008
TURNIN	0.002	0.014	0.001	0.013	0.001	0.011	-0.001	0.013
TURNINO	0.019	0.016	0.019	0.014	0.016	0.013	0.017	0.015
PROPAT	0.068 ***	0.020	0.068 ***	0.020	0.060 ***	0.016	0.072 ***	0.021
Behavioural add.								
TRAINENG	0.048 **	0.023	0.048 **	0.022	0.061 ***	0.018	0.048 **	0.024
COOPFIRM	0.073 ***	0.021	0.075 ***	0.020	0.073 ***	0.015	0.073 ***	0.019
COOPORG	0.099 ***	0.018	0.099 ***	0.016	0.103 ***	0.013	0.096 ***	0.017
INFOFIRM	0.019	0.018	0.021	0.020	0.020	0.013	0.017	0.020
INFOORG	0.105 ***	0.021	0.105 ***	0.022	0.121 ***	0.019	0.115 ***	0.023
N treat. on support	876		874		876		836	
N treated total	879		879		879		879	
N non treated	3231		3231		3231		3231	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

Finally, like in the case of the Italian national policies, also the Spanish regional programmes are characterised by a negative Spearman's rank correlation coefficient (i.e. -0.6593, see Tab. A6 in the Appendix). This denotes a negative relation between the ATTs and the dispersion of the effects. In other terms, the higher is the average additionality of the policy, the lower is the polarisation of the impact across the beneficiaries.

4.4 Spanish national policies

The results of the additionality evaluation presented in Tab. 4 pertain to the policies implemented by the Spanish central government. In this case the sample is made of 3,795 firms (564 treated and 3,231 potential controls).

Like in the Italian case, input additionality effects are found to be in place only when the national interventions are considered. Also in Spain, national policies are characterised by a larger scale and a greater support to formal innovation activities, when

compared to regional interventions (Garcia-Quevedo and Afcha-Chávez, 2009; Afcha-Chávez, 2011). This results in the capacity of the national programmes to stimulate an additional investment in intramural R&D (from + 354,036.2 Euros to + 371,922.7 Euros). However, a similar positive effect is not found for the intensity of the R&D investment.

Tab. 4 Additionality of the national policies in Spain

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
Input add.								
RDEXP	367677.1 **	162523.3	371922.7 **	164501.7	359347.8 ***	132797.8	354036.2 **	156419.1
RDINT	0.071	0.049	0.072	0.046	0.075	0.054	0.074	0.050
Output add.								
PRODINNO	0.001	0.027	0.001	0.028	0.014	0.022	0.015	0.030
PROCINNO	0.022	0.030	0.026	0.028	0.037	0.023	0.012	0.029
TURNMAR	0.037 ***	0.011	0.038 ***	0.012	0.040 ***	0.010	0.040 ***	0.011
TURNIN	-0.013	0.015	-0.012	0.016	-0.018	0.013	-0.009	0.015
TURNINO	0.024	0.019	0.026	0.018	0.022	0.015	0.032 *	0.019
PROPAT	0.059 **	0.025	0.062 ***	0.023	0.064 ***	0.020	0.073 ***	0.025
Behavioural add.								
TRAINENG	0.060 **	0.030	0.061 **	0.031	0.051 **	0.026	0.060 *	0.032
COOPFIRM	0.086 ***	0.026	0.086 ***	0.029	0.081 ***	0.020	0.081 ***	0.025
COOPORG	0.111 ***	0.021	0.113 ***	0.023	0.110 ***	0.019	0.105 ***	0.023
INFOFIRM	0.061 ***	0.024	0.061 ***	0.023	0.050 ***	0.018	0.070 ***	0.024
INFOORG	0.100 ***	0.026	0.100 ***	0.028	0.116 ***	0.021	0.101 ***	0.028
N treat. on support	564		564		564		536	
N treated total	564		564		564		564	
N non treated	3231		3231		3231		3231	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

In terms of output additionality effects, national policies are similar to the regional ones. With respect to similar non funded companies, supported firms are characterised by a higher percentage of turnover due to radical product innovations (from +3.7% to +4.0%) and a higher propensity to file patent applications (from + 5.9% to +7.3%).

In addition to this, a number of behavioural changes seem to be induced by the public support. At first, funded firms are more likely to implement training programmes (from +5.1% to +6.0%). Looking at the impacts on the interactions of supported companies, national policies enhance the propensity to cooperate with both research

organisations (from +10.5% to +11.3%) and other firms (from +8.1% to +8.6%)[52]. This increased attitude to interact with business and research partners is associated to the higher propensity to acquire relevant information from both other firms (from +5.0% to +7.0%) and research organisations (from +10.0% to +11.6%)[53].

All in all, joining the results concerning the national policies to those pertaining to the regional interventions, there emerges the clear consistency of the Spanish multi-level system of policy. The two levels of intervention here analysed are indeed inducing similar behavioural and output additionality effects on the beneficiaries.

Finally, also in the case of the Spanish national policies, the Spearman's rank correlation coefficient is negative and significant (i.e. -0.6099, see Tab. A6, in the Appendix), meaning that the ATTs are negatively related to the corresponding coefficients of variation. Hence, the higher is the average additionality effect the lower is the dispersion of the policy impact.

5 Concluding remarks

The paper, focusing on Italy and Spain, has analysed the additionality of the public support to firms' innovation activities. To this purpose, a multi-dimensional approach and a multi-level perspective have been adopted. The former has allowed for the investigation of the three additionality dimensions. With this respect, the paper has demonstrated that public interventions can have different types of effects on firms' innovation activities: policies can affect the allocation of innovation inputs, the achievement of innovation outputs and induce changes in the innovation behaviours. The multi-level perspective has allowed for analysing the impact of both the national and the regional interventions implemented in the two countries. With this respect, the evidence has pointed to two distinct pictures. Italian policies are found to be characterised by a largely dissonant relation between national interventions, which are capable of inducing a relatively large set of significant positive effects, and regional support schemes, whose impact is very low and in some case a negative. In Spain, on the contrary, the two levels of intervention

[52] From Tab. A5 in the Appendix, it is possible to notice a positive effects on firms' propensity to cooperate with national firms in the same group, national suppliers, national and foreign competitors. As for the cooperation with research organisations, national policies increase the propensity to cooperate with national public and private R&D institutes and national universities.

[53] In particular, from customers, private R&D institutes and universities (See Tab. A5 in the Appendix).

are found to be more consistent, stimulating similar output and behavioural additionality effects.

Moving to the specific impacts of the different types of public support schemes analysed in the paper, some interesting results are worth mentioning in these concluding remarks. At first, both in Italy and in Spain, regional policies are not characterised by input additionality effects. Considering the characteristics of the interventions initiated at the sub-national level, it seems that input additionality cannot emerge when policies are characterised by a low amount of public contribution and a greater support to less formalised innovation activities. However, in Spain, the lack of input additionality of the regional policies is associated to a good performance in the other additionality dimensions. This evidence contrasts the standard linear innovation model, according to which higher innovation outputs can be achieved only by increasing the allocation of innovation inputs. In fact, at least in the case of Spanish regional policies, it seems plausible that the capacity to target (successfully) important behavioural changes might compensate for the lack of an additional investment in R&D and lead to obtain higher innovation outputs. This is not the case for the Italian regional interventions, which are characterised by a general weak effectiveness. The reason for such a result, however, deserves a deeper investigation, which has necessarily to consider two aspects. On the one hand, the heterogeneity of the regional policies, and thus of their effects. On the other hand, the fact that the period considered in this analysis (2002-2004) is only immediately subsequent to the 2001 reform of the Italian Constitution that gave to regions a substantial autonomy in terms of innovation policy.

Another interesting aspect emerged in the analysis pertains to the substantial differences between the output additionality of Italian and Spanish policies. Whereas the former are characterised only by the capacity to stimulate process innovation, the latter are found to enhance the economic exploitation of the radical innovations introduced and patent applications. In this sense, the Italian multi-level system of policy, at least in the considered period, does not seem to be able to trigger a quality leap in the performances of the overall national innovation system.

A third aspect emerged through the paper, which justifies the adoption of a multi-dimensional approach that extends the analysis beyond the input and output additionality, is the spectrum of behavioural changes induced by the public support schemes. Italian national policies are found to stimulate funded firms to interact more with other companies and research organisations. In addition to this, Spanish policies, both regional

and national, are found to affect firms' learning process by increasing their engagement in formal training programmes aimed at upgrading employees' competencies.

The paper has provided also a tentative analysis of the relation between the average impact of the public intervention and the dispersion of the effect across the beneficiaries. In so doing, the present work has tried to investigate whether the average level of additionality is associated to the presence of a large share of individual effects that are located well below or above the mean impact. From the analysis of the Spearman's rank correlation coefficients, with the only exception of the Italian regional policy, the rank of the ATTs is found to be negatively related to rank of the coefficients of variation. In other terms, the higher is the average impact of the policy, the lower is the polarisation of the effect across the beneficiaries. Of course, this evidence cannot point to general policy implications in absence of other similar studies that extend the external validity of such a result.

This work has not been free from limitations. A relevant one is due to the cross-sectional nature of the data. On the one hand, this has hampered the possibility to capture long-term effects. On the other hand, this has limited the possibility to overcome (completely) the problems due to the potential endogeneity of the participation in the policy. Indeed, the availability of panel data, or at least of lagged variables for the public support, would have improved the additionality evaluation, by allowing for a more complete assessment of the causal relation between the public funding and the additionality effects. In particular, specific methods could have been employed to account also for the potential bias arising from the omission of unobservable characteristics (e.g. Cameron and Trivedi, 2005; Angrist and Pischke, 2009).

Appendix

Tab. A1 Probit estimation of the propensity scores

	FUNLOC – Italy		**FUNGMT – Italy**		**FUNLOC – Spain**		**FUNGMT – Spain**	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
SMALL	0.185	0.159	-0.234	0.164	0.535 ***	0.101	-0.325 ***	0.095
MEDIUM	0.330 ***	0.123	-0.119	0.116	0.381 ***	0.096	-0.271 ***	0.086
lnTURN02	-0.029	0.034	0.066 *	0.038	0.009	0.006	-0.018 ***	0.006
GP	-0.250 ***	0.085	-0.002	0.088	-0.008	0.064	0.288 ***	0.067
MNC	-0.295 **	0.125	-0.346 ***	0.116	-0.203 **	0.093	-0.419 ***	0.093
EXPORT	-0.005	0.075	-0.004	0.088	0.011	0.055	0.053	0.070
RDENG	0.125	0.082	-0.035	0.096	0.215 ***	0.065	0.280 ***	0.086
RDCONT	0.295 ***	0.077	0.397 ***	0.089	0.069	0.063	0.357 ***	0.076
HFENT2	0.036	0.083	0.079	0.091	0.147 **	0.063	-0.014	0.072
HFENT3	0.083	0.100	-0.148	0.117	0.057	0.073	-0.079	0.087
HFOUT2	0.104	0.085	0.196 **	0.094	0.076	0.063	0.074	0.074
HFOUT3	-0.311 ***	0.099	-0.059	0.111	-0.035	0.071	-0.037	0.086
SPRO2	0.255 ***	0.085	0.106	0.093	0.116	0.060	-0.062	0.073
SPRO3	0.551 ***	0.134	0.117	0.159	-0.069	0.116	0.077	0.126
SGMT2	-0.056	0.192	0.667 ***	0.161	0.374 ***	0.093	0.496 ***	0.100
SGMT3	0.294	0.249	0.148	0.271	0.702 ***	0.197	0.576 ***	0.218
CONST.	-0.346	0.640	-1.603 **	0.715	-1.494 ***	0.194	-1.174 ***	0.219
Sectoral dummies	*Included*		*Included*		*Included*		*Included*	
N	2006		1845		4110		3795	
Prob>χ^2	0.000		0.000		0.000		0.000	
Pseudo R^2	0.059		0.077		0.039		0.098	

***, **, * indicate a significance level of 1%, 5%, 10%. A VIF test leads to exclude the multicollinearity of the covariates (all the VIF values are lower than 10)

Tab. A2 Behavioural additionality effects on firms' interactions. Italian regional policies

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
COOPGPNAT	-0.010	0.008	-0.010	0.008	-0.009	0.006	-0.013	0.008
COOPGPFOR	0.001	0.005	0.001	0.005	0.000	0.004	0.001	0.005
COOPSUPNAT	-0.016	0.016	-0.016	0.015	-0.005	0.013	-0.024	0.017
COOPSUPFOR	0.001	0.004	0.001	0.004	0.000	0.003	0.001	0.003
COOPCUSNAT	-0.021	0.014	-0.021 *	0.012	-0.011	0.009	-0.027 **	0.011
COOPCUSFOR	-0.008	0.007	-0.008	0.008	-0.005	0.007	-0.010	0.008
COOPCOMNAT	-0.026 **	0.012	-0.026 **	0.010	-0.012	0.009	-0.031 ***	0.011
COOPCOMFOR	-0.001	0.006	-0.001	0.006	0.000	0.005	-0.001	0.006
COOPINSNAT	-0.010	0.014	-0.010	0.014	-0.005	0.012	-0.017	0.014
COOPINSFOR	0.003	0.004	0.003	0.004	0.004	0.004	0.004	0.004
COOPUNINAT	-0.013	0.012	-0.013	0.012	-0.012	0.010	-0.018	0.013
COOPUNIFOR	0.001	0.004	0.001	0.004	0.001	0.003	0.001	0.004
COOPPUBNAT	-0.004	0.006	-0.004	0.005	-0.004	0.004	-0.006	0.005
COOPPUBFOR	0.000	0.003	0.000	0.003	0.000	0.002	0.000	0.003
INFOSUP	-0.053 *	0.030	-0.059 *	0.030	-0.041 *	0.024	-0.053 *	0.030
INFOCUS	-0.005	0.031	0.000	0.034	0.008	0.027	-0.010	0.033
INFOCOM	-0.009	0.028	-0.004	0.031	0.008	0.025	-0.020	0.030
INFOINS	0.114 ***	0.029	0.119 ***	0.030	0.116 ***	0.024	0.118 ***	0.029
INFOUNI	-0.039 **	0.019	-0.038 **	0.019	-0.033 **	0.013	-0.040 **	0.017
N treat. on support	598		598		598		570	
N treated total	599		599		599		599	
N non treated	1407		1407		1407		1407	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

Tab. A3 Behavioural additionality effects on firms' interactions. Italian national policies

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
COOPGPNAT	0.012	0.014	0.012	0.015	0.013	0.013	0.010	0.015
COOPGPFOR	0.001	0.009	0.001	0.010	0.004	0.009	-0.003	0.009
COOPSUPNAT	0.046 **	0.020	0.045 **	0.023	0.049 ***	0.018	0.046 **	0.023
COOPSUPFOR	0.014 **	0.007	0.014 **	0.007	0.013 *	0.007	0.012 *	0.007
COOPCUSNAT	0.017	0.017	0.016	0.017	0.022	0.014	0.015	0.016
COOPCUSFOR	0.010	0.013	0.010	0.013	0.013	0.011	0.005	0.011
COOPCOMNAT	0.011	0.014	0.010	0.015	0.009	0.012	0.014	0.014
COOPCOMFOR	-0.004	0.007	-0.004	0.007	-0.003	0.006	-0.007	0.007
COOPINSNAT	0.072 ***	0.024	0.070 ***	0.021	0.081 ***	0.020	0.076 ***	0.022
COOPINSFOR	0.008	0.007	0.008	0.007	0.008	0.006	0.006	0.008
COOPUNINAT	0.093 ***	0.025	0.093 ***	0.023	0.103 ***	0.021	0.096 ***	0.023
COOPUNIFOR	0.001	0.006	0.001	0.005	0.002	0.005	0.001	0.006
COOPPUBNAT	0.018	0.012	0.017	0.012	0.017 *	0.010	0.020 *	0.011
COOPPUBFOR	0.000	0.001	0.000	0.001	-0.001	0.001	0.000	0.001
INFOSUP	-0.005	0.034	-0.004	0.034	-0.007	0.027	-0.004	0.035
INFOCUS	0.028	0.033	0.028	0.032	0.019	0.030	0.036	0.034
INFOCOM	0.006	0.033	0.004	0.033	0.003	0.029	0.016	0.032
INFOINS	0.100 ***	0.034	0.099 ***	0.033	0.094 ***	0.028	0.111 ***	0.037
INFOUNI	0.063 **	0.026	0.062 **	0.027	0.070 ***	0.021	0.059 **	0.027
N treat. on support	433		433		433		417	
N treated total	438		438		438		438	
N non treated	1407		1407		1407		1407	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

Tab. A4 Behavioural additionality effects on firms'interactions. Spanish regional policies

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
COOPGPNAT	0.018 **	0.009	0.019 **	0.008	0.016 **	0.007	0.018 **	0.008
COOPGPFOR	-0.002	0.006	-0.002	0.007	-0.002	0.005	-0.002	0.007
COOPSUPNAT	0.039 ***	0.014	0.041 ***	0.015	0.041 ***	0.012	0.037 **	0.015
COOPSUPFOR	0.008	0.009	0.008	0.009	0.008	0.008	0.007	0.010
COOPCUSNAT	0.011	0.012	0.012	0.011	0.012	0.009	0.012	0.011
COOPCUSFOR	0.003	0.008	0.003	0.007	0.004	0.006	0.000	0.008
COOPCOMNAT	0.016 *	0.009	0.018 *	0.010	0.018 **	0.008	0.019 **	0.009
COOPCOMFOR	0.003	0.005	0.003	0.004	0.001	0.004	0.003	0.005
COOPINSNAT	0.053 ***	0.012	0.053 ***	0.013	0.053 ***	0.011	0.052 ***	0.012
COOPINSFOR	0.009 *	0.005	0.010 *	0.005	0.008 *	0.005	0.008	0.005
COOPUNINAT	0.057 ***	0.013	0.058 ***	0.014	0.061 ***	0.012	0.055 ***	0.013
COOPUNIFOR	-0.001	0.003	-0.001	0.002	-0.001	0.002	-0.001	0.003
COOPPUBNAT	0.016 **	0.007	0.015 **	0.006	0.014 **	0.006	0.014 **	0.007
COOPPUBFOR	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
INFOSUP	0.013	0.023	0.014	0.024	0.022	0.018	0.012	0.024
INFOCUS	0.027	0.024	0.029	0.023	0.026	0.019	0.027	0.024
INFOCOM	0.010	0.022	0.012	0.024	0.001	0.016	0.009	0.025
INFOINS	0.052 **	0.020	0.053 **	0.021	0.065 ***	0.018	0.062 ***	0.020
INFOUNI	0.055 ***	0.016	0.056 ***	0.017	0.065 ***	0.015	0.062 ***	0.017
N treat. on support	876		874		876		836	
N treated total	879		879		879		879	
N non treated	3231		3231		3231		3231	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

Tab. A5 Behavioural additionality effects on firms'interactions. Spanish national policies

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
COOPGPNAT	0.029 **	0.014	0.029 *	0.015	0.026 **	0.012	0.023	0.014
COOPGPFOR	0.012	0.013	0.012	0.014	0.010	0.010	0.013	0.013
COOPSUPNAT	0.059 ***	0.020	0.059 ***	0.019	0.052 **	0.017	0.057 ***	0.018
COOPSUPFOR	0.013	0.015	0.013	0.014	0.014	0.012	0.010	0.014
COOPCUSNAT	0.025	0.016	0.025	0.017	0.016	0.014	0.028	0.017
COOPCUSFOR	0.015	0.013	0.015	0.013	0.012	0.010	0.010	0.011
COOPCOMNAT	0.029 **	0.013	0.029 **	0.012	0.026 **	0.010	0.027 **	0.011
COOPCOMFOR	0.022 **	0.009	0.022 **	0.010	0.021 ***	0.007	0.022 **	0.010
COOPINSNAT	0.053 ***	0.017	0.053 ***	0.019	0.054 ***	0.015	0.048 ***	0.016
COOPINSFOR	0.016 *	0.009	0.016	0.010	0.015 *	0.008	0.008	0.009
COOPUNINAT	0.086 ***	0.021	0.088 ***	0.020	0.090 ***	0.017	0.082 ***	0.019
COOPUNIFOR	0.004	0.005	0.004	0.006	0.004	0.005	0.002	0.005
COOPPUBNAT	0.020 *	0.011	0.020 *	0.010	0.020 **	0.010	0.015	0.010
COOPPUBFOR	0.000	0.002	0.000	0.003	0.001	0.002	0.000	0.002
INFOSUP	0.054 *	0.028	0.057	0.029	0.035	0.022	0.056 *	0.030
INFOCUS	0.058 **	0.028	0.062 **	0.027	0.054 **	0.023	0.064 **	0.034
INFOCOM	0.041	0.027	0.036	0.030	0.025	0.023	0.035	0.029
INFOINS	0.055 **	0.024	0.055 **	0.026	0.059 ***	0.022	0.059 **	0.028
INFOUNI	0.075 ***	0.024	0.079 ***	0.022	0.088 ***	0.020	0.068 ***	0.026
N treat. on support	564		564		564		536	
N treated total	564		564		564		564	
N non treated	3231		3231		3231		3231	

***, **, * indicate a significance level of 1%, 5%, 10%. Standard errors are calculated with a 200-replication bootstrap procedure.

Tab. A6 Spearman's rank correlation coefficients (on the main set of additionality indicators)

Policy level and country	Spearman's rho	Prob>|t|	N. additionality indicators
Italian regional policies	-0.2527	0.4048	13
Italian national policies	-0.8462***	0.0003	13
Spanish regional policies	-0.6593**	0.0142	13
Spanish national policies	-0.6099**	0.0269	13

***, **, * indicate a significance level of 1%, 5%, 10%

Tab. A7 Spearman's rank correlation coefficients (including specific types of cooperation and information sourcing)

Policy level and country	Spearman's rho	Prob>|t|	N. additionality indicators
Italian regional policies	0.1373	0.4536	32
Italian national policies	-0.7232***	0.0000	32
Spanish regional policies	-0.5876***	0.0004	32
Spanish national policies	-0.3845**	0.0298	32

****, **, * indicate a significance level of 1%, 5%, 10%*

4

The effects of a R&D subsidy on firms' innovation behaviour. The case of the Emilia-Romagna region of Italy *

Abstract

The paper aims at identifying the extent to which regional innovation policy affect firms' innovation behaviour. Some research hypotheses are put forward. At first, the policy support is supposed to induce relevant changes in the beneficiaries' behaviour, which can help to solve potential regional system failures. Moreover, an increasing amount of regional subsidy is expected to enhance the geographical range of the cooperation with research organisations. These hypotheses are tested with respect to a sample of firms located in the Emilia-Romagna region of Italy, by making use of a unique dataset including information on pre-policy characteristics and post-policy behaviours. A set of propensity score matching procedures and a generalised propensity score method are applied. At first, the policy is found to enhance the competencies upgrading of the beneficiaries, as well as their interactions with both regional and extra-regional research organisations. Furthermore, the amount of subsidy is found to be important to extend beyond the regional borders the cooperation with research partners: over a minimum efficient scale of public funding, an increase in the subsidy enhances the propensity to cooperate with extra-regional universities and research institutes.

1 Introduction

In the last decades, a large amount of academic research has analysed the impact of location and geographical aspects on innovation activities and performances (e.g. Asheim and Gertler, 2005). This has inspired a number of academic contributions that deal with regional innovation policy objectives and rationale, mainly adopting an evolutionary approach and/or a system-kind of perspective (e.g. Lambooy and Boschma, 2001;

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Boschma, 2005b; Tödtling and Trippl, 2005; Laranja et al., 2008; Uyarra, 2010). This increased attention to the regional level of innovation policy is not confined to the academic research: it has also resulted in the definition of a number of support schemes and strategies (e.g. European Commision, 2001, 2011; Walendowski et al., 2010).

Due to the upraising relevance of the regional innovation policy, the investigation of its impact is fundamentally important. First, to complement the academic literature that is concerned with the rationale and objectives of the regional support to innovation. Second, to contribute to the policy-learning process, thus allowing for a better implementation of future policy interventions. Although the evaluation of innovation policy is a diverse research field (e.g. Edler et al., 2010), the present paper is focused on a specific type of impact assessment. In particular, it analyses the additionality effects of a regional R&D subsidy. In providing this analysis, it does not consider the standard input and output additionality dimensions, which are concerned with the effect of the policy on the R&D investment and the innovation performances, respectively (Georghiou and Clarysse, 2006). This paper is rather focused on a third dimension of the additionality: the behavioural one. This latter, introduced by Buiesseret et al. (1995), is consistent with the evolutionary approach and the innovation system perspective and allows for the evaluation of the policy impact on both firms' internal organisation and interactions with external actors.

In particular, the present work analyses, at first, whether the public support to R&D stimulates changes in the firms' behaviours that can help to reduce potential system failures (e.g. Smith, 2000; Metcalfe, 2005; Malerba, 2009). In this sense, three types of behavioural additionality effects are considered. These pertain to: the improvement of firms' learning process; the enhancement of networking activities and interactions; the acquisition of diverse knowledge and the consequent possibility to reduce the risk of lock-ins.

Furthermore, the paper addresses another aspect that is still under-investigated in the literature on the innovation policy additionality. Instead of focusing only on the impact of the participation in a support scheme, it also analyses whether and to what extent an increasing amount of public support affects the behaviour of the beneficiaries. In particular, this analysis is aimed at gauging whether an additional amount of subsidy enlarges the geographical range of the cooperation with research organisations, allowing firms to collaborate with distant (i.e. extra-regional) and, possibly more advanced, universities and research institutes. This research interest has a twofold motivation in a

regional innovation system perspective. First, the importance of the interactions between the actors involved in knowledge generation and diffusion (e.g. universities and research institutes), and the actors involved in knowledge application and exploitation (e.g. firms) (e.g. Autio, 1998; Cooke, 2002). Second, the relevance of the cooperation with extra-regional partners for enriching and complementing the regional knowledge base (e.g. Uyarra, 2010).

The empirical investigation provided in the paper is focused on the innovation policy of the NUTS 2 Emilia-Romagna region of Italy. Among the different measures included in the Emilia-Romagna Regional Programme for the Industrial Research, Innovation and Technology Transfer (PRRIITT) the paper specifically analyses the R&D subsidy scheme. This latter has been previously evaluated in terms of input additionality by Bronzini and Iachini (2011), who find a certain positive effect for small firms but not for large ones. In the present work, the econometric analysis, which is based on an original dataset made of firm-level data deriving from an *ad hoc* survey and companies' balance sheets, is carried out with two approaches. As for the comprehensive analysis of the behavioural changes induced by the policy, a set of propensity score matching estimations is employed. The effect of an additional amount of subsidy on the firms' cooperation strategy is estimated with a very recent method, i.e. the generalised propensity score (Hirano and Imbens, 2004). For a set of subsidy levels, this estimates the effect of an extra amount of public support on three cooperation strategies: no cooperation, cooperation with a regional research organisation, cooperation with an extra-regional research partner.

The reminder of the paper is organised as follows. Section 2 is devoted to a review of the relevant literature, which helps to identify a set of hypotheses to be tested. Section 3 provides a brief description of the regional context and the policy scheme. Section 4 deals with the econometric strategy and describes the characteristics of data and variables. Section 5 presents the results of the empirical investigation. Section 6 concludes.

2 Background literature and hypotheses

Despite the large attention devoted to the analysis of the input and output additionality dimensions, these are affected by the same limitations of the standard neoclassical approach they originate from. Focusing only on the allocation of resources to innovation

activities, input additionality evaluation does not consider the impact of the policy on the organisation, the strategic behaviour of the beneficiaries and the acquisition of knowledge and capabilities. Similarly, output additionality evaluation, relying on the strict linear relation between inputs (allocated with the support of the policy funding) and outputs, fails to take into account the complexity of the innovation process and to provide a proper investigation of the effects that occur within the "black-box" of the beneficiaries (Georghiou and Clarysse, 2006).

To overcome these limitations the behavioural dimension of the additionality concept has been recently developed in the literature[54]. A first group of works analyses the behavioural additionality to complement the linear and strict nature of input additionality (Gök and Edler, 2010) with questions related to the scale and the scope of the funded R&D projects (e.g. Lukkonen, 2000) or considering also the acceleration of the innovation activities (e.g. Falk, 2007). However, the analysis of the behavioural additionality can be focused on more relevant changes in the behaviours of the agents supported by the policy. As it emerges from the seminal contribution by Buisseret et al. (1995), the evaluation of the behavioural additionality has to analyse "the change in a company's way of undertaking R&D which can be attributed to policy actions" (p. 590). In so doing, it is possible to open the 'black-box' of the beneficiaries (Clarysse et al. 2006; Hall and Maffioli, 2008) to investigate the impacts occurring within their innovation process. This perspective allows for considering the likely presence of profound impacts generated by the policy intervention. These impacts affect companies' behaviour and strategy and cannot be captured by the simple input and output additionality dimensions (Buisseret et al., 1995; Georghiou and Clarysse, 2006). Indeed, public support to innovation activities, as R&D subsidies, can induce a wide range of behavioural effects. First, by carrying out publicly funded R&D activities, supported firms can upgrade or acquire new competencies, capabilities and organisational routines (e.g. Falk, 2006; Magro et al., 2010; Marino and Parrotta, 2010). Second, R&D subsidies, through an explicit support or by supporting firms to face the intrinsic cost of collaborating with external actors, might also enhance beneficiaries' networking and interactions with both other firms and research organisations (e.g. Fier et al. 2006; Busom and Fernández-Ribas, 2008; Hall and Maffioli, 2008; Magro et al., 2010; Afcha Chavez, 2011). Third, the participation in R&D support schemes might induce firms to acquire competencies in

[54] A complete review of the theoretical and empirical contributions dealing with the behavioural additionality of innovation policy is provided in the second Chapter of the present Thesis.

new or extended areas and technologies, which enhance the capacity to adapt to future unpredictable situations and thus the possibility to overcome potential lock-in positions (Georghiou and Clarysse, 2006). These behavioural additionality effects represent the capacity of the policy to overcome the system failures (e.g. Smith, 2000; Metcalfe, 2005; Malerba, 2009) that occur (also) at the level of the beneficiaries: (i) problems in learning process and accumulation of capabilities, (ii) missing or inappropriate interactions, (iii) lock-ins due to unbalanced evolutionary trade-offs (between exploitation and exploration or between selection and variety).

A comprehensive assessment of this capacity has not been provided yet in the literature. Existing empirical contributions are rather concentrated on a limited set of behavioural impacts, with the majority of them being focused on effects pertaining to the cooperation strategy of funded firms and to the upgrading of competencies, capabilities and human capital. That is not surprising though. Whereas it is quite straightforward to analyse these two types of effect with standard survey questions, it seems more complicated to assess whether the policy has helped to overcome eventual lock-ins. That because it is quite complex to provide a direct estimation of whether the policy has increased the capacity to explore new and less consolidated technological paths and to adapt to future unpredictable trajectories. Nevertheless, being focused on a regional innovation policy, a way out to capture, at least partly, this type of policy effect is that of adopting an Open Regional Innovation System (ORIS) perspective. This is focused on open innovation modes that overcome the boundaries of the organisation (Chesbrough, 2003) but also the boundaries of the region (Belussi et al. 2010). In this viewpoint, the interactions with extra-regional actors, which are not subject to the same localised path-dependencies, are expected to enhance knowledge generation and circulation (Bunnel and Coe, 2001; Bathelt et al., 2004), the renewal and the increasing diversity of the ideas within the local knowledge base (MacKinnon et al., 2002; Gertler and Levitte, 2005; Boschma and ter Wal, 2007; Uyarra, 2010). In this sense, by investigating whether the policy increases the cooperation with extra-regional partners, it is possible to analyse, at least partially, the impact of the public support on the possibility to explore diverse and less consolidated technological paths.

All in all, given the likely presence of profound impacts on firms' behaviour generated by the policy intervention, a first hypothesis can be tested through a proper and comprehensive operationalisation of the behavioural additionality evaluation.

HP 1: *The public support to R&D stimulates changes in funded firms' behaviour that might help to reduce potential system failures occurring at the level of the beneficiaries.*

As noted above, large part of the empirical contributions dealing with the behavioural additionality of R&D policies analyses the effect on the collaborations of the beneficiaries. This is actually an extremely relevant impact due to the beneficial effects of being engaged in R&D cooperation: the minimisation of transaction costs involving intangible assets and tacit knowledge; the possibility to share risks, costs and to exploit economies of scale and scope; the internalisation of knowledge spillovers; the possibility to access to external complementary tangible and intangible resources; the opportunity to improve learning capabilities (e.g. Hagerdoorn et al. 2000; Caloghirou et al. 2003; Busom and Fernández-Ribas, 2008). In addition to this, collaborations with research organisations enhance the possibility to draw on new scientific knowledge that is particularly fundamental for qualitatively advanced and/or radical innovations (e.g. Tödling et al., 2009).

However, when dealing in particular with regional innovation policies, the effect on the propensity of supported companies to cooperate with research organisations deserves a further analysis. This should be aimed at capturing whether the public intervention enhances the collaborations with regional or extra-regional universities and research institutes. Indeed, as it emerges from Belussi et al. (2010), who focus on the life-science industry of the same Emilia-Romagna region, collaborations with distant research organisations are likely to characterise the strategy of firms looking for "global best" and diverse partners. In a sense, this conclusion is supported by Laursen et al. (2011). Their empirical evidence, on the university-industry relations in the UK, indicates that firms looking for high-quality scientific research are willing to establish a distant collaboration, when suitable partners are not available in their proximity. On a similar vein, D'Este and Iammarino (2010), who also analyse the interactions between firms and universities in the UK, point out that firms searching for cutting-edge and unique research are expected to look for the best partner regardless its location. That because, the more advanced and exploratory is the research the companies are looking for, the narrower is the choice of suitable partners in their proximity. However, in the case of a cooperation with a distant research organisation the advantages due to the geographical co-location (e.g. personnel interaction, knowledge exchange, face-to-face contacts) are obviously annulled,

aggravating also the drawbacks given by the lack of other forms of proximity[55] (e.g. cognitive and institutional, Boschma, 2005a) between firms and research organisations. This might hamper the interactions with distant research partners, which not only are strategically relevant for the firms, but also –in a broader regional policy perspective- are crucial to renew the local knowledge base (e.g. Bathelt et al., 2004; Gertler and Levitte, 2005; Uyarra, 2010). With this respect, the policy intervention may be particularly important. More precisely, the higher is the amount of public support, the higher is expected to be the possibility to counterbalance the intrinsic disadvantages due to the lack of proximity (-ies) that affects extra-regional collaborations, more than regional interactions. In this sense, an increasing amount of subsidy is expected to enhance a change in the cooperation strategy, allowing firms to look for a suitable research partner, regardless its location. Two parallel hypotheses can be advanced.

HP 2a (2b): *An additional amount of subsidy increases firms' propensity to extend the geographical range of the cooperation with research institutes (universities).*

3 The regional context and the R&D subsidy

The geographical context considered in the paper is the NUTS 2-level Emilia-Romagna region. This is located in the North-East of Italy, has a population of nearly 4.5 million (ISTATa, 2011), accounts for about the 9% of the national GDP (EUROSTAT, 2011) and for slightly more than the 10% of the national industrial production (ISTATb, 2011). The Emilia-Romagna regional innovation system (RIS) is characterised by some peculiar elements: a strong district-based industrial system; a deep rooted unionism, especially strong in most industrialised and productive provinces; active institutional and economic actors. All these elements, and others more, have created a successful milieu defined by several scholars in the past economic literature (e.g. Brusco, 1982; Becattini, 2001) as the "Emilian model". Together with the Lombardia region, Emilia-Romagna is a leading innovator in the Italian context and is classified as medium-high innovator region, at the EU27 level, according to the Regional Innovation Scoreboard (Hollanders et al., 2009). The top ranking position in the Italian context is occupied both in 2004 and in 2006. The Regional Innovation Scoreboard report highlights some relative weaknesses of the regional system, due to the lack of some strong enablers of innovation (population with

[55] For a critique to the sometimes ambiguous classification of the different dimensions of the proximity see Knoben and Oerlemans (2006).

tertiary education; participation in life-long learning; public R&D expenditures as percentage of GDP; broadband access). However, a peculiar strength is given by the firms activity indicator, which captures the innovative effort undertaken by the business sector (business R&D expenditures as percentage of GDP; non-R&D innovation expenditures; SMEs innovating in-house; SMEs cooperation for innovation; EPO patents per million population).

To support the innovation performances of the RIS, the policy-maker launched in 2003 the Regional Programme for the Industrial Research, Innovation and Technology Transfer (PRRIITT)[56]. This conjugates the attempt to mitigate the weakness of the RIS with the exploitation of the peculiar strengths given by the firms dynamism in terms of innovation activities. In particular, the present paper is focused on the first two calls (February and September 2004) of the measure 3.1 A. This was aimed at sustaining industrial research and pre-competitive development through more detailed objectives. In addition to the direct support to R&D activities, these were: the creation of new R&D employment opportunities; the reinforcement of the collaboration among the components of the RIS; the development of new technologies and the adoption of intellectual property rights. Regional funds were allocated on the basis of the assessment of firms' innovation projects. An independent committee of experts evaluated each project along several dimensions (each of those having a different potential score): technical-scientific aspects (45 points); economic-financial aspects (20 points); managerial aspects (20 points); regional impact (15 points). The threshold to be funded was fixed at 75 points. The eligible firms were then subsidised by grants covering up to 50% of the total cost of the industrial research activities and up to 25% (35% for SMEs) of the total cost of the pre-competitive development activities. The overall number of projects subsidised through the two calls was 529, for a total of 557 recipient firms[57]. The total cost of the projects proposed by the beneficiaries was about 236 million Euros and the public funding about 96 million, covering around the 40% of the total projects' cost, with an average regional contribution of 175,000 Euros per-project.

[56] The PRRIITT is a complex policy programme that includes a number of measures and funding schemes aimed to sustain the development of the RIS. All these actions are taken within the framework of the Regional Law 7/2002 for the "Promotion of a regional system for the industrial research, innovation and technological transfer" and under the "Triennial Regional Programme for the Production Activities 2003-2005".

[57] Firms were allowed to create temporary association or consortia.

4 Empirical application

4.1 Econometric strategy

The econometric strategy is divided in two parts. The first concerns HP 1, while the second is for testing HP 2a and HP 2b.

As for the first part, it is widely recognised that the simple econometric application of an OLS regression to estimate the impact of the participation in a policy programme is likely to be affected by the selection bias (e.g. Heckman et al., 1998). As the Emilia-Romagna regional subsidy is devised with a "picking the winner" strategy (Cerulli, 2010), the policy support cannot be considered as an exogenous element. The problem in such kind of situation essentially depends on the lack of a randomly assigned policy (treatment). This calls for specific econometric techniques to be adopted in order to mitigate the bias and obtain reliable estimates of the policy effects[58]. To provide a proper additionality evaluation the focus is basically on the average treatment effect on the treated (ATT), which is the average difference between the actual outcome of the funded firms and the potential outcome in case they had not received the subsidy (i.e. the counterfactual). Denoting by Y_1 and Y_0, respectively, the outcome in presence and in absence of treatment and with D the treatment status (D=1: treated; D=0: untreated) - which indicates the receipt of the subsidy-, the ATT can be formalised as follows:

$$ATT = E(Y_1 - Y_0 \mid D = 1) = E(Y_1 \mid D = 1) - E(Y_0 \mid D = 1). \quad (1)$$

While $E(Y_1 \mid D=1)$, can be estimated with a simple mean of the outcome in the group of funded firms, it is not possible to observe $E(Y_0 \mid D=1)$. In order to overcome this problem, it is necessary to create a suitable counterfactual and compare the outcomes of the treated firms with the outcome of their non treated “twins”. As in many recent econometric studies aimed at analysing the impact of R&D policy supports (e.g. Fier et al. 2006; Czarnitki and Licht, 2006; Aerts and Schmidt, 2008; Busom and Fernández-Ribas, 2008), in this work a propensity score matching approach (Rosenbaum and Rubin, 1983) is employed to estimate the ATT of the Emilia-Romagna R&D subsidy[59]:

$$PSM^{ATT} = E_{P(X)|D=1}\{E[Y_1 \mid D = 1, P(X)] - E[Y_0 \mid D = 0, P(X)]\}. \quad (2)$$

[58] For a review of suitable econometric methods see, among the others, Cerulli (2010).

[59] A complete description of the propensity score matching is provided in the Section 3.1 of the third Chapter of this Thesis. See also, among the others, Smith and Todd (2005), Cameron and Trivedi (2005), Caliendo and Kopeinig (2008).

This method is aimed at estimating the treatment effect of the R&D subsidy by controlling for the selection bias on the observables. To this purpose, treated units are paired with similar non treated ones, so that the only difference in the outcome of the two groups is due to the policy intervention. To reduce the dimension of conditioning, treated and non treated firms are matched on the basis of their propensity score, $Pr\ (D=1|X)$ (or $P(X)$). This latter, which is estimated with a probit model, is the probability of being funded given the set of pre-treatment characteristics X that are supposed to affect both the treatment and the outcome.

In the following analysis, different matching procedures identified in the literature (e.g. Becker and Ichino, 2004; Cameron and Trivedi, 2005; Smith and Todd, 2005; Caliendo and Kopeinig, 2008) are implemented: 5 nearest-neighbours (5NN), caliper and kernel. These basically differ in the way non treated firms to be used as matches are selected and weighted, as well as in the capacity to trade bias reduction with efficiency (Caliendo and Kopeinig, 2008; Smith and Todd, 2005). A comparison of the results obtained with different algorithms provides information on the stability and, indirectly, on the reliability of the evidence. For all the implemented matching procedures the common support condition is imposed[60]. Furthermore, the quality of the matching is checked by controlling that beneficiaries and matched controls are correctly aligned with respect to the vector of covariates X[61].

To test HP 2a and HP 2b, building on Hirano and Imbens (2004) and Bia and Mattei (2008), a continuous treatment[62] approach, namely the generalised propensity score method, is employed. This estimates the dose response function (i.e. the average potential outcome for each level of treatment) and the treatment effect due to an additional amount of regional subsidy. The generalised propensity score (GPS), R, can be seen as an extension of the propensity score introduced by Rosenbaum and Rubin (1983)

[60] In addition to the *minima and maxima* comparison, the 5NN matching is implemented imposing the common support condition also with a "trimming" procedure (Leuven and Sianesi, 2003; Caliendo and Kopeinig, 2008).

[61] Drawing on Leuven and Sianesi (2003) and Caliendo and Kopeinig (2008), three tests on the quality of the matching have been carried out. A first one has checked the reduction, after the matching, of the joint significance of probit model for the propensity score estimation. A second test has checked the reduction, after the matching, of the pseudo-R^2 of the probit model. Third, a regression-based *t*-test on the differences in the covariates means has been run. The results of these tests, available upon request, largely support the quality of the matching procedures.

[62] Note that in this case the treatment is the amount of subsidy, rather than the participation in the subsidy scheme.

and it is defined by Hirano and Imbens (2004) as following. Let the propensity function $r(t, x)$ be the conditional density of the actual treatment, t, given the observed covariates, x. Then the GPS is:

$$R = r(T, X). \tag{3}$$

As the propensity score, the GPS score has a balancing propriety. Within strata with the same value of $r(t, x)$, the probability that $T=t$ does not depend on X. Hirano and Imbens (2004) demonstrate that when this balancing propriety is associated with a suitable unconfoundedness assumption, the treatment is unconfounded given the GPS. Hence, the GPS can be used to eliminate the bias, associated with differences in the covariates, in the estimation of the dose response function and of the treatment effect.

Drawing on Bia and Mattei (2008), who propose a parametric operationalisation of the method introduced by Hirano and Imbens (2004), the estimation strategy here employed consists of three steps. The first one is the estimation of the conditional distribution of the treatment given the covariates. The treatment, or its transformation $g(T_i)$ -which in our case is a logarithmic one-, is assumed to normally distributed conditional on the covariates:

$$g(T_i) \mid X_i \approx N\{h(\gamma, X_i), \sigma^2\}, \tag{4}$$

where $h(\gamma, X_i)$ is a function of the covariates, which depends on a vector of parameters, γ. Once the parameters γ and σ^2 are estimated by maximum likelihood, the GPS for each firm can be obtained as:

$$\hat{R}_i = \frac{1}{\sqrt{2\pi\hat{\sigma}^2}} \exp\left\{-\frac{1}{2\hat{\sigma}^2}\left[g(T_i) - h(\hat{\gamma}, X_i)\right]^2\right\}. \tag{5}$$

Once the GPS is estimated, the normality of $g(T_i)$ and the fulfilment of the assumption on the balancing propriety are tested[63].

In the second step, the conditional expectation of the outcome Y_i given T_i and R_i is modelled as follows[64]:

[63] A Kolmogorov-Smirnov test for the normality of $g(T_i)$ and the test proposed by Hirano and Imbens (2004) for the balancing propriety of the GPS are implemented. Both of them largely support the quality of the estimation. Results are available upon request.

[64] The choice of this functional form (i.e. linear in R_i and quadratic in T_i) "maximises" the joint significance and the goodness of fit of the estimation of the conditional expectation of the outcome.

$$E(Y_i \mid T_i, R_i) = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 R_i. \quad (6)$$

Given HP 2a and HP 2b, the conditional expectation of the outcome is estimated with an ordered probit model[65]. This latter turns out to be particularly suitable to estimate the effect of an additional amount of subsidy on three different decisions regarding the geographical distance of funded companies' interactions: i.e. no-cooperation, cooperation with a regional partner and cooperation with an extra-regional partner[66].

The final step consists of estimating the dose-response function and the treatment effect of an additional amount of subsidy, getting the standard errors through a bootstrapping procedure. Given the parameters estimated in the previous stage, the average potential outcome at level *t* of treatment is:

$$\widehat{E[Y(t)]} = \frac{1}{N}\sum_{i=1}^{N}[\hat{\alpha}_0 + \hat{\alpha}_1 t + \hat{\alpha}_2 t^2 + \hat{\alpha}_3 \hat{R}(t, X_i)]. \quad (7)$$

Doing this for each level of treatment *t* we are interested in, it is possible to obtain the overall dose-response function. The treatment effect is then calculated for each level of *t*, as a difference between (9) calculated at level $t + \Delta t$ and (9) calculated at *t*. With this respect, considering the average regional contribution (€ 175,000), the chosen Δt value is € 20,000. As a sort of robustness check a Δt of € 40,000 is also employed.

4.2 Data

The dataset used in the econometric analysis integrates information stemming from a unique survey of 555 manufacturing firms (with at least 20 employees) located in the Emilia-Romagna region (Antonioli et al., 2011) and balance sheets extracted from the AIDA-Bureau Van Dijk database. The data coming from the survey include information on firm's structural and organisational characteristics and innovation strategies. The random sample of 555 firms is stratified by size, province (geographic location at NUTS 3 level) and sector. The information collected mainly refers to the period (2006-2008). Balance sheets include other relevant pre-policy variables (year 2003). These are used, together with (supposed) time invariant firms' characteristics drawn from the survey, for

[65] The estimated GPS, $\hat{R}_i$, is used.

[66] A test on the cut-points aimed at excluding the overlapping of their confidence intervals has been conducted. The possibility of collapsing the three ordinal values in two values, generating a simple probit, is rejected. Results are available upon request.

the estimation of the propensity score and the GPS. A main point should be stressed here. Considering that the information on the public support (i.e. both the binary participation status and the amount of subsidy) is referred to the year 2004 (when the policy was administrated), the overall structure of the dataset helps in reducing potential endogeneity problems. Indeed, the econometric analysis can rely on both pre-policy (and time invariant) information for the estimation of the propensity score and of the GPS, and on post-policy data for the definition of the outcome variables[67].

The merging procedure defined above and the cleaning of the dataset leads to a working sample of 408 observations: 99 subsidised and 309 non subsidised firms. What is important for the analysis is the representative capacity of the working sample of recipient firms. As it can be seen in Tab.1, the sample of 99 funded firms shows a distribution by size (SMEs and large firms) and sector (à la Pavitt/OECD) similar to that of all the manufacturing firms (with more than 20 employees) that received the regional R&D subsidy.

Tab.1 Distribution of recipient manufacturing firms with more than 20 employees

Recipient population distribution	SMEs (< 250 employees) %	Large (≥ 250 employees) %	*Total* %	*Total (a.v.)*
Sector				
PAVITT1 (Labour Intensive)	8.55	0.43	8.97	*21*
PAVITT2 (Resource Intensive)	9.83	2.56	12.39	*29*
PAVITT3 (Science Based)	11.11	1.28	12.39	*29*
PAVITT4 (Scale Intensive)	14.96	4.70	19.66	*46*
PAVITT5 (Specialised Suppliers)	39.74	6.84	46.58	*109*
Total	84.19	15.81		
Total (a.v.)	*197*	*37*		*234*
Recipient sample distribution	SMEs %	Large %	*Total %*	*Total (a.v.)*
Sector				
PAVITT1 (Labour Intensive)	9.09	1.01	11.11	*11*
PAVITT2 (Resource Intensive)	7.07	2.02	9.09	*9*
PAVITT3 (Science Based)	15.16	1.01	16.16	*16*
PAVITT4 (Scale Intensive)	14.15	7.07	21.21	*21*
PAVITT5 (Specialised Suppliers)	34.34	8.08	42.42	*42*
Total	80.81	19.19		
Total (a.v.)	*80*	*19*		*99*

[67] When compared with this "lagged policy variable(s)" setting, panel data would have allowed for a more robust treatment of the potential bias arising from the omission of unobservable characteristics (e.g. Cameron and Trivedi, 2005; Angrist and Pischke, 2009), but mainly for testing HP1. Whereas some methods for the estimation of the ATT employing longitudinal data are available (e.g. difference in differences), there is not an established approach that accommodates the analysis provided through the GPS technique (employed to test HP2a and HP2b) to panel data.

4.3 Variables

To implement the econometric strategy defined above, two sets of variables are created: (i) a set of suitable covariates *X* to be included in the estimation of the propensity score and of the GPS (Tab. A2 - A3 in the Appendix); (ii) a set of outcome variables that capture the behavioural changes induced by the policy (HP 1) and the effects of an additional amount of subsidy on the cooperation strategy with research organisations (HP 2a and HP 2b).

As for the covariates[68] we control, at first, for the fact that innovation strategies are sector specific and related to the firm's dimension, as a vast literature has demonstrated (e.g. Malerba, 2002; Cohen, 2010). More precisely, dummy variables (PAVITT1-PAVITT5) capturing the *à la* Pavitt/OECD sector and the natural logarithm of the number of employees (lnEMP_2003) are included. Second, a set of dummies (GEO1-GEO10) that capture the firm's location in terms of province (NUTS 3-level)[69] is also employed. Since a RIS should not be understood as a homogeneous system due to the likely presence of many clusters and industrial districts (Tödling and Trippl, 2005), the inclusion of these dummies controls for the intra-RIS heterogeneity in the innovation strategies. This is particularly relevant in the case of the present analysis, given the existence of different local production systems in the Emilia-Romagna region (e.g. Montresor et al., 2009; Mazzanti et al., 2009). Another relevant variable captures the pre-policy expenditure (per capita) in intramural R&D and advertising. Even if with the available data it was impossible to clean the variable from the share of the advertising expenditure, RDADV_2003 is used as a proxy of the firm R&D capabilities that may act as a driver for subsequent intense innovation activities. More precisely, previous expenditure in R&D might influence the willingness and ability to apply for public subsidies and to do further steps on the innovation path. Finally, two opposite measures of innovative expenditure capacity are included. The cash flow per capita

[68] Considering the characteristics and the rationales of the econometric methods here employed (see Section 4.1), the covariates used to estimate the propensity score and the generalized propensity score essentially represent the observable characteristics we control for. Hence, these can be considered, in a sense, as analogous to the control variables included in the specification of a standard parametric regression model. Descriptive statistics are provided in Tab. A1 in the Appendix.

[69] One of the dummies (GEO1) captures firms based outside the regional borders, but having at least a production unit in the region.

(CASHFLOW_2003)[70] proxies the possibility of the firm to invest in innovation activities without recurring to external source of financing. The higher the cash flow per capita, the higher is expected to be the possibility for the firm to plan an investment in R&D. On the contrary, firm's financial constraint, here proxied with the short-term debt index (FINCONST_2003), is expected to act as an obstacle to R&D investment. The short-term debt is here considered to be probably more relevant than the long- term one. The former is indeed expected to influence more heavily a contingent decision to plan a R&D project and thus the participation in the policy.

All the considered covariates are thus conceptually relevant and several of them have a continuous nature, which guarantees a better determination of the propensity score and of the GPS[71]. Also in absence of contrasting empirical evidences, the intention was to include the aforementioned variables in the specification of both the propensity score and the GPS. However, to respect the balancing propriety of this latter some covariates are excluded from its estimation: i.e. the provincial dummies (GEO1-GEO10) and the expenditure in R&D and advertising in year 2003 (RDADV_2003).

The second set of variables created for the empirical analysis consists of proxies for the behavioural changes induced by the policy (to test HP 1) and variables capturing the effects aimed to be tested with HP 2a HP 2b (Tab. 2). As mentioned above, the possibility to carry out an *ad hoc* survey has allowed for an extremely relevant advantage: all the outcome variables used in the econometric analysis are referred to the period 2006-2008, hence reducing the risk of endogeneity with the policy support, which was adjudicated in 2004.

[70] Both CASHFLOW_2003 and RDADV_2003 are expressed in "per capita" terms (i.e. divided by the number of employees) to avoid multicollinearity with firm size.

[71] Unfortunately, due to the lack of available data, it was impossible to include in the estimation of the propensity score and of the GPS covariates that are more directly related to, and likely to influence, the behavioural changes induced by the policy. A sign of the possible bias arising from this exclusion is difficult to hypothesise. According to the regional policy-maker, SMEs in particular were willing to introduce behavioural changes, included among the policy objectives, that did not characterise their innovation strategy before the funding. On the other hand, some large firms were reluctant to introduce strategic improvements in line with the policy objectives.

Tab.2 Descriptive statistics of the outcome variables

	Overall mean (408 obs)	Mean subsidised (99 obs)	Mean non subsidised (309 obs)	Min.	Max.
HP 1					
Learning process and accumulation of competencies					
COMPUP	0.740	0.869	0.699	0	1
TRAIN	0.819	0.879	0.799	0	1
TECHTRAIN	0.718	0.818	0.686	0	1
Networking Intra-RIS					
COOPCUS_REG	0.172	0.162	0.175	0	1
COOPSUP_REG	0.184	0.152	0.194	0	1
COOPCOM_REG	0.074	0.040	0.084	0	1
COOPGP_REG	0.100	0.131	0.091	0	1
COOPUNI_REG	0.370	0.717	0.259	0	1
COOPRESINS_REG	0.311	0.566	0.229	0	1
Networking Extra-RIS					
COOPCUS_EXTRA	0.275	0.263	0.278	0	1
COOPSUP_EXTRA	0.331	0.364	0.320	0	1
COOPCOM_EXTRA	0.076	0.121	0.061	0	1
COOPGP_EXTRA	0.113	0.172	0.094	0	1
COOPUNI_EXTRA	0.145	0.343	0.081	0	1
COOPRESINST_EXTRA	0.199	0.394	0.136	0	1
HP2a - HP2b					
COOPRESINS_ORD	0.654	1.19	0.482	0	2
COOPUNI_ORD	0.596	1.21	0.398	0	2

As for the outcome variables used to capture the behavioural additionality of the intervention (HP 1), three types of effect induced by the R&D subsidy are considered. First, the impact of the policy on firms' learning process and accumulation of competencies. To capture this type of effect three outcome variables are used: (i) a dummy indicating whether the workers' competencies have been improved or upgraded (COMPUP), (ii) a dummy capturing whether undifferentiated training programmes have been implemented (TRAIN) (iii) a dummy indicating whether the firm has implemented training programmes to improve technical/specialised competencies (TECHTRAIN). Differently from the first one, the second and the third variables capture changes that can be argued to be a complementary, indirect consequence of firms' engagement in publicly funded R&D activities. The second type of behavioural changes here considered concerns

the cooperation agreements of funded firms with other components of the RIS. This allows for analysing the effectiveness of policy in strengthening the networking activities within the RIS, and, in turn, interactive learning processes. To this aim, two sets of dummies are employed. The first captures whether a firm has cooperated with other regional companies: i.e. customers (COOPCSUS_REG), suppliers (COOPSUP_REG), competitors (COOPCOM_REG), firms in the same group (COOPGP_REG). The second whether the firm has cooperated with regional research organisations: i.e. universities (COOPUNI_REG) and research institutes (COOPRESINS_REG). The last impact of the policy on firms' behaviours that is considered pertains to the cooperation with extra-regional actors. That to assess the ability of the regional subsidy to open-up the RIS to external sources, which are considered as suitable channels for the acquisition of new competencies and for the renewal of the regional knowledge base. With this respect, a set of dummies captures cooperation agreements with extra-regional firms: i.e. customers (COOPCSUS_EXTRA), suppliers (COOPSUP_EXTRA), competitors (COOPCOM_EXTRA) and companies in the same group (COOPGP_EXTRA). Other two dummies capture the cooperation with extra-regional research organisations: i.e. universities (COOPUNI_EXTRA) and research institutes (COOPRESINS_EXTRA).

Finally, to test HP 2a and HP 2b, two ordinal outcome variables reflect the geographical range of the interactions between funded firms and research organisations. COOPRESINS_ORD (COOPUNI_ORD) takes three values: 0 if the firm has not cooperated with any research institute (university), 1 in case of cooperation with a regional research institute (university), 2 in case the firm has cooperated with an extra-regional research institute (university).

5 Analysis and results

This section presents the results concerning the behavioural changes induced by the R&D subsidy (HP 1,Tab. 3) and the effects of an additional amount of public support on the geographical range of the cooperation with research organisations (HP 2a - HP 2b, Tab. 4-5).

The results presented in Tab. 3 lead to a general support of HP 1: the policy is found to induce a set of behavioural changes that might be helpful in limiting possible system failures. The first type of behavioural changes that is taken into account pertains to the effects on firms' learning process. With this respect, funded firms are more likely

(from +16.6% to +20.0%) to report an upgrading in their competencies, when compared to similar non subsidised companies. Hence, carrying out funded R&D activities generates a relevant learning process. However, it seems that to carry out the same funded R&D activities, supported firms do not need to upgrade the skills of their employees through complementary training schemes. In fact, taking into account both general training programmes and programmes targeted to technical competencies, the effect of the policy is found to be generally not significant.

The second type of behavioural changes considered pertains to the networking activities with other regional actors, both other firms and research organisations. As far as the cooperation with these latter is concerned, the results clearly depict a success of the policy in strengthening the connections between firms and regional actors involved in research activities. With all the four matching procedures employed, the regional subsidy is found to stimulate firms' interactions with universities and research institutes. More precisely, with respect to similar non supported companies, funded firms are more likely to cooperate with regional universities (from + 37.4% to + 40.2%) and with regional research institutes (from +32.8% to + 33.5%). A similar positive effect is not found for the cooperation between funded firms and other regional companies. On the one hand, interactions with clients, suppliers and firms in the same group are generally not significantly affected by the regional policy intervention. On the other hand, the subsidy reduces (from – 7.4% to – 10.9%) the propensity of the supported firms to cooperate with companies operating in the same sector. A clear motivation for such a behavioural change should be investigated and tested more in depth. However, a reason could be found in the "not-invented-here (NIH) syndrome", that in this case could be strengthened by the willingness of the firms to assure their own distinctiveness with respect to very similar companies (i.e. operating in the same sector) (Wastyn and Hussinger, 2011). In this case, it may be hypothesised that the policy has pushed firms to activate relationships with other partners rather than with very similar companies, possibly sharpening the NIH syndrome.

Tab. 3 Behavioural additionality effects of the regional R&D subsidy

	5NN		Caliper		Kernel		5NN Trim	
	ATT	S.E.	ATT	S.E.	ATT	S.E.	ATT	S.E.
Learning process and accumulation of competencies								
COMPUP	0.198 ***	0.072	0.166 **	0.073	0.181 ***	0.067	0.200 ***	0.076
TRAIN	0.026	0.055	0.026	0.061	0.052	0.047	0.025	0.059
TRAINTECH	0.085	0.071	0.072	0.076	0.103*	0.062	0.082	0.081
Networking Intra-RIS								
COOPCUS_REG	-0.096	0.067	-0.056	0.067	-0.054	0.059	-0.105	0.071
COOPSUP_REG	-0.109	0.072	-0.089	0.070	-0.058	0.058	-0.112*	0.063
COOPCOM_REG	-0.109 **	0.048	-0.089 *	0.048	-0.074 *	0.045	-0.101 *	0.057
COOPGP_REG	0.000	0.056	0.022	0.052	0.037	0.048	-0.006	0.055
COOPUNI_REG	0.374 ***	0.082	0.393 ***	0.082	0.402 ***	0.072	0.381 ***	0.077
COOPRESINS_REG	0.335 ***	0.073	0.335 ***	0.076	0.330 ***	0.075	0.328 ***	0.075
Networking Extra-RIS								
COOPCUS_EXTRA	-0.028	0.077	-0.069	0.077	-0.067	0.071	-0.040	0.081
COOPSUP_EXTRA	0.072	0.088	0.073	0.083	0.092	0.071	0.069	0.082
COOPCOM_EXTRA	0.043	0.050	0.043	0.043	0.041	0.043	0.063	0.047
COOPGP_EXTRA	0.096 *	0.056	0.098 *	0.057	0.099 **	0.048	0.103 *	0.054
COOPUNI_EXTRA	0.189 ***	0.060	0.130 *	0.071	0.138 **	0.065	0.198 ***	0.069
COOPRESINS_EXTRA	0.193 ***	0.074	0.218 ***	0.075	0.226 ***	0.075	0.202 ***	0.077
N treated on support	92		92		92		95	
N treated total	99		99		99		99	
N non treated	309		309		309		309	

Methods: 5 nearest neighbours (5NN), 5 nearest neigbhours with a 0.05 caliper (Caliper), Epanechnikov kernel matching (Kernel), 5 nearest neighbours with 1% trim (5NN Trim). Standard errors are estimated with a 200-replication bootstrap procedure. ***, **, * indicate a significance level of 1%, 5%, 10%.

The last type of behavioural change induced by the policy here considered concerns the collaborations with extra-regional actors, both firms and research organisations. This type of effect captures whether the policy enhances the renewal of the regional knowledge base by opening-up the RIS. As it emerges from Tab.3, a positive and significant policy effect is found for the cooperation with extra-regional universities and research institutes. More precisely, with respect to similar non subsidised companies, funded firms are more likely to cooperate with an extra-regional university (from +13.0% to +19.8%) or a research institute located outside the Emilia-Romagna region (from + 19.3% to + 22.6%). A similar positive effect cannot be observed for the interactions with extra-regional firms. Only the propensity to cooperate with extra-regional companies belonging to the same group is positively affected by the R&D support scheme (from

+9.6% to +10.3%).

With respect to firms' interactions with research institutes and universities, the evidence emerged above points to an interesting result. The simple participation in the policy scheme, irrespectively from the amount of public funding received, increases firms' cooperation with research organisations, but more within rather than outside the region. However, the capacity to get across the boundaries with cooperation might actually depend on the amount of subsidy.

As for the effect of an additional amount of public support on the geographical range of the cooperation with research partners (HP 2a and HP 2b), the evidence emerging from the GPS estimations are reported in Tab. 4 and 5[72].

The results concerning the impact on the interaction with research institutes (Tab. 4 and Fig. A1 in Appendix) lead to a support of HP 2a, which is conditional to the level of subsidy. For levels of subsidy higher than € 200,000 (€ 180,000), an increase of € 20,000 (€ 40,000) in the amount of public support reduces the likelihood of not being engaged in any cooperation with a research institute (Y=0)[73], regardless the location of this latter. As a mirror image, for the same levels of subsidy, an additional amount of public support has a positive impact on the propensity of funded firms to cooperate with an extra-regional research institute (Y=2). More precisely, over a certain threshold of public support (€ 200,000 for Δt= € 20,000 and €180,000 for Δt= € 40,000), the higher is the level of subsidy, the higher is the effect of receiving an additional amount of public monies. With Δt = € 20,000, the range of the treatment effects goes from +6.4% to +14%. With Δt = € 40,000, from +9.7% to +30.1%. Two points should be stressed here. First, the fact that a financial incentive, as a higher amount of subsidy, triggers the engagement in extra-regional collaborations implies that the difficulties due to the lack of proximity (-ies) also increases the pure economic cost of the interaction and coordination with extra-regional research institutes. Second, the existence of a minimum threshold of subsidy, over which an extra-amount of public monies significantly and increasingly affects the propensity to cooperate with an extra-regional research institute, leads to the following insight. Distant

[72] It is worth stressing that the establishment of a distant (i.e. extra-regional) cooperation was neither a requirement nor an explicit criterion for the allocation of the policy incentives here investigated. This makes the results presented below even more robust to eventual problems of endogeneity.

[73] For a very low level of subsidy (€ 60,000 with Δ_t= € 20,000) an increase in the amount of support is found to reduce the likelihood of cooperating with a research institute. The significance of the treatment effect, however, is quite low.

collaborations are characterised by an indivisible fixed cost, which can be overcome with a minimum efficient scale of public funding.

Tab. 4 Effects of an additional amount of subsidy on the cooperation with research institutes

(Δt =20000)	Y=0		Y=1		Y=2	
Treatement Level	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE
60000	0.141*	0.078	-0.003	0.064	-0.138	0.108
80000	0.128	0.087	-0.040	0.045	-0.088	0.070
100000	0.096	0.068	-0.034	0.034	-0.062	0.045
120000	0.059	0.047	-0.012	0.017	-0.047	0.037
140000	0.026	0.029	0.002	0.008	-0.028	0.032
160000	0.000	0.017	0.000	0.008	0.000	0.023
180000	-0.022	0.016	-0.010	0.009	0.032	0.020
200000	-0.042*	0.023	-0.022	0.015	0.064**	0.031
220000	-0.061**	0.030	-0.032	0.023	0.094**	0.044
240000	-0.076**	0.037	-0.048	0.036	0.124**	0.057
250000	-0.080**	0.039	-0.060	0.043	0.140**	0.063
(Δt =40000)	Y=0		Y=1		Y=2	
Treatement Level	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE
60000	0.271	0.180	-0.050	0.089	-0.220	0.173
80000	0.226	0.161	-0.090	0.088	-0.136	0.103
100000	0.160	0.118	-0.065	0.065	-0.095	0.069
120000	0.090	0.080	-0.021	0.033	-0.069	0.059
140000	0.026	0.046	0.002	0.011	-0.028	0.050
160000	-0.022	0.028	-0.009	0.014	0.031	0.040
180000	-0.060*	0.034	-0.037	0.029	0.097*	0.056
200000	-0.093**	0.046	-0.068	0.049	0.161*	0.083
220000	-0.122**	0.058	-0.097	0.066	0.220**	0.106
240000	-0.140**	0.067	-0.136	0.083	0.275**	0.123
250000	-0.140**	0.069	-0.161*	0.089	0.301**	0.128

Standard errors are estimated with a 200-replication bootstrap procedure. ***, **, * indicate a significance level of 1%, 5%, 10%. Critical values of the two sided t-test (df=100): 10% 1.660; 5% 1.984; 1% 2.626

Tab. 4 reports another interesting result. As a counterpart of the positive impact on the cooperation with extra-regional research institutes, an additional amount of subsidy has no significant effects on the cooperation with regional partners of the same type (Y=1)[74]. With this respect, it seems that funded firms do not perceive regional and extra-regional research institutes as substitutes. In this sense, it might be argued that an

[74] The only exception is the treatment effect at € 250,000 with Δ_t= € 40,000, which is found to be slightly significant and negative.

increasing amount of subsidy allows firms to interact with extra-regional research institutes in which they can find distinctive and specific research capabilities, not available within the regional borders. Indeed, it is quite likely that the research institutes located in a given region follow some specialisations covering only a limited set of scientific and technological fields.

The picture emerging from the results presented in Tab. 5 (Fig.A2 in Appendix) is a bit different, but leads to support HP 2b. Also in this case, this support is conditional to the level of subsidy. More precisely, similarly to what emerged before, for levels of subsidy higher than € 180,000 (€160,000), an extra amount of € 20,000 (€ 40,000) reduces firms' probability of not being engaged in any cooperation with an academic partner (Y=0), whatever its location is[75]. For the same levels of subsidy, adding an extra €20,000 (€40,000) enhances firms' propensity to cooperate with an extra-regional university (Y=2): from +5.6% (+7%) to + 20.4% (+39.1%). Thus, also considering the collaborations with academic partners, there is a minimum efficient scale of public funding that allows firms to overcome the economic cost of distant interactions. However, differently from what emerged for the collaborations with research institutes, the increasing attitude to cooperate with extra-regional academic partners is associated to a reducing propensity to collaborate with a regional university (Y=1). For levels higher than €180,000, an extra €20,000 (€40,000) induces firms to cooperate less with regional academic partners: from -2.4% (-8.6%) to -15.9% (-32.8%). Hence, an increasing amount of subsidy is inducing a sort of shift from an "inward-looking" to an "outward-looking" cooperation strategy. This result seems to suggest a sort of substitution effect: the broader geographical range of the interactions with academic partners is paid at the price of a reduced propensity to collaborate with the regional universities. A possible explanation can be found again in the relation between the research skills available within the region and those located outside the regional borders. In the case of cooperation with academic partners -whose research programmes are more homogeneous than in non academic

[75] For a very low level of subsidy (€ 60,000 with Δ_t= € 20,000 and Δ_t= € 40,000) an increase in the amount of support is found to reduce the likelihood of cooperating with a university (the significance of the treatment effects however is quite low). It is worth mentioning also the non significant treatment effect at € 250,000 with Δ_t= € 40,000. For this high level of support, an extra amount of subsidy does not alter firms' propensity of not being engaged in any cooperation with a university.

research institutes-, those located in the region[76] are likely to offer a range of research skills which is similar –in terms of breath- to that available outside the regional borders. As a consequence, when, due to the public support, firms have the possibility to deal with the higher cost of a distant cooperation, the collaborations with regional universities are substituted by interactions with extra-regional academic institutes, which probably offer alike but more qualitatively advanced and suitable research capabilities.

Tab. 5 Effects of an additional amount of subsidy on the cooperation with universities

(Δt =20000)	Y=0		Y=1		Y=2	
Treatement Level	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE
60000	0.131*	0.070	0.029	0.118	-0.160	0.121
80000	0.137	0.087	-0.049	0.070	-0.088	0.074
100000	0.104	0.076	-0.049	0.054	-0.055	0.041
120000	0.059	0.051	-0.020	0.028	-0.039	0.033
140000	0.018	0.028	-0.001	0.009	-0.018	0.028
160000	-0.011	0.014	-0.004	0.008	0.015	0.019
180000	-0.032**	0.013	-0.024*	0.013	0.056***	0.018
200000	-0.048**	0.019	-0.052**	0.026	0.100***	0.033
220000	-0.056**	0.024	-0.088**	0.039	0.144***	0.050
240000	-0.053**	0.026	-0.134**	0.053	0.187***	0.062
250000	-0.045*	0.024	-0.159***	0.057	0.204***	0.064
(Δt =40000)	Y=0		Y=1		Y=2	
Treatement Level	Treat. Eff.	SE	Treat. Eff.	SE	Treat. Eff.	SE
60000	0.273*	0.142	-0.031	0.156	-0.242	0.194
80000	0.250	0.160	-0.121	0.102	-0.129	0.104
100000	0.172	0.129	-0.093	0.090	-0.080	0.060
120000	0.082	0.083	-0.030	0.046	-0.052	0.051
140000	0.005	0.042	0.000	0.014	-0.005	0.044
160000	-0.045*	0.024	-0.024	0.019	0.070**	0.034
180000	-0.075**	0.032	-0.086**	0.041	0.160***	0.054
200000	-0.091**	0.039	-0.159**	0.068	0.250***	0.085
220000	-0.094**	0.042	-0.235***	0.088	0.328***	0.106
240000	-0.077*	0.041	-0.305***	0.097	0.383***	0.108
250000	-0.063	0.038	-0.328***	0.093	0.391***	0.102

Standard errors are estimated with a 200-replication bootstrap procedure. ***, **, * indicate a significance level of 1%, 5%, 10%. Critical values of the two sided t-test (df=100): 10% 1.660; 5% 1.984; 1% 2.626

[76] Particularly considering that in Emilia-Romagna there are four regional universities (Parma, Modena and Reggio Emilia, Bologna, Ferrara) and two branches of extra-regional universities (Catholic University of Milan and Polytechnic University of Milan).

6 Conclusions

The paper has provided an analysis of the R&D subsidy included in the Emilia-Romagna Regional Programme for the Industrial Research, Innovation and Technology Transfer (PRRIITT). Particular attention has been devoted to the behavioural dimension of the additionality and to the effect of an increasing amount of subsidy on the beneficiaries' cooperation strategy with research organisations.

The paper, at first, has tested a hypothesis concerning the likely presence of behavioural changes induced by the R&D subsidy. In particular, through a proper operationalisation of the behavioural additionality evaluation, the paper has investigated the policy capacity to limit potential regional system failures pertaining to: problems in learning processes and accumulation of competencies, missing or inappropriate interactions and networking activities, lock-ins. With respect to the last point, it has been considered the effectiveness of the policy in stimulating funded firms' cooperation with extra-regional partners. As stressed in some recent contributions (e.g. Bathelt et al., 2004; Gertler and Levitte, 2005; Uyarra, 2010), interactions with extra-regional actors are indeed expected to enhance the renewal and the increasing diversity of the regional knowledge base. The main results, based on the econometric evaluation of the ATT with a propensity score matching approach, have pointed to the presence of a set of behavioural changes induced by the R&D subsidy. At first, the R&D support scheme is found to have a positive impact on firms' competencies upgrading, but not on the engagement in formal training programmes. Looking at the effects on firms' intra-RIS interactions and networking activities, the policy is found to be largely successful in stimulating beneficiaries' cooperation agreements with regional research organisations, i.e. universities and research institutes. Notwithstanding, the impact on the collaborations with other regional firms is found to be generally not significant. For the negative effect on the cooperation with competitors an hypothetical explanation to be found in the NIH syndrome (Wastyn and Hussinger, 2011) has been advanced. Finally, the results concerning the interactions with extra-regional partners has shown that the public intervention succeeded in opening-up the RIS, inducing firms to cooperate with companies belonging to their same group and, in particular, with academic partners and research institutes.

The positive effect of the policy on the cooperation with regional and extra-regional research organisations (i.e. universities and research institutes) has been further

investigated. In particular, the paper has analysed the effect generated by an additional amount of public support on the geographical range of the cooperation with research partners. The results, emerged from a GPS method have provided a support to the advanced hypotheses that is conditional to the level of subsidy. In particular, over a minimum efficient scale of public funding, an extra-amount of subsidy increasingly enhances the propensity to cooperate with extra-regional research organisations. As for the cooperation with academic partners, this effect is associated to a change from an "inward-looking" to an "outward-looking" cooperation strategy: an higher amount of support induces firms to cooperate less with regional universities and more with extra-regional ones.

A main policy implication can be drawn from this analysis. The amount of subsidy granted to the firms is of fundamental importance. It allows firms to overcome the economic cost of a distant collaboration, deriving from the lack of proximity (-ies), and to establish interactions with "global-best" research partners. More generally, the amount of public support triggers the transition process towards an Open Regional Innovation System (Belussi et al. 2010), characterised by the presence of open modes of innovation (Chesbrough, 2003) that overcome not only the boundaries of the firm but also of the region. However, some further analyses on the issue are required to increase the generality of this conclusion. In fact, the results here presented might partially depend on the characteristics of the context and of the policy considered in the paper: in particular, the fact that SMEs were the main beneficiaries of the intervention and the low average public support.

Appendix

Tab. A1 Description and statistics of the covariates used in the propensity score and GPS estimation

Variables	*Description*	*Mean (408 obs.)*	*Min*	*Max*	*Mean Subsidised (99 obs.)*	*Min*	*Max*	*Mean Not Subsidised (309 obs.)*	*Min*	*Max*
Time invariant survey data										
Geographical location* (10 dummies)	Dummies of geographical location of the firm. Nine dummies corresponding to the regional provinces and one dummy for firms whose headquarter is located outside of regional borders (GEO1: Extra-Region, GEO2: Bologna GEO3: Forlì Cesena GEO4: Ferrara GEO5: Modena GEO6: Piacenza GEO7: Parma GEO8: Ravenna GEO9: Reggio Emilia GEO10: Rimini)	\	0	1	\	0	1	\	0	1
Sector* (5 dummies)	Five dummies to capture *a là* Pavitt/OECD sectors (PAVITT1: labour intensive; PAVITT2: resource intensive; PAVITT3: science based; PAVITT4: scale intensive; PAVITT5: specialised suppliers).	\	0	1	\	0	1	\	0	1
Balance sheets data										
lnEMP_2003	Log number of employees in year 2003	4.218	0.693	7.961	4.516	2.639	7.754	4.122	0.693	7.961
FINCONST_2003	Short-term debt index in year 2003	0.871	0.320	1.000	0.838	0.33	1	0.882	0.320	1.000
CASHFLOW_2003	Cash flow per capita in year 2003 (thousands of Euros)	0.792	-1.105	185.222	0.183	-0.475	1.555	0.987	-1.105	185.222
RDADV_2003	Expenditures per capita in research and advertisement in year 2003 (thousands of Euros)	0.007	0.000	0.405	0.016	0	0.326	0.003	0.000	0.405

Tab.A2 Probit estimation of the propensity score

	Coeff.	S.E.
lnEMP_2003	0.119	0.083
GEO1	3.420 ***	1.146
GEO2	1.755 *	1.053
GEO3	0.789	1.155
GEO5	1.839 *	1.057
GEO6	2.639 **	1.096
GEO7	1.531	1.077
GEO8	2.184 **	1.083
GEO9	1.849 *	1.064
GEO10	1.187	1.122
PAVITT1	0.148	0.290
PAVITT3	1.361 ***	0.326
PAVITT4	0.575 **	0.279
PAVITT5	0.726 ***	0.255
FINCONST_2003	-0.881 *	0.525
CASHFLOW_2003	-0.005	0.005
RDADV_2003	0.162 ***	0.043
_cons	-2.671**	1.219
N	408	
Pseudo R^2	0.217	
Prob>χ2	0.000	

***, **, * indicate a significance level of 1%, 5%, 10%. A VIF test excludes the presence of multicollinearity among the covariates (all the VIF values are lower than 10).

Tab.A3 Maximum likelihood estimation of the generalised propensity score

	Coeff.	S.E.
lnEMP_2003	0.057 *	0.030
PAVITT1	0.203	0.133
PAVITT3	0.210 *	0.126
PAVITT4	0.073	0.120
PAVITT5	0.206 *	0.111
FINCONST_2003	-0.525 ***	0.182
CASHFLOW_2003	0.000	0.003
_cons	12.100 ***	0.221
N	99	
Pseudo R^2	0.293	
Prob>χ2	0.009	

***, **, * indicate a significance level of 1%, 5%, 10%. A VIF test excludes the presence of multicollinearity among the covariates (all the VIF values are lower than 10). Critical values of the two sided t-test (df=100): 10% 1.660; 5% 1.984; 1% 2.626

Fig.A1 Effects of an additional amount of subsidy on the cooperation with research institutes (Left: No cooperation Y=0, Centre: Cooperation with regional partner Y=1, Right: Cooperation with extra-regional partner Y=2 . Top: Δt= 20,000; Bottom: Δt= 40,000. Confidence bounds at 95 % level)

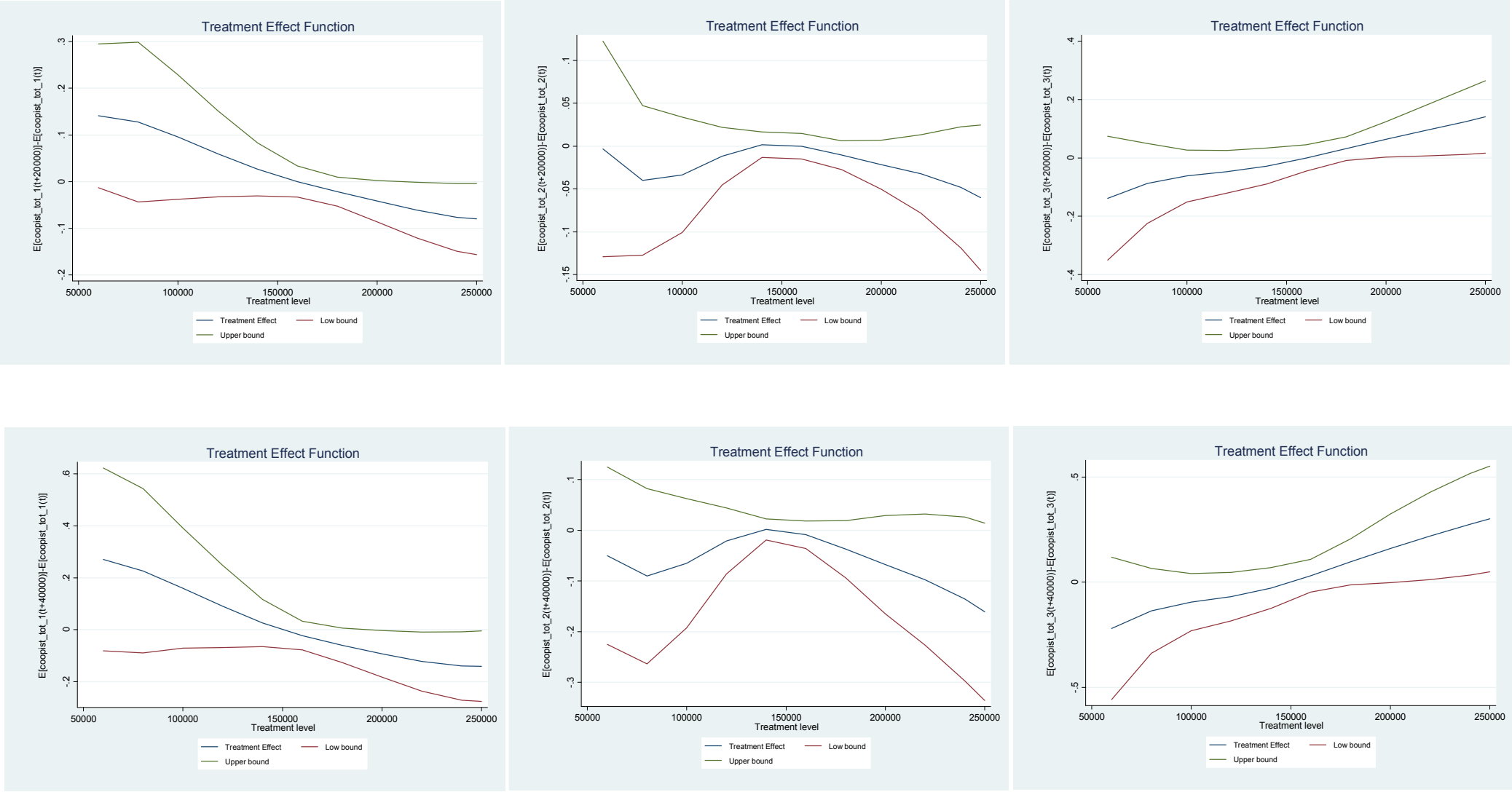
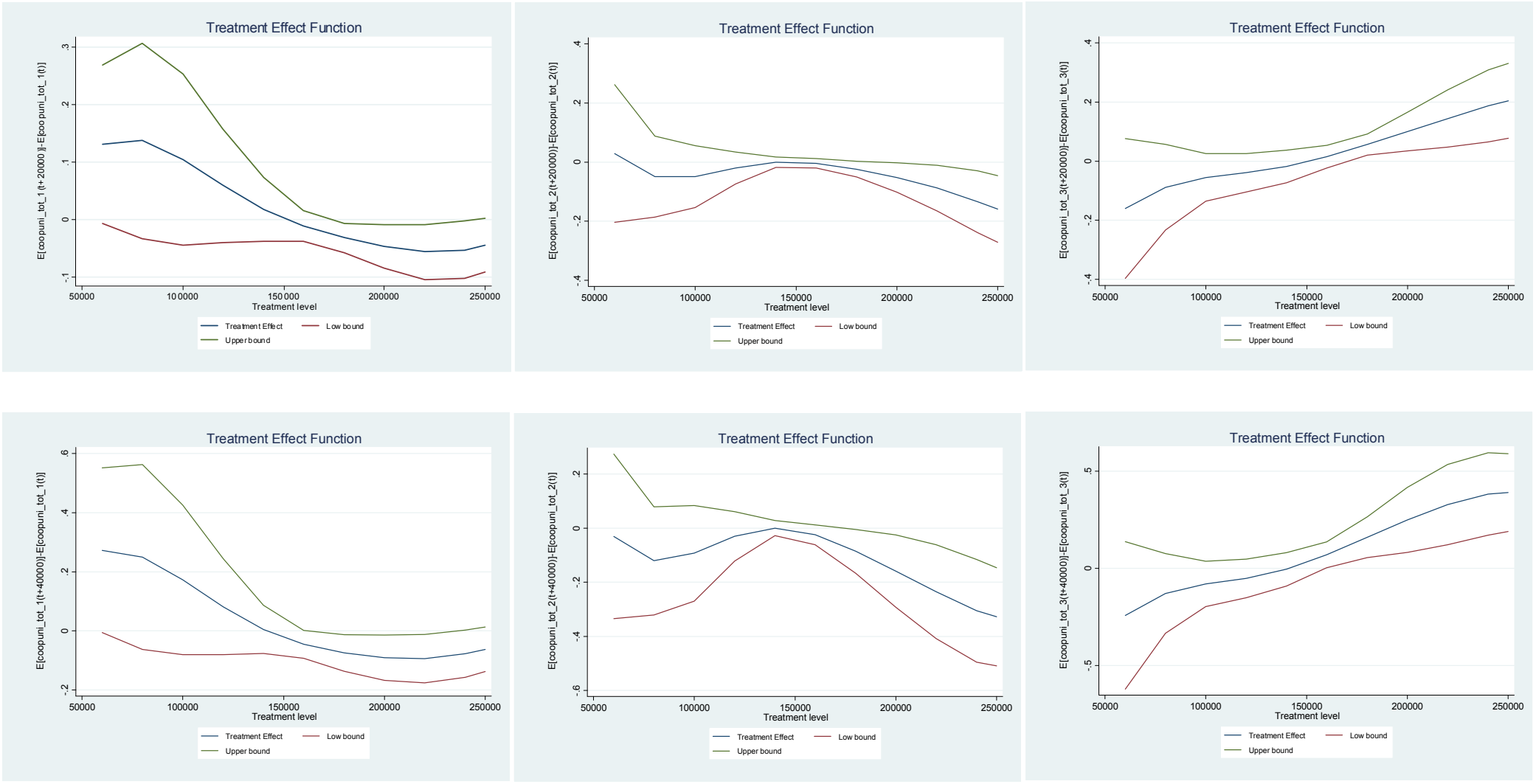


Fig.A2 Effects of an additional amount of subsidy on the cooperation with universities (Left: No cooperation Y=0, Centre: Cooperation with regional partner Y=1, Right: Cooperation with extra-regional partner Y=2. Top: Δt= 20,000; Bottom: Δt= 40,000. Confidence bounds at 95 % level)



5
Conclusions

This Thesis has provided an investigation of the additionality of the innovation policy: it has analysed the way in which public support "supplements" beneficiaries' innovation activities, performances and behaviours. This research has been motivated by the increasing relevance of the innovation policy as a mean to enhance the growth and the competitiveness of economic systems. In Europe, for instance, the definition of the Lisbon agenda (European Council, 2000) and the recent Europe 2020 strategy (European Commission, 2010) have put public support to innovation activities at the core of the economic policy-making, from the regional to the EU level. However, the ongoing economic crisis calls for a particularly efficient and effective use of the scarce public resources available. This implies the need for a proper evaluation of the public interventions not only for an assessment purpose. Evaluation is also fundamental for a better implementation of future support schemes, due to its contribution to the policy-learning process (e.g. Arnold, 2004). With this respect, the present Thesis has been inspired by the idea that the necessity and the possibility to contribute, in a scientific and rigorous way, to a better understanding of the policy effects is far from being exhausted.

The evaluation of innovation policy is nowadays a large and diverse research field characterised by different purposes, methods employed, impacts and stage of the funded projects considered (e.g. Capron and van Pottelsberghe de la Potterie, 1997; Piric and Reeve, 1997; Edler et al., 2010). In this framework, as said, this Thesis has been focused on a specific specific type of ex-post (techno-)economic impact assessment: the analysis of the additionality of the public support to innovation activities. The main advantage of this type of evaluation is that of providing an analysis of the net effect of the policy intervention, comparing the actual situation after the implementation of the policy with an hypothetical counterfactual which captures what would have happened in absence

of public support (or in case of a lower support). More precisely, the Thesis has considered the additionality as a multi-dimensional concept and has devoted particular attention to the behavioural dimension (e.g. Buisseret et al. 1995), which is focused on the way in which the public support re-shapes the characteristics of the beneficiaries' innovation process, their behaviour and strategy.

The Thesis, in each of the three essays, has contributed to the existing literature on the additionality of innovation policy addressing specific theoretical, methodological, empirical issues and research questions. From a theoretical point of view, the Thesis has stressed the consistency of the behavioural additionality evaluation with the evolutionary and system perspectives, and its usefulness, especially when integrated with other evaluation tools, in providing an assessment of the policy capacity to deal with the system failures. From a methodological point of view, the Thesis has extended the analysis beyond the simple effect due to the participation in the policy. It has investigated in particular the effect due to an additional amount of subsidy and the relation between the average additionality level and the dispersion of the policy effect across the beneficiaries. The Thesis, through its empirical applications, has obtained a number of interesting results. On the one hand, it has provided a systematic analysis of the additionality of the public support schemes implemented in the two EU countries characterised by a relevant regional level of policy-making (i.e. Italy and Spain). In this sense, the Thesis has also offered a complement to the intense reporting activities carried out at the EU level to monitor and assess innovation policy interventions (e.g. INNO-Policy TrendChart, INNO-Appraisal). On the other hand, the Thesis has analysed the way in which a regional R&D subsidy (i.e. the one implemented in the Emilia-Romagna region of Italy) affects firms' innovation behaviour and, in particular, the cooperation attitude with distant sources of knowledge.

The first paper (Chapter 2) has provided an updated review of the theoretical and empirical contributions dealing with the additionality of the innovation policy, devoting particular attention to its behavioural dimension. This latter, which is focused on the behavioural and strategic changes induced by the policy intervention, can complement the more standard input and output additionality evaluations. In particular, the evaluation of the behavioural additionality allows for the analysis of the effects that occur within the "black-box" of the beneficiaries' innovation process, considering the impacts on beneficiaries' competencies, capabilities and interactions with external sources of knowledge. To reduce the potential vagueness of the behavioural additionality notion, the

paper has stressed the importance of a theoretically-guided use of the concept. In particular, the evaluation of the behavioural additionality should be aimed at capturing the capacity of the policy to mitigate the system failures that occur (also) at the level of the beneficiaries: problems in learning processes, missing or inappropriate connections, lock-ins due to unbalanced evolutionary trade-offs (e.g. Smith, 2000; Metcalfe, 2005; Malerba, 2009). The paper has also presented some key aspects that should be taken into account when evaluating the behavioural additionality of a policy intervention: the problems in isolating the effects of the single funded projects and the consequent need to focus on the overall innovation strategy of the beneficiaries; the possible presence of spillovers and indirect effects on the non funded organisations; the heterogeneous nature of the additionality effects. Particular attention has been devoted to the likely presences of synergies, implying mutual causations, between the behavioural, the input and the output additionality dimensions. As for the review of the empirical contributions, this has led to support the need to evaluate the behavioural changes induced by the policy intervention. Indeed, almost all the reviewed works report the presence of relevant policy effects that cannot be captured with the simple input and output additionality assessments. In particular, previous contributions point to the presence of significant behavioural effects that pertains to the increased cooperation with external actors (i.e. firms and research organisations) and to the upgrading of internal innovation capabilities. The paper has also considered some criticalities in the quantitative analysis of the behavioural additionality. On the one hand, the usual methodological issues in the (ex-post) impact assessment (e.g. selection bias). On the other hand, the blurriness that characterise the conceptualisation of the behavioural additionality is found to be reflected also in the definition of the outcome variables. In the reviewed empirical contributions, different proxies for different behavioural changes are used, even if the majority of the studies are focused on the cooperation with both firms and research organisations. To improve the comprehensiveness of the analysis, preserving its parsimony, in the conclusion of the first paper an idea has been advanced. That of collecting information on the various indicators of behavioural change and then applying multivariate statistical techniques, such as factor analysis, to reduce the number of potential outcome variables. Another conclusion reached by the paper concerns the usefulness of the social network analysis as a methodological approach that, taking the system rather than the single beneficiary as the unit of analysis, can complement the more "traditional" econometric techniques for impact assessment. The last concluding remark arising from the first paper concerns a

methodological device that can be employed in investigating the likely synergies that might be in place between the behavioural and the other two dimensions of the additionality. The use of a system of simultaneous equations is probably a promising tool of analysis that might help to shed some light on this issue.

The framework provided in the first paper has guided the two empirical investigations included in the Thesis. More precisely, the first one, considering the three additionality dimensions identified in the review, has provided a comprehensive analysis of the policy effects on the firms' innovation activities, performances and behaviours. The second empirical application has been particularly focused on the behavioural additionality and, drawing on the first paper of the Thesis, it has investigated those changes in the beneficiaries' behaviour that might help to reduce potential system failures.

The empirical investigation provided in the second paper (Chapter 3) has analysed the extent to which policy effects can differ in contexts in which innovation policy is administrated with relatively similar governance systems. To this purpose, the paper has focused on the impacts of the public support to firms' innovation activities implemented in two EU countries, namely Italy and Spain. To provide a multi-dimensional investigation of the additionality, the paper has considered the input, output and behavioural additionality effects. The additionality evaluation has been carried out with a multi-level perspective to analyse the impact of the regional and national policies and the consistency in the effects generated by the two levels of public support. The analysis of the addtionality effects has been carried out on the basis of propensity score matching estimations implemented over CIS 4 microdata. Considering in general terms the two multi-level systems of policy, in Italy national and regional interventions are found to be largely dissonant, with the latter having many not significant and in some cases negative impacts. In Spain, on the contrary, central and sub-national policies are found to be more consistent, inducing a similar broad range of output and behavioural additionality effects. Coming to the specific additionality effects, in both the countries, regional interventions are found to be unable to affect the private investment in R&D. This evidence, considering the characteristics of the policies implemented (Cefis and Evangelista, 2007; Garcia-Quevedo and Afcha-Chávez, 2009; Barbieri et al., 2010; Afcha-Chávez, 2011), has led to argue that input additionality cannot emerge when the interventions are characterised by a low average amount of public contribution and a support to less formalised innovation activities. The multi-dimensional analysis of the

additionality has led to specific conclusions on the output and behavioural additionality effects too. As for the former, Italian national and regional policies, increasing only the propensity to introduce process innovations, are found to be unable to sustain a quality leap in firms' innovation performances. This is not the case of the Spanish public support schemes, which are found to increase firms' capacity to introduce marketable, radical and patentable product innovations. Concerning the behavioural additionality, Italian national policies are found to stimulate funded firms to interact more with other companies and research organisations. In addition to this, Spanish regional and national interventions are found to affect firms' learning process, by increasing the engagement in formal training programmes. The possibility to investigate the three dimensions of the additionality is a first step towards a clearer understanding of how the policy support affects the entire innovation process of the beneficiaries. As emerged in the first paper included in the Thesis, more effort should be devoted to analyse the possible relations between the three additionality dimensions. With this respect, an insight has emerged in the second paper. Differently from the Italian regional policies, in Spain the lack of input additionality of the regional interventions is associated to a good performance in the other two additionality dimensions. In particular, Spanish regional policies are found to enhance the introduction of patentable and radical product innovations even in the absence of a positive effect on the R&D investment. With this respect, it has been argued that the policy capacity to target (successfully) important behavioural changes might compensate for the lack of an additional investment in R&D and lead to higher innovation outputs. All in all, the multi-dimensional analysis of the additionality has allowed for a comprehensive investigation of the innovation policy interventions. This has shown that the public support to innovation activities not only can affect the amount of R&D investment, but also the innovation performances, the accumulation of competencies and the cooperation with external sources of knowledge. Furthermore, this type of multi-dimensional investigation, when comparing policy interventions, can also lead to conclude that public support schemes characterised by similar effects on the R&D investment can have quite dissimilar impacts, when the output and the behavioural additionality are considered too. The second paper has addressed another issue that is largely under-investigated in the literature: the relation between the average impact of the policy and the dispersion of the effect across the beneficiaries. In other terms, the paper has provided a tentative analysis of the extent to which the average level of additionality is generated by the concentration or by the polarisation of the effects on the beneficiaries.

The analysis of the Spearman's rank correlation between the average treatment effects on the treated (i.e. ATTs) and the coefficients of variation of the "*i-th* firm's" effects has pointed to an interesting result. With the exception of the Italian regional policies, the Spearman's rank correlation coefficients are found to be negative and significant. This means that the highest average impacts are characterised by the lowest dispersions. In other terms, high average levels of additionality are generated by the concentration of the effects around the mean impact.

The third paper included in the Thesis (Chapter 4) has been focused on a specific regional intervention: the R&D subsidy of the Regional Programme for the Industrial Research, Innovation and Technology Transfer (PRRIITT) implemented in the NUTS2 Emilia-Romagna region of Italy. The paper has mainly analysed the way in which a regional public support to R&D affects the innovation behaviour of the funded firms. Particular attention has been devoted to the role of the policy in enhancing the cooperation with distant and diverse sources of knowledge. Exploiting an original dataset created upon data coming from an *ad hoc* survey and companies' balance sheets, the paper has tested three main hypotheses. The first one has concerned the expected capacity of the policy to induce a set of behavioural changes that can help to reduce potential system failures due to problems in learning processes, missing or inappropriate connections and unbalanced evolutionary trade-offs (e.g. Smith, 2000; Metcalfe, 2005; Malerba, 2009). The results, emerging from a set of propensity score matching estimations, have pointed to a general support of the hypothesis. More precisely, the R&D subsidy is found to be successful in upgrading firms' competencies. The effect on the intra-RIS interactions between funded firms and research organisations is found to be positive and significant too. The regional R&D subsidy is also found to increase funded firms' cooperation with extra-regional sources of knowledge, which are expected to enhance the renewal and the diversity of the regional knowledge base (e.g. Bathelt et al., 2004; Gertler and Levitte, 2005; Uyarra, 2010). Similarly to the case of the intra-RIS cooperation, the policy mainly increased the propensity of funded firms to cooperate with research organisations. All in all, these findings point to a general success of the investigated policy. This contrasts with the evidence, emerged from the second paper (Chapter 3) included in the Thesis, indicating a general weak impact of the regional policies implemented in Italy. Even if the results arising from the two papers are not directly comparable, given the different data and reference periods considered, the better performance of the Emilia-Romagna policy was somehow expected. This latter represents

indeed a unique case in the Italian context and a notable example in Europe too[77]. The current Emilia-Romagna innovation policy is the result of a successful and long lasting experience of public interventions, which dates back to the 70s and has led to the definition, in 2002, of the Regional Programme for the Industrial Research, Innovation and Technology Transfer (PRRIITT), the investigated R&D subsidy is part of (Bianchi and Giordani, 1993; Marzocchi, 2009). Not only the third paper included in the Thesis has focused on the evaluation of the behavioural additionality effects induced by the participation in the policy. As an additional contribution, the effect of the subsidy on the collaborations with research organisations has been further investigated. In particular, the paper has analysed whether an increase in the amount of public support stimulates the cooperation with distant (extra-regional) and possibly "global-best" universities and research institutes. To this aim, two parallel hypotheses have been tested: these have concerned the impact of an additional amount of subsidy on the geographical range of the cooperation with universities and research institutes. The results, emerging from a generalised propensity score estimation, have shown that, over a minimum efficient scale of public support, an additional amount of subsidy increasingly boosts firms' propensity to cooperate with distant research partners. In sum, the amount of subsidy is found to be fundamentally important to overcome the cost of a distant collaboration and to trigger the transition towards an Open Regional Innovation System (Belussi et al. 2010), characterised by the presence of open modes of innovation (Chesbrough, 2003) and interactions that cross not only the boundaries of the firm but also of the region. Some further analyses are required to increase the generality of these conclusions: the results obtained in the paper might depend on to the characteristics of the context and of the policy considered, such as the fact that SMEs were the main beneficiaries of the intervention.

Of course, the present Thesis does not pretend to have addressed all the unanswered questions and issues. Many research lines are still open.

The first of these is related to the necessity to improve the analysis of the way in which innovation policy affects beneficiaries' innovation process. On this first point the Thesis has tried to advance a step ahead of the previous contributions, considering the additionality of the innovation policy as multi-dimensional in its nature. In particular, the Thesis has demonstrated that the public support to innovation activities not only can

[77] See for instance http://www.rim-europa.eu/index.cfm?q=p.baseline&r=ITD5.

affect the allocation of innovation inputs, but also the innovation performances and the beneficiaries' behaviour. Nevertheless, this is only a first step in the right direction. To have a full understanding of how the policy affects the innovation process of the supported organisations, as stressed in the first paper of the Thesis, some further research should be devoted to analyse the likely synergies between the additionality dimensions. This is a very complex task from a methodological point of view given the likely simultaneity and reverse causality in almost all the possible relation between the three additionality dimensions. The very recent work by Garcia (2011), which has been produced just at the time of the present writing, employs a system of simultaneous equations for this kind of analysis and represents an important methodological starting point.

The second open research line concerns the important contribution to the analysis of the policy effects that can come from the investigation of the capacity of the public support to reduce innovation barriers. This implies a change in the prospective, with respect to the additionality evaluation. Whereas this latter is generally concerned with the spurring effects of the public support, the analysis of the policy impact on the innovation barriers would be focused on the capacity to reduce the factors that hamper innovation. In providing this type of analysis, some points emerging from recent contributions (e.g. D'Este et al., 2012) have to be necessarily considered. At first, the different nature of the deterring and revealed barriers. The former prevent firms from engaging in innovation, the latter obstruct firms' achievements in innovation activities. A further issue, which creates serious problems when moving to the econometric operationalisation, is the possible reverse causality between firms' barriers assessment and engagement in innovation. This has a serious implication when it comes to the estimation of the policy effect: firms that are heavily engaged in innovation activities might be more willing (and able) to participate in the policy and have, at the same time, a higher perception of the barriers that hamper their innovation activities. If not properly controlled for, this would obviously create a bias when estimating the impact of the policy. Unfortunately, as some preliminary investigations have shown, the commonly used Community Innovation Survey data seem to exacerbate this problem. The questions concerning the barriers are indeed intimately related to firms' perception rather than to the actual effect of the barriers on the innovation performance. This necessarily implies the need to collect data on purpose.

Another main point that deserves a rigorous and deep investigation is the analysis of the characteristics of policy impact which are not captured by the simple average effect of the participation in the policy. With this respect, the present Thesis has provided an important contribution, investigating, with its third paper, the effect due an additional amount of subsidy. Another partially neglected aspect in the literature that requires a further investigation is the analysis of the distribution of the policy effects. This is a crucial issue for its relevant policy implications: two policies characterised by the same average impact, but different distributions of the effects on the single beneficiaries, cannot be considered to have had the same result. A tentative analysis of the relation between the average level of additionality and the dispersions of the policy effect has been provided in the second paper included in the present Thesis. However, further steps should be done in this direction. Some recent developments in the econometric literature, as the recently proposed methods to estimate the quantile treatment effects, would allow for a more rigorous analysis of the distribution of the impacts (e.g. Battistin and Fort, 2008; Angrist and Pischke, 2008). However, these methodologies have necessarily to be operationalised with continuous outcome variables. Unfortunately, in this Thesis, the lack of proper data has impeded the creation of continuous outcome variables for the behavioural additionality in particular, and, to some extent, for the output additionality too.

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