Designing ex-post assessment of corporate RDI policies: conceptualisation, indicators and modelling

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Abstract: This paper discusses different aspects related to the *ex-post* assessment of the effect of R&D and innovation (RDI) policies. To this end, the paper puts forward a comprehensive 'conceptual framework' where agents' behaviours, factors affecting their decisions, and quantitative (econometric) methods for impact evaluation are linked together and analysed. In particular, this work puts forward the following issues:

1 a generalised RDI investment model for explaining the potential occurrence of subsidy success (i.e., *additionality*)
2 a logical framework for the *functioning* of a project-funding RDI policy, rooted in the policy-cycle approach
3 the identification of the main factors driving the actors' behaviour, expressed through interconnected behavioural relations
4 a list of critical aspects regarding the design of public support to RDI, which need to be better addressed in future work to reach more reliable conclusions on the actual impact of an RDI policy.

Keywords: R&D policy; ex-post evaluation; STI indicators; firm performance.

Reference to this paper should be made as follows: Cerulli, G. and Potì, B. (2012) 'Designing ex-post assessment of corporate RDI policies: conceptualisation, indicators and modelling', *World Review of Science, Technology and Sustainable Development*, Vol. 9, Nos. 2/3/4, pp.96–123.

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1 Introduction

Evaluation is progressively becoming an integral part of any R&D and innovation (hereinafter RDI) policy: a study at European level on the main characteristics of various innovation policies (European Commission, 2006) finds out that about 50% of the surveyed measures have a budget specifically dedicated to evaluation, while about two thirds have been planned to incorporate ex-post evaluation within the design of incentive schemes.

The usefulness of ex-post evaluation of RDI support measures concerns in particular information on the achievement of policy objectives and on the (quantitative and qualitative) impacts of the specific instruments applied (EPEC, 2005).

In particular, impact analyses are having an increasing relevance, given the growing demand for robust (and quantifiable) results on the effect of policy interventions. They represent a good example of governance since they provide transparency to the use of public funds both in terms of relevance and effectiveness. Moreover, as the implementation of a policy intervention could sometimes differ from the original goals, evaluation looks also at 'how' policy interventions have been actually realised.

The economic ex-post (or impact) assessment is a central component of many evaluation studies and it should include both 'direct' and 'indirect' impact analyses. Direct impact analyses are focused on the appraisal of achievement of declared policy RDI objectives such as, normally, the R&D performance and innovation upgrading of supported subjects. Indirect impact analyses concern rather external (or *spillover*) effects activated by the pursuing of direct effect. They generally can produce relevant welfare changes also to subjects that are not participating to the program under scrutiny.

Within direct impact a central role is attributed – on the part of policymakers – to the concepts of 'input' and 'output' additionality. Input additionality occurs when the 'net' privately funded R&D (R&D outlay *minus* the amount of subsidy) of a supported firm is greater when compared with the situation in which the same firm does not benefit of any support. Output additionality indicates precisely the output produced by the additional research activity induced by the subsidy and it is therefore connected to the impact of the input. Generally, output additionality concerns policy downstream effects, starting from improvements in firm innovative capacity to productivity and profitability improvement.

Nevertheless, another concept of additionality has become more recently a fundamental part of many RDI ex-post evaluation exercises: the so-called 'behavioural' additionality, aimed at recording a more *qualitative* change in firms' RDI behaviours. In the academic literature on this subject, there are four types of behavioural additionality [Pro Inno Europe, (2010), p.XII]:

1. an extension of input additionality, enriched by various additional qualitative information
2. a change in the non-persistent behaviour related to RDI activities
3. a change in the persistent behaviour related to RDI activities
4. a change in the general conduct of the firm with substantial reference to the building blocks of behaviour.

While input and output additionality are generally measured via econometric-quantitative methods, case studies and qualitative surveys are used for measuring behavioural additionality (see also IPTS, 2002).

Institutionally, results from ex-post evaluation serves two main goals:

1 *learning*, aimed at proposing improvements of various kind for future policies, generally directed to programs' managers and administrators

2 *legitimation*, directed to higher political levels.

Together with policymakers and managers, also participants and other stakeholders (such as, for instance, industrial associations) can be interested to evaluation results.

As such, evaluation is a key policy tool and its usefulness, defined as the capacity of providing actionable recommendations, can be assessed too (EPEC, 2005). In particular, it could be examined whether its worth can be associated with particular types of RDI support measure. Further, a second question regards to what extent a relation between specific policy instruments and evaluation methods can be envisaged. A study at European level [Pro Inno Europe, (2010), p.123] reports that, within a large number of different experiences, a convergence on the usefulness (split into various categories) of the evaluation activity has been found in two specific cases: evaluations of measures for 'science-industry cooperation' and for 'creation of start-ups and spin-offs'. The same study reports that a policy-mix evaluation, based on a portfolio approach, is associated with a judgement of low usefulness.

Establishing a causal relation between observed company changes and a specific RDI policy instrument presents both theoretical and empirical relevant problems that we will discuss at length in the paper. Some pre-conditions are anyway important for an impact assessment of good quality:

1 an appropriate design, given the declared policy goals

2 well documented sources of data/information

3 broad coverage of beneficiaries

4 broad coverage of the spatial context, when geographically-based measures are under scrutiny (such as RDI support actions within Structural Funds in Europe).

As for the ex-post evaluation methods, almost all qualitative and quantitative toolboxes are generally used (including, of course, quasi-experimental design based on counterfactual control-group approaches). When possible, the combination of quantitative and qualitative methods can better cope with the complexity and multifaceted reality of RDI policies, especially when not all the impacts are immediately quantifiable. Some open problems, representing room for improvement, concern the timing of the impact evaluation, since many effects can appear only in the long-term and, when the RDI policy measure is a mission-oriented program (this is the recent trend in RDI policy within European countries), issues such as regional development, user needs and sustainability can be also included. A categorisation of main objectives, type of support measures and approaches used in the ex-post evaluation can be found in Papa (2009) and Potì and Reale (2009).

This paper discusses various aspects related to the ex-post assessment of RDI policies, by focusing on direct financial incentives (grants and supported loans), either in the bottom-up or top-down form, and by paying specific attention to *input additionality*. Fiscal measures, as they are not based on project proposals, are not at the heart of our analysis, although some conclusions can be extended also to them.

The main objective of the paper is that of providing the reader with a detailed discussion of the elements needed to design suitably RDI policy ex-post evaluation. It is done by providing a (comprehensive) conceptual framework where agents' behaviours, factors affecting their decisions and quantitative (micro-econometric) methods for impact evaluation are presented. The paper includes three main aspects, which can be considered 'innovative' with respect to previous literature:

1. a generalisation of the model by David et al. (2000), explaining the ground for potential RDI additionality
2. a logical framework characterising the *functioning* of RDI policy (inspired by the *policy-cycle* approach of political science, looking at the ultimate effect of a policy as the result of several actors' behaviour and interaction)
3. the identification of the main factors driving actors' behaviour, which can be also expressed through behavioural equations, underlying the functioning of the policy tools
4. a list of critical aspects, such as actors heterogeneity, potential policy spillovers, etc., which have to be taken into account for getting more reliable policy evaluation results.

As far as we know, no other papers seem so far to have addressed these aspects in an extensive and interconnected manner.

The paper is organised as follows. Section 2 reviews the main arguments suggested in the literature to justify public intervention for supporting private RDI activities (Section 2.1), and the main mechanisms and factors leading to produce policy success/failure (Section 2.2). This last part presents a generalisation of the David, Hall and Toole (2000) model on the effect of a public subsidy on firm R&D performance. Section 3 presents a logical framework for the assessment of an RDI policy based on project-funding. In its subsections, we propose to identify the determinants of agency and firm behaviours and the main factors determining them[1]. From this analysis, we also derive a workable model as the basis for estimating econometrically the policy effect on beneficiaries[2]. Section 4 provides a broad discussion of some open issues in designing policy effect ex-post assessment. We consider a number of questions to which the literature does not seem to have answered in a satisfactory way yet. The question of how to treat heterogeneity and unobservable factors, the issue of subsidy measurement and spillovers treatment, the widespread 'curse' of data availability and that of long-run effects assessment are all extensively reported and commented. Section 5, finally, concludes the paper.

2 Rationale for corporate RDI support and causes of policy failure/success

2.1 *The rationale*

According to a long-standing literature on the subject, the rationale for providing public RDI incentives to private business entities resides in some special features characterising RDI activity:

1. RDI activity is generally characterised by *low appropriability* of results. It is especially true when research is far from downstream market activity. This occurs since the benefits associated to RDI are easily and freely accessible to subjects that are not directly engaged in R&D efforts. As this generates some sort of positive externalities due to knowledge spillovers, it can be proved that private returns of companies undertaking such an investment are generally lower than social returns and government intervention is intended to narrow this distance (Nelson, 1959; Arrow, 1962).
2. RDI activity is plagued by highly uncertain returns and this strengthens the *information asymmetries* between RDI fund borrowers and financers (Stiglitz and Weiss, 1981). These asymmetries generate capital market imperfections, whose general effect is that of leading to some fund rationing and thus financial-constraint for firms willing to invest in such activities. But also projects' *complexity* and *asset specificity* related to RDI investment projects may make it particularly difficult for outsiders to judge the expected return. RDI projects which face long and uncertain pay-offs are subject to high lemon's premia because of the inability of external investors to know their quality. Additionally, firms may be reluctant to reveal details of the projects to potential investors (Bhattacharya and Ritter, 1983). External finance opportunities for inventive activities are also restricted by moral hazard arising from risk assessment problem, as suggested by Arrow (1962).
3. R&D also *lacks tangible assets* that can be used as collaterals for lenders. Bester (1985), for instance, observed that a high percentage of R&D expenditure is essentially devoted to salaries for researchers: knowledge is tacit and embedded in researchers who can also leave the firms. Asset intangibility created by RDI investment may well make the rising of external funds heavily more costly for R&D than for other types of investments (Berger and Udell, 1995; Harhoff, 1998; Myers and Majluf, 1984).
4. Finally, RDI is an *irreversible* activity and this produces relevant sunk costs that firms have to take into proper account when deciding the extent of their R&D commitment. Under irreversibility both market entry and exit is no longer costless. It renders the market far from perfect competition, generating some sort of market power, and external regulation is justified on this basis.

Besides previous reasons, RDI support can be invoked also in case of *systemic failures*, such as in presence of:

1. lack of technological infrastructures and bridging institutions
2. coordination failure of profitable R&D joint ventures, producing duplications in R&D efforts and other wastes of resources.

Martin and Scott (2000) suggest that, when systemic failures are at work, policy intervention to promote R&D activity should be targeted and sector-specific rather than widespread and generic; they make use of Pavitt (1984) taxonomy to identify: main sectoral modes of innovation, sources of sectoral innovation failure, and suitable policy instruments. Systemic failure might depend on scarce material and immaterial knowledge infrastructures and on various 'traps' in the functioning of the national system of innovation (Mowery, 1995; Metcalfe, 1995; Malerba, 1993).

2.2 Factors promoting/hampering additionality performance

2.2.1 A graphical representation of subsidy effect

Input additionality is usually defined as a net privately funded R&D investment that firms should have not done in absence of public funds. Its amount can go from simply the amount of the subsidy upwards. Crowding-out occurs in the opposite case. For a firm doing additionality or crowding-out depends on a number of aspects that deserve a specific discussion. Nevertheless, before going into this, it seems useful to present a conceptual framework for understanding the mechanisms through which public incentives affect R&D. This scheme is due to David et al. (2000) (hereafter DHT) although its theoretical underpinning has been provided by the so-called 'pecking order' theory of corporate financing (Myers and Majluf, 1984; Fazzari et al., 1988). According to this approach, that in its early applications referred to fixed investment decisions, in choosing their desired level of investment firms use an ordered sequence of sources of financing, from the cheapest to the most costly: firstly cash-flow, secondly bank credit and thirdly new equity. This suggests the form of the marginal capital cost of investment that starts flat (according to firm cash-flow availability), it raises when bank credit is used and then it increases even more when firms issue new equity. Of course, firms face also a marginal rate of return associated to investment. According to the standard neoclassical profit maximisation condition, the level of investment chosen by firms is found where the curve of marginal capital costs (MCC) and that of marginal rate of returns (MRR, that is a decreasing function of the investment[3]) meet each other. Depending on the point in which costs and returns are equal, firms finance their capital accumulation only by cash-flow or with a mix of sources.

As suggested by Hall (2002), the main difference between fixed and R&D capital investment is that, in the R&D case, cash-flow plays a major role (Hall and Lerner, 2009). Firms doing R&D normally finance their activity mainly by past (non-distributed) profits, while they find difficult to raise resources externally for the specific features of R&D (discussed in the previous subsection). Hence, in the R&D case, liquidity constraints play a fundamental role, so that the MCC curve starts flat by then becoming strictly vertical at a certain threshold: this 'bottleneck' is exactly what a subsidisation scheme aims at relaxing. In the DHT model a subsidy is interpreted as an 'exogenous injection of cash-flow', so that it has the effect of shifting the MCC schedule to the right. But it can also have the additional effect of relaxing the inelasticity due to the vertical part of the MCC curve (the bottleneck), thus providing ground for potential additionality. To better clarify the potential effects of a subsidy, Figure 1 reports three possible outcomes on firm R&D:

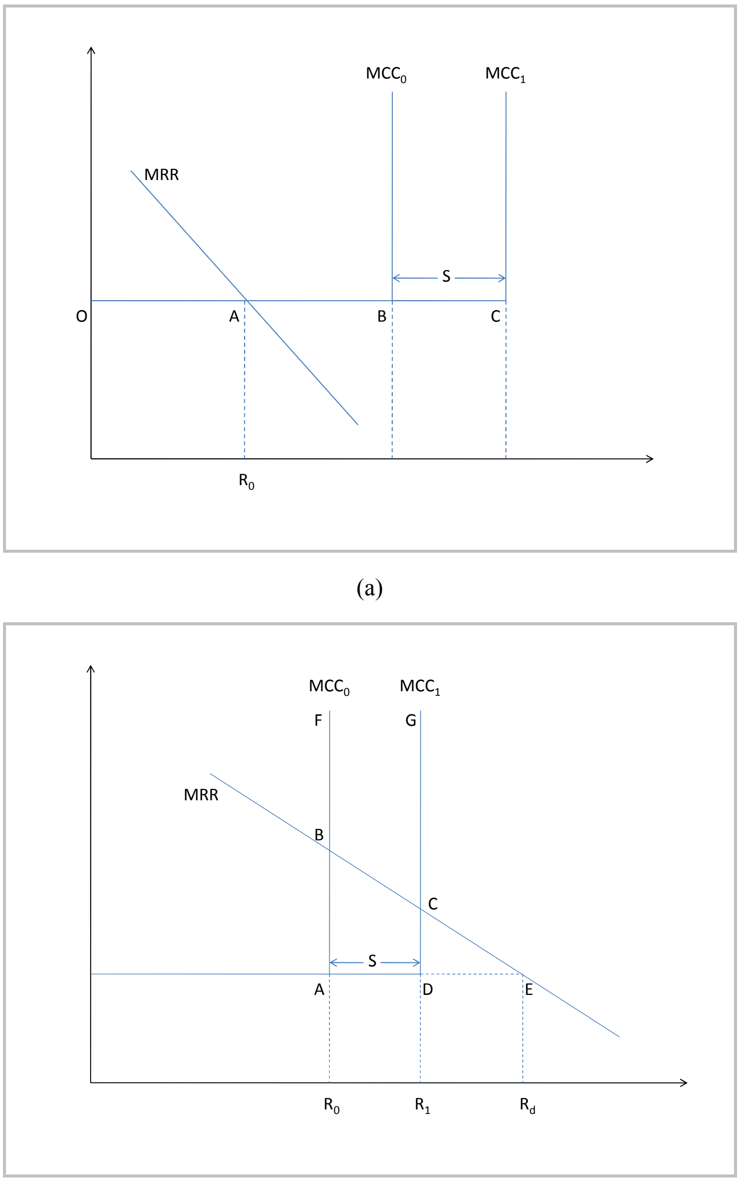
a crowding-out

b neutral effect

c additionality.

Let us comment on this.

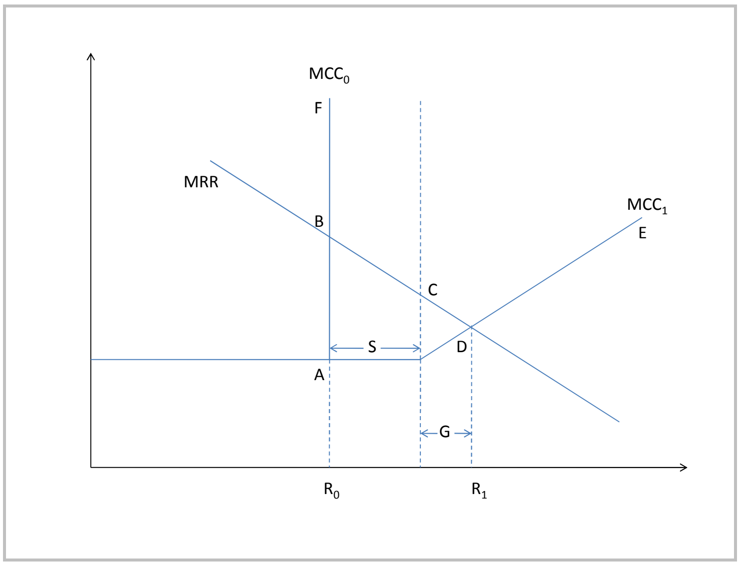
Figure 1 Graphical representation of the effect of a subsidy on firm R&D performance (see online version for colours)



(a)

(b)

Figure 1 Graphical representation of the effect of a subsidy on firm R&D performance (continued) (see online version for colours)



(c)

a *Crowding-out*. It happens when the MRR curve meets the MCC curve between point O and point B [point A in Figure 1(a)]. In this case the optimal (or desired) level of R&D is R_0. After receiving a subsidy S, the MCC curve moves to the right, but the level of R&D does not change (it remains in R_0), thus producing a crowding-out effect as the difference between the 'net R&D' (R&D outlay *minus* the amount of subsidy) expenditure with and without subsidy is negative and equal exactly to -S.

b *Neutral effect*. This occurs when the MRR curve meets the MCC curve in its vertical part, between point A and point F [point B in Figure 1(b)]. In this case, after receiving the subsidy, the firm finds it optimal to move from R_0 to R_1. Nevertheless, since the subsidy does not change the form of the MCC curve, but it just produces its shift to the right, the difference between the net R&D with and without the subsidy is the same, thus producing no crowding-out nor additionality (that is, a neutral outcome).

c *Additionality*. When receiving a subsidy produces, besides the MCC movement to the right, *also* an oblique shift of the MCC vertical part [as visible in Figure 1(c)], then an additionality effect can arise. Figure 1(c) shows, in fact, that after getting the subsidy S, the new level of firm R&D becomes R_1 (point D, where MRR meets MCC_1). In this case the difference between the net R&D with and without the subsidy is positive and exactly equal to G.

2.2.2 Factors affecting crowding-out/additionality

Although rich in details, the previous graphical representation runs the risk to be a sort of black box without identifying more in depth what factors are likely to lead to one of the three possible outcomes examined above. According to the literature, we distinguish among 'seven' pivotal factors, within which firm 'liquidity constraint' plays a key role. In what follows we discuss at length on these.

2.2.2.1 Liquidity constraint

A firm is said to be liquidity constrained when the level of cash-flow dedicated to R&D activity is unable to finance the whole desired level of its R&D activity and external sources of financing are not accessible. Figure 1(a) shows the case of a firm that is not liquidity constrained. Its desired level of R&D is exactly equal to that realised (i.e., R_0). This firm owns a sufficient amount of cash-flow to realise its desired level of R&D and some extra cash-flow is also left. In this case getting a subsidy, that takes the form of an exogenous injection of cash-flow, does not produce any effect because the firm was already satisfied with what it did. But when the cash-flow availability does not allows for performing the desired level of R&D, then the firm is liquidity constrained and the subsidy can help it to increase its R&D effort. Figure 1(b) shows the case of a liquidity constrained firm. In this case the desired amount of R&D would be R_d, a level that the firm cannot reach with its available cash-flow. Indeed, by using its cash-flow this firm can perform just a maximum amount of R_0. This always happens when the MRR meets the MCC curve in its vertical part. In this case an exogenous injection of cash-flow (i.e., a subsidy) produces a positive increase of R&D that in the Figure 1(b) reaches the level R_1.

This proves that a liquidity-constrained firm is likely to benefit more from an RDI subsidy than firms that have sufficient cash-flow availability. Generally SMEs are considered more financially constrained than larger companies. Nevertheless, the extent of this 'constraint' depends on the dimension of R&D projects in relation to firm size. For example, a small firm that presents a very small RDI project is less likely to be constrained that a large firm presenting a very big project.

2.2.2.2 The presence of a liquidity constraint is a necessary but not sufficient condition to produce additionality

As suggested by Figure 1(c), another condition is needed for this purpose, that is, a modification of the MCC curve producing an oblique shift of its vertical part (after receiving the subsidy, of course). But which factors generate this last shift? In what follows we discuss it at length; of course, a combination of these factors can be present.

2.2.2.3 Modification in the propensity to bear risk

Firms have a desired level of R&D activity that depends on objective external conditions and structural aspects (liquidity constraint, appropriability, demand, state of technology, etc.), but also on the subjective (firm specific) propensity to bear risks and strategy orientation. Other things equal, the higher the propensity to bear risks the higher the level of R&D investment performed. Beyond some extent of cash flow availability, this propensity could be no longer constant, but increasing. In this sense, if the subsidy allows for overcoming a certain threshold, it could be the case that the propensity to bear risk increases, thus augmenting firm's R&D commitment. This could be done by subtracting additional resources from other firm activities or by a greater exposure to indebtedness.

In any case, the subsidy has the effect to 'change' the subjective perception of risk, thereby modifying firm R&D behaviour.

2.2.2.4 Project economies of scale

When the project size is remarkable (related to firm size and available assets) and, above all, the realisation of the project cannot be partitioned into single subprojects, a subsidy can generate additional R&D expenditures than otherwise. It occurs when the subsidy allows for overcoming a certain threshold of the (indivisible) projects costs. In this case firms can be able to realise the entire project, a possibility that was denied because of the scale of the project. We can say that the subsidy, by allowing for overcoming relevant project fixed costs, generates some sort of 'scale economies'. An example can better explain the functioning of this mechanism: suppose that a firm would like to spend 70,000 Euros for a project that can be realised only by spending a total amount of 100,000 Euros. Currently, without any subsidy, this firm performs zero R&D although is availability is of 70,000 Euros. Suppose that government provides this firm with a subsidy of 30,000 Euros. In this case the project of 100,000 Euros will be realised and the R&D additionality will be of exactly 70,000 Euros.

2.2.2.5 Project economies of scope

Receiving a subsidy for realising a specific R&D project could generate further R&D spending due to the capacity of extending the benefit associated to this financed project to other non-supported firm RDI projects. It occurs when a firm has a portfolio of (more or less) linked and interrelated R&D projects. In this case other projects can take advantages of costs related to the financed one. An example can illustrate fairly well this possibility. Suppose that the financing of a given project allows for the acquisition of, let's say, ten computers and that they will be used to perform calculations for the ongoing supported project. Yet, these computers can also be employed for calculations related to other (non-supported) projects that - without their availability - would have not been put at work at all. In conclusion, if this mechanism actually works, firms will have an incentive to further enlarge their R&D spending, thus providing further input additionality. But besides the case of material facilities, scope economies can occur also thanks to immaterial (knowledge) spillovers. Indeed, knowledge accumulated for implementing a given financed project, could be re-used in an additional (non-supported) project. In this case, the subsidy might produce a cost-saving effect on a non-supported project that could become profitable for a firm to implement.

2.2.2.6 Positive external effect on other sources of financing

One possible beneficial effect of a public support could be that of facilitating firm access to other sources of financing (and in particular, bank credit). It could occur as soon as public financing works as a signal of firm/project quality, thus reducing the costs associated to asymmetric information on the part of private lenders. In other words, public support may represent a guarantee for outside financers who can become more willing to provide resources, thus reducing the wedge between the parties involved in contracting loans. In another perspective, banks might become more generous because the cost associated to the project/firm quality screening is borne by the public agency, thereby saving resources for this purpose.

2.2.2.7 Opportunistic behaviour

Generally, firms apply for public support since public funding is less costly than 'external' sources of financing. Compared to banks or venture capitalists, nevertheless, a public agency does not normally own comparable instruments to check and monitor effectively firm R&D behaviour during the project realisation. Put in other words, firms can better exploit asymmetric information when capital lenders are public rather than private agencies. This event can encourage opportunistic behaviours. Firms could perform a project that would have been in any case realised just to have at its disposal cheaper cash to invest in other non-R&D activities, thus generating a crowding-out (final) effect [Wallsten, (2000), p.85; Antonelli, (1989), p.76].

2.2.2.8 Policy institutional failures

When the implementation of the policy fails to be coherent with its declared purposes and expected managerial procedures, subsidies can become ineffective. For instance, long delays in taking decisions on firm/project selection, unexpected shortage of funds dedicated to the program, delays in providing funds by changing the time schedule of instalments, are all elements that could discourage firms to invest in additional R&D, as they might remarkably increase the perceived risk associated to invest additional resources. It makes entrepreneurs more inelastic to increase R&D efforts, thus reducing considerably firms' additionality potential. Many interviews with entrepreneurs have put into evidence this occurrence.

3 Conceptualisation: logical framework, behavioural modelling and indicators

A correct ex-post evaluation analysis of an RDI policy needs primarily to draw upon a rich and qualified set of information. This information generally takes the form of:

1 suitable *indicators*, both qualitative and quantitative

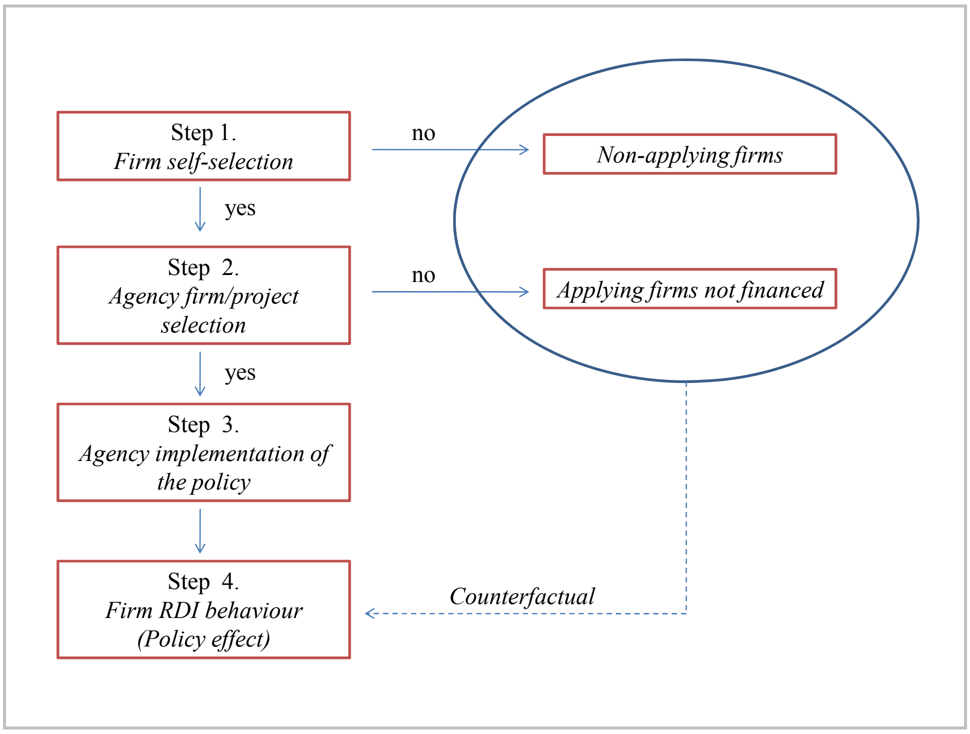
2 availability of a correct *sample of firms*.

While indicators are primarily aimed at measuring specific aspects of the decisional processes characterising subjects involved in the policy, a good sample of firms are the basis for implementing a correct statistical design needed for assessing (ex-post) the effectiveness of the policy in question (the so-called 'counterfactual setting').

The use of suitable indicators and of a correct sample of firms is the product of a 'logical framework' that characterises the *functioning* of the policy (Jaffe, 2002). In a very simplified way Figure 2 tries to set out such a framework within a graphical representation showing the actors involved, their role and relations. This logical framework, although general, is the essential basis for steering both the choice of indicators and the statistical design for ex-post evaluation.

In this scheme we can observe the participation/decision process of two distinct actors: public agency and firms. Their strategies and interactions, along with those of other subjects we can roughly identify with the 'environment' (whose role, at this stage, is left out for simplicity[4]), represent the basis for identifying the determinants of the policy implementation and effect. Let us briefly describe this framework.

Figure 2 *Logical framework* for the ex-post assessment of an RDI policy (see online version for colours)



Step 1 – firms have firstly to decide whether to apply for receiving some RDI support or not. It is a starting step known as 'firm self-selection' into program. This choice is guided by 'eligibility criteria' which, if fixed by policy makers, pre-select firms and a firm specific objective function comparing benefits and costs of applying. Firms deciding to not apply are then collected within the group of 'non-supported' firms, and they will be used to build the 'counterfactual' set used for the ex-post impact evaluation analysis.

Firms choosing to apply for an RDI incentive go to Step 2 where the public agency 'selects' the beneficiaries of the incentive program on the basis of a specific 'social welfare function' whose arguments will be considered below. Also in this case, the choice is guided by a cost-benefit comparison. Those subjects that are not selected to benefit from the program, become part of the counterfactual set too.

Step 3 concerns the factual *implementation* of the policy in question operated, again, by the public agency. Indeed, after receiving applications and choosing beneficiaries, the public agency has to decide – project by project – the magnitude of financing (taking into account the current public resources availability), the number of instalments, and it has to monitor the state-of-the-art of financed projects at specific dates.

Finally, Step 4 concerns the RDI behaviour of selected firms. Given the level of financing, firms have now to decide how much R&D spending to perform, a choice fundamentally guided by a profit-maximising strategy, balancing marginal costs and marginal returns to R&D. Step 4 is the downstream part of the logical framework, where the impact of the policy is measured by means of one of the various counterfactual (econometric) methods exploiting the counterfactual set built along the policy implementation.

The identification of the arguments of the agency's and firms' objective function and behaviour in the form of specific indicators and the use of a suitable econometric approach to deal with the *non-random* assignment of beneficiaries of RDI incentive programs are at the heart of an ex-post evaluation. Thus, it seems useful to make explicit, step by step and subject by subject, the main 'factors' guiding agents' behaviours in order to translate them into suitable indicators to be included in appropriate econometric models for RDI policy ex-post assessment. The next subsections will be then devoted to this purpose.

3.1 Firm self-selection

Firms participate to the policy selection process through their 'self-selection' into program. The choice to apply for receiving an RDI support compared to not apply is at the basis of this step. Generally, the analysis of this step has been little studied, as it is normally incorporated into the public agency selection process (Busom, 2000). Nevertheless, the analysis of this step appears of worth especially for a more detailed understanding of factors leading firms to demand for subsidies (Takalo et al., 2005). As suggested above, in fact, this step requires for a firm a cost-benefit approach of applying compared to non-applying.

Applying for an RDI policy program can be costly to some extent. Among costs, the main ones are those linked to:

1 opportunity costs, due to subtracting time and resources to other activities when firms are engaged in collecting information on the program

2 (private) information disclosure of firm ongoing innovative projects, that can penalise would-be applicant compared to non-applicant companies

3 effort and administrative costs needed for making an application

4 expected delays in the public decision that could be detrimental for firms especially when engaged in innovative projects subject to competitive pressure and fast obsolescence.

If some (observable) indicators meant as capable to measure these factors are available, we can collect them into a vector X_1. Nevertheless, additional unobservable-to-analyst factors (indicators) can affect firm choice at this stage. By indicating unobservables with u_F, we can define the *self-selection rule* adopted by the firm to decide if applying or not as function of all these components, that is, $I_F = I_F[X_1, u_F]$ where I_F assumes value 1 or 0 for applying and non-applying respectively. This function depends crucially on expected firm profitability. It is assumed to be an optimal (or satisfactory) response of firm to the current state of X_1 and u_F: given the value assumed by these variables, the firm decides to participate or not according to the specific features of the considered supporting program.

3.2 Agency selection and policy implementation

The public agency is generally characterised by the pursuit of two kinds of objectives: *direct* (on target-variables) and *indirect* (welfare effects). Within the direct objective we can distinguish between:

1 R&D intermediate (first-level) objective

2 innovativeness intermediate (second level) objective

3 downstream (or final) objective on firm business competitiveness.

Indirect or welfare objectives, on the contrary, refer to all those externality effects generated by the pursuing of direct effect, such as: knowledge and rent spillovers, increasing employment, development of depressed areas, human capital upgrading, environmental sustainability, technological advancement, etc.

Given this picture, the agency has to deal with two main actions:

1 selecting firms/projects to finance

2 implementing the design of the policy.

3.2.1 Agency selection

In doing selection process on the basis of the above mentioned objectives, the public agency aims at:

1 allocating RDI funds among firms/projects more able to maximise the additionality effect, i.e. the enlargement of R&D spending and innovative capacity

2 taking into account potential welfare effect associated to the operation of point (1).

To that end, three main factors are remarkable in directing agency selection (*selection criteria*):

1 firm economic and financial soundness

2 firm and project quality in terms of RDI

3 project consistency with welfare objectives.

- *Firm economic and financial soundness*: a firm proposing a project is thought of as more able to accomplish its RDI purposes, and exploit their commercial benefits, as soon as some business soundness is present. Economic and financial soundness is generally assumed as a guarantee against project failures. More importantly, as stated above, firm financial structure is generally assumed to predict additionality potential as financially constrained firms are generally more likely to produce additionality. Yet, other factors than financial structure can be assumed to be good predictors of additionality potential, such as: scale and scope economies, capital (or labour) deepening (cost structure), human capital availability, business experience, access to commercial networks, exposure to competitiveness, sectoral and regional location.

- *Firm and project quality in terms of RDI*: for the same economic and financial soundness, firms presenting a higher project quality and/or a sounder experience in terms of RDI activity are more likely to succeed. The quality of the project can depend on several facets. Anyway the agency generally relies on the judgement of a board of experts who are entitled to express an opinion on the technical correctness and feasibility of projects. Further, also the potential commercial exploitation can be part of the board's assessment, as well as project intrinsic innovativeness. Besides project quality, also the RDI experience could be a relevant criterion. It can be assessed, for instance, by looking at recent figures on firm R&D investments, innovating activity (such as patenting) and past experience in terms of previous RDI financing.
- *Consistency with welfare objectives*: given the same business soundness as well as project/firm RDI quality, the agency might prefer to finance projects promising to generate better and wider external benefits. This could have been already assessed by the board of experts (with some scores given to this facet), or the agency can try to assess it by looking at aspects, such as: declared project employment potential or quality for sustainable development. The analyst having access to projects' databases could draw this information quite directly, although it is not always possible to get it, nor easy to extract.

By collecting into the vector X_2 all the observable indicators feeding into the agency welfare function, as well as unobservables (here indicated by u_A), we can write down the *agency selection rule* as $I_A = I_A(X_2, u_A)$ where I_A assumes value 1 and 0 for supported and non-supported firms respectively. This function depends on agency profitability so that, given the value assumed by variables in X_2 and u_A, the agency decides whether or not to finance a given project/firm.

3.2.2 Agency implementation of the policy

Besides the selection process, the public agency has to implement the policy. This step is included only as a descriptive component of the logical framework. A first element characterising the implementation phase concerns the administrative costs, while a second element is the *timing* of the policy operation. By and large, three are the moments characterising policy execution: promulgation and notification of specific incentive measures, project/firm selection (on a competitive basis), provision of funds (by a specific time schedule of instalments). Indeed, the time passing from notification to selection and from selection to the provision of funds is a very critical aspect affecting severely the effectiveness of the policy, and some indicators of this essential factor should be taken into specific account in designing ex-post evaluation.

A third aspect deserving attention for its capacity to influence policy tasks, regards the availability of funds during the timing schedule of instalments. Shortage of funds, ongoing reductions or just delays in provision are generally heavily responsible for policy failure, as they can induce considerable (accidental) penalties to firms.

A fourth aspect deals with the *monitoring* process. It can be realised during the policy implementation or just at its end. In any case, monitoring requires some cost and its quality can have important effect on policy success/failure. Although monitoring costs can be assimilated to other administrative costs, we prefer to separate them as they play a specific role. We can collect variables relating to the implementation phase in a vector, X_3 which can be added to the previous agency function.

3.3 Firm RDI behaviour

There is a huge literature on the determinants of firm RDI behaviour[5]. Part of these factors are similar to those set out for explaining agency selection, but others determinants are specific to firm RDI strategy. We have decided to distinguish among:

1 financial

2 economic

3 knowledge-related

4 experience

5 market factors.

Each of these can be then divided into sub-factors and indicators (see Potì and Cerulli, 2011). Let us give a brief explanation of why these factors are important for firm RDI strategies.

3.3.1 Financial

There is a well established literature on the importance of firm financial structure on R&D investment. Both internal and external availability of funds is a key condition to predict higher R&D investment by profit-seeking enterprises. As financed mainly by internal revenues, R&D (and innovation) is strongly affected by shortages of free cash-flows. As stated in Section 2 firms whose desired level of R&D is higher than cash-flow availability are said to be 'financially constrained' and are forced to rise external funds from bank credit and the stock market (via new equity issues), as well as from venture capitalists. This latter source of funding is particularly relevant in the early steps of an innovative firm life-cycle, thus offering financing to seed ideas. Firms suffering from severe financial constrains and incapacity to rise (cheaply) external funds are more prone to demand for a public support. Furthermore, as discussed previously, more financially constrained companies are normally assumed to have a higher additionality potential.

3.3.2 Economic

Scale and scope economies as well as firm cost structure are important drivers of R&D investment and additionality performance. A high scale and scope allows for spreading the same spending on a higher number of products and over a wider set of differentiated lines of business, respectively (as maintained by the Schumpeter Mark II argument). But also firm cost structure, identifying relative efficiency in production and more or less capital, labour and materials intensity, is a relevant predictor of RDI propensity. Finally, also opportunity costs, related to alternative types of investment (different from R&D), such as ICT of fixed capital, can have specific relevance.

3.3.3 Knowledge-related

It is fairly obvious that factors related to knowledge competence are extremely correlated to higher R&D investment. A higher cumulated R&D, a flourishing patenting activity, the presence of skilled human capital and access to internal and external knowledge networks are all elements that should increase the RDI additionality capacity of firms.

3.3.4 Experience

The level of R&D investment may be highly affected by firm life-cycle as well as by cumulated experience coming from participating to previous RDI supporting programs. But also participation to previous non-RDI supporting programs could matter.

3.3.5 Market

The awareness that R&D is inherently a market 'strategic' choice is nowadays a well established and shared belief within economic scholars. The family of 'patent race' models, inspired by the New Industrial Organization School, has clearly shown that both level and nature of R&D investments are driven by motivations strictly related to firm industrial environment. Firms' strategic interplay, market competitiveness and concentration, market power and externalities as well as barriers to entry and exit are among the best known factors affecting R&D commitment on the part of profit-seeking companies. In this sense R&D is linked to firm profitability not only thanks to its direct relation to innovative outcomes (that is, the traditional input-output innovation function), but also via other strategies such as: the need to rise sharper barriers for avoiding new entrants (and protecting incumbents), the strategy of being continuously in the lead of product innovation to saturate any potential space for competitors (sometimes without any commercial exploitation of new inventions, as in the case of 'silent patenting') and so forth. Also the state of demand and macroeconomic conditions are important factors although decidedly more external to firm manipulation. Appropriabilty conditions and exposure to competitiveness are partly linked to the industrial organisation in which companies operate, but they deserve a separate treatment as R&D is strongly sensitive to the type of market (domestic, foreign), the proprietary form of the firm (national or multinational) and the capacity to better exploit new products from a commercial point of view (appropriability). In this last sense also the geographical location of the firm is of some importance.

As done before, except for the subsidy indicator S – that can take a binary or a level form – we can collect part of (or all, depending on the specific design) the indicators into the vector X_4. According to the DHT model, part of X_4 affects the firm *marginal rate of returns* to R&D ($X_{4,mrr}$) and part of it the *marginal capital costs* ($X_{4,mcc}$). The optimal level of R&D expenditure (R) is found where marginal rate of returns and marginal capital costs are equal:

$$\mathrm{MRR}\left(\mathrm{R}, \mathrm{S}, \mathrm{X}_{4,\mathrm{mrr}}, v_{\mathrm{mrr}}\right) = \mathrm{MCC}\left(\mathrm{R}, \mathrm{S}, \mathrm{X}_{4,\mathrm{mcc}}, v_{\mathrm{mcc}}\right)$$

where v_{mrr} and v_{mcc} are unobservable-to-analyst factors. By solving this equation in R, we get an explicit form of the optimal level of R&D as function of S and X_4:

$$\mathrm{R} = \mathrm{R}\left(\mathrm{S}, \mathrm{X}_4, v\right)$$

where *v* is a compounded unobservable component. This is the RDI behavioural equation to use in the estimation phase along with the firm self-selection and agency selection rules. Indeed, the systems of equations generated by these three behavioural rules are at the basis of a number of econometric models used to estimate the effect of policy on specific RDI target-variables.

3.4 A general treatment model

The previous framework provides a basis for setting up a 'general' econometric model for policy ex-post evaluation. It seems interesting to derive a workable model from previous behavioural rules. Generally, firm self-selection and agency selection are collapsed into a unique behavioural rule (as data availability are sometimes lacking for self-selection). In this case the so-called treatment variable, d, is exactly equal to:

$$d = I_A \cdot I_F$$

where d is in this case a binary indicator (tacking 1 for supported and 0 for non-supported units). In a counterfactual setting, where both supported and non-supported firms are needed for evaluation purposes, we have that:

$$R = R(H, X_4, v)$$

with:

$$H = I_A \cdot I_F \cdot S = d \cdot S \textit{ if the level of the subsidy } S \textit{ is known}$$
$$H = d \quad \textit{if the level of the subsidy } S \textit{ is unknown}$$

In the second case (binary treatment setting), the model boils down to this system of equations[6]:

$$\begin{cases} d = d(X_1, X_2, u) \\ R = R(d, X_4, v) \end{cases}$$

The aim of the evaluator is to estimate the magnitude and statistical significance of the effect of d on R. When a parametric version of functions d(·) and R(·) is provided, the effect of d on R assumes the form of one singleton parameter (generally indicated with the letter α) known as 'treatment effect of d on R'.

Starting from the previous system of equations, the literature has provided two different strategies to estimate the treatment effect of d on R. One strategy requires less theoretical considerations, apart from that regarding the control-variables to be considered (the various Xs). We label this stream of models as 'non-structural' as just a reduced-form of the model is estimated. Among them, *Control-function* (based on OLS or GLS estimation) and *Matching* and *Regression discontinuity* are the most applied. The second approach, on the contrary, is richer of theoretical speculations and aims at estimating directly the previous structural system, by adopting a specific partitioning of variables to be included in the first and second equation. Heckman (1978) selection-model (Heckit) instrumental-variables (IVs) are part of this latter approach. We define them as 'structural' models.

Essentially, the most important difference between non-structural and structural models regards the way in which 'observable' and 'unobservable' factors – affecting selection-into-treatment and RDI behavioural rules – are treated. Non-structural models assume that unobservables are negligible aspects, roughly unable to affect the correctness of treatment-effect estimation. In this regard, these methods are valid only under the so-called assumption of 'selection on observables' that is, only under the knowledge of variables known to the analyst.

Structural models, on the contrary, suggest that unobservable components, such as u and v, are non-negligible. If not accurately taken into account, unobservables might generate substantial estimation biases and the analyst need to provide in this case suitable statistical tools to handle this major complexity. It is said that structural models are suitable *also* in the case of 'selection on unobservables'.

Nevertheless, an important exception is represented by the difference-in-differences (DID) approach, as it is a non-structural approach, yet at the same time able to deal with selection on unobservables. This is possible as DID exploits a longitudinal dataset, allowing also for before-after estimation.

Besides the 'type of specification' (structural vs. non-structural) other two additional aspects generally differentiate the evaluation approach followed by various studies within this literature: 'type of data' and 'nature of the policy variable'.

As for type of data, the majority of works are embedded in a *cross-section* data structure, and only few make use of *longitudinal* data. Yet, when possible, longitudinal data are preferable for at least two reasons:

1. they allow for implementing a before/after analysis
2. they make it possible to take into-account unobservable components, by exploiting panel fixed-effects estimation (as in the above mentioned case of DID).

As for the nature of the subsidy considered, few studies have exploited so far level data. The majority of them relied on a binary indicator (supported vs. non-supported). As we will see in Section 4, nonetheless, knowledge of subsidy level is important in two directions:

1. because it allows for identifying different intensity of support
2. because it allows for calculating, in the case of R&D-based measures, the exact amount of additionality via the use as target-variable of the 'net R&D expenditure' (instead of the 'total' one).

A taxonomy of RDI evaluation studies met in the literature is in Cerulli and Potì (2010), while an in-depth analysis of different treatment effect estimation methods are in Cerulli (2010).

4 Open questions in ex-post assessment of RDI policies

Although the literature on ex-post assessment of RDI policies' effect has been rapidly growing, and a wider awareness of problems concerning the design of ex-post evaluation in this field is nowadays sounder than some years ago, many questions are still open and deserve further comment.

In what follows we address some specific aspects we believe to deserve particular attention, especially for future works in this field. They concern the following issues: role played by unobservables, heterogeneity of behaviours and effects, subsidy measurement, long term analysis, relation between input and output additionality, treatment of policy spillover, full cost-benefit analysis, data availability and, finally, general robustness.

4.1 Role of unobservables

As remarked in previous discussions on econometric methods, unobservable-to-analyst factors, thought of as affecting policy effect in one or more steps of the logical framework, are important drivers of estimation biases when not taken into proper account. The nature of unobservables, however, can be twofold: on one hand, there are unobservable elements due to some lack of information in available datasets. This is more a problem of data availability than genuine incapacity of gauging specific phenomena. An example is represented by information on firm RDI project quality. In many contexts researchers have full access to a great bulk of information on firm characteristics, while poor data are available on proposed projects. On the other hand, there are genuine unobservables that would be fairly impossible to measure also in case of abundant information. Examples of this kind are represented by factors such as, for instance, entrepreneurial innate ability, propensity to risk or ethical attitudes (that, for example, could mitigate opportunistic behaviours) and so on. This last class of unobservables could be relevant, although complex or hard to translate into feasible indicators. Econometric methods like Control-function or Matching are unable to deal with both of these types of unobservables. Heckit, IVs and especially DID, on the contrary, are probably more suited to deal with the second type. In fact, for the first type of unobservables, when a considerable set of (potentially measurable) variables is (for some reason) missing, also methods like Heckit, IV and DID may suffer from a 'specification error' due to *variable-omission*, thus generating distortion in estimation. The problem, in other terms, regards the extent of this variable-omission bias. Sometimes it is just a problem of common sense: when a researcher is convinced of having dropped out a nearly irrelevant number of factors, he can trust both structural and non-structural models. This is the general justification brought by those who make an extensive use of Matching, for example. Indeed, they seem to suggest that, when it is the case of missing instrumental variables or unreliable distributional hypothesis, provided that the magnitude of variable omission is not too much strong, Matching becomes an appealing estimation tool. Undoubtedly, DID would be preferable to Matching also in this case. But what about it when a longitudinal dataset is not available? All this probably explains the great diffusion of matching methods within this literature compared to other techniques.

4.2 Heterogeneity

Heterogeneity is a relevant aspect in many field of economic and econometric modelling. In this context heterogeneity has a specific meaning: a researcher, in fact, could be interested in capturing that behavioural heterogeneity leading to differential policy effects. This aspect goes far beyond, for instance, an analysis on clusters of firms as usually done in some studies (on the basis of firm size, technology or geographical location). Looking at firm idiosyncratic effect is no doubt an essential step to better understand the success/failure of the policy in question. The majority of studies, nevertheless, draw their conclusions just on the basis of an 'average' level of the treatment effect. Although useful, looking just at the average could be sometimes misleading, especially when long right and left tails associated to the variability across firms of the treatment effect are present. Fortunately, econometric techniques can be fairly easily extended to take into account firm specific effects. This can be done by embedding these models in a 'random coefficient' environment. Nevertheless, few studies have made use of this approach [for a first attempt, see Cerulli and Potì (2010)]. One of the explanations could be that no in-built commands for standard statistical packages have been provided yet for random coefficient estimation. But it probably mirrors an old-fashioned attitude of researchers to communicate their econometric results to the scientific arena and policymakers on a 'one-catch-all' manner, that is, by reporting magnitude and significance of a single parameter. Of course, treatment effect heterogeneity is strictly linked to another aspect that generates considerable variability across firms, namely, the level of received support. We address this more general aspect in the next point.

4.3 Subsidy measurement

As stated above, firms generally receive a different level of subsidisation. More precisely, the public agency usually covers just a share of the entire firm RDI project costs. The extent of project co-financing depends on normative aspects (such as legal thresholds decided al political level), but it can have also an economic justification as a way to get a deeper commitment of firms in terms of project risk sharing (thus playing, in this case, as an incentive mechanism). One way or another, this aspect is clearly likely to affect firm RDI decisions and policy effect remarkably. Far from being a simple concern, the exact measurement of subsidy is on the contrary a complex question for at least two motives:

1 public project-funding does not take only the form of simple grants, but also of subsidised loans

2 provision of funds are distributed over time so that, in a specific range of time, a firm could be treated more than once.

Point (1) is particularly important as generally data on agency's total financing contains the total amount of subsidised loans that, by definition, is not equal to the actual subsidy received by firm, since part of this amount has to be refunded to banks. The European Commission, for example, has defined an actuarial procedure to express the amount of repayable loans in terms of standard grants, the so-called gross grant equivalent (GGE) method. To calculate the level of GGE several additional information are needed, such as: the current market interest rate on loans, the favourable interest rate enjoyed by firms, the duration of the loan (that can exceed the duration of the RDI project) and the firm specific risk of credit (to calculate an idiosyncratic rate of interest). Once the (gross) grant equivalent of a subsidised loan is calculated, it can be summed to the standard grants received, thus providing an exact measure of the actual support. It goes without saying that having access to all this information is far from being easy in many policy contexts, what makes an in-depth ex-post evaluation sometimes impossible to perform. Yet, the knowledge of the exact amount of support allows for improving substantially the analysis in two related directions:

1 it permits to calculate the net R&D expenditure (total R&D *minus* subsidy) in R&D-targeted policy instead of the total R&D as usually done

2 it allows for calculating the effect of the policy at different level of subsidisation.

It is immediate understandable that only by using 'net R&D' it is possible to determine the exact amount of R&D additionality performed by firm. Otherwise, only a spurious (wrong) measure of it is attainable. Many ex-post evaluation works in this field have suffered from this 'curse', having no access to the level of subsidy, but only to a binary form (supported vs. non-supported) of it. It is now clearer as a binary setting could be extremely limiting, not to say misleading.

4.4 Multiple and mix of treatment

Besides the question of subsidy measurement, there is a related aspect concerning the 'uniqueness' of the support received. Firms generally are likely to participate to more than one RDI program. In Italy, for instance, two public programs provide incentives for firm RDI upgrading: FAR and FIT. When more than one supporting program is at work, the evaluator needs to have access to an exceptionally extensive amount of information. For instance, at least the amount of actual support in the various programs has to be recovered. But also institutional and implementation rules, generally specific to each program, are important to take into account. A recent literature in the econometric of policy evaluation has developed suitable techniques to deal with the so-called 'multiple-treatment' setting. Good references are Lechner (2000) and Flores and Mitnik (2009). These methods generalise those previously reviewed to the case of more than one single support, thereby providing in principle extensions of those approaches. Nevertheless, a multiple treatment setting generates additional problems, the most important one being probably the actual availability and consistency of data coming – in this case – from sometimes very different sources (also managed by different institutional actors). Building a unique, coherent and detailed set of information on various RDI incentive programs is far from being easy, so that researchers usually tend to pool information or reduce their extent. In doing so, they are forced to limit the scope of their analysis by considering just a reduced number of factors affecting firm RDI behaviours. In other words, a sort of trade-off seems to emerge: if a researcher analyses only one single measure, by ruling out all other potentially concomitant RDI incentive programs, he would be able to perform a more detailed and informed analysis, although he runs the risk of reaching misleading results when other confounding incentives are at work. On the contrary, if the researcher considers all the RDI programs potentially at work, it is in principle more correct, but at the same time he has to rely – for consistency purposes – on a reduced informational set, thus running the risk to leave out important factors affecting firm RDI performance. Both cases, in other words, might generate potential biases in results. We will come back to this aspect later on when we will discuss general problems of data availability. Finally, a related problem arises when, within the same RDI program, a researcher is interested in pinpointing the effect of single measures (such as, that of *grants* separately from *subsidised loans*). Generally, limited sample sizes prevent the analysis of mix of instruments [see, again, Cerulli and Poti (2010) for a simple/partial application].

4.5 Long-term effect

An essential issue regarding ex-post evaluation is the study of long-run subsidisation effect. This is particularly relevant in an RDI context as RDI activities show their benefits over time and with remarkable delays. R&D, in particular, could take the form of intangible investments such as human capital devoted to new explorative blueprints whose downstream effect, from prototypes to final commercialised goods, may take place after a long time span, years in some specific fields of economic activity (such as, for instance, in pharmaceuticals). This suggests to be particularly careful when one of the evaluation objectives is that of measuring policy effects on downstream target-variables, such as firm profitability or productivity. But also when only R&D is the target, a fundamental question arises: have firms come back to their pre-policy R&D spending or have they permanently moved up to a higher magnitude of R&D activity? This question reminds to the related issue of 'inter-temporal substitution effect': firms, once supported, could currently anticipate R&D spending planned for the future, thus reducing remarkably their R&D activity in the next future. In this case the net additionality over time would be null, as firm first increases and then decreases accordingly their R&D commitment. Testing whether or not an 'inter-temporal substitution effect' is at work is a central concern in policy ex-post evaluation and it asks for extending the analysis some periods after the treatment. Of course, a sufficiently long time series of R&D is needed for this purpose, an aspect that could meet anyway (usual) problem of data availability. It is probably for this reason that only few works have tried to test this occurrence. The majority of them concentrates on the concomitant (same year) effect of the policy.

4.6 Relation between input and output additionality

The majority of studies in R&D evaluation deal with R&D or 'input additionality'. Nevertheless, from a societal point of view, R&D is not an objective *per se*. The society is probably more interested in what R&D can produce in terms of economic performance (growth, productivity, profitability and innovativeness), technological upgrading, improved living standard and quality of life, equity (by, for instance, a more balanced territorial development) and so on. For this reason, linking R&D (input) additionality to firm output performance is a necessary step to give a complete account of 'subsidy effectiveness'. This calls to mind the key question of how to move from an input to an output measurement of additionality, a point that still deserves careful attention in the literature. Early RDI evaluation works did not give special attention to the issue. They only considered the 'direct effect' of the subsidy on output indicators, without passing from input (R&D) effect. Recently, however, an interesting effort to provide a more sound approach to measure output additionality has been proposed by Czarnitzki and Hussinger (2004). They use a two-step procedure to measure output additionality induced by R&D subsidies: in the first step they calculate the idiosyncratic (firm) input additionality through a Matching procedure (that is, the effect on the firm's 'own R&D'), while in the second step they try to measure the effect of this R&D additionality on the number of patents filed by the firm. A similar approach has been implemented also by Cerulli and Potì (2010).

4.7 Policy-induced spillovers

The question of RDI support evaluation in the presence of policy spillovers does not seem to have received a satisfactory treatment up to now. This might be linked to the difficulty of measuring spillovers, especially those related to the provision of RDI subsidies. In this sense: do subsidies generate 'knowledge' or 'rent' spillovers? And to which extent? This is still an open question. Furthermore, we cannot rule out the possibility of generating an additional bias when an incorrect spillover measure is provided. What is better? To risk incurring in a bias due to a lack in spillover specification or to risk introducing a spillover proxy in the hope that it is sufficiently appropriate? Another important element to be taken into account in presence of policy spillover effect regards the modification generated in the statistical design. Indeed, previous econometric methods are all based on the so called 'stable unit treatment value assumption' (SUTVA) that rules out cases where the treatment of one unit affects another's outcome. But this event is exactly what a spillover effect does provoke. In other words previous econometric methods can become useless when strong spillover effects are thought of to be present.

4.8 Data availability

The problem of data availability is usual in many empirical analyses. In this context, as suggested several times in the text, it can assume roughly the form of a lack of:

1 an adequate database structure (such as the availability of cross-section instead of longitudinal data)

2 a satisfactory information on the form of policy variable (binary instead of continuous) and type of financing (without distinguishing among grants, favourable loans, fiscal measures, etc.)

3 reasonable knowledge of firm and, above all, project quality

4 minimal availability of implementation and other institutional (program-specific) indicators.

But even in presence of a good information set, a typical problem of RDI ex-post evaluation is that it normally requires to merge at least three different types of datasets:

1 datasets relating to the specific program to be evaluated, containing basic information on proposed RDI projects that are generally built for administrative purposes

2 dataset on firm balance sheets that are generally collected for corporate accounting objectives

3 datasets on wider (generally national) RDI surveys (such as, the European Community Innovation Survey), that are built with an eye toward measuring country RDI performance (and less for policy evaluation purposes).

This complicates substantially the objective to reach some data consistency when merging these datasets. It is for this reason that many scholars have preferred to draw upon national RDI surveys alone. The advantage of this choice is that national surveys allow for reaching major data consistency, but at the price of being more superficial, as they usually present an aggregation of RDI support with poor or totally absent specification of what belongs to single measures. This choice, hence, turns out to be quite useless for policy purposes, as no detailed information on single incentives is provided. On the contrary, the use of administrative datasets provides an extensive mass of figures, but generally related only to one single measure at a time, thus overlooking the role played by the presence of other measures that are working contemporaneously. The use of targeted questionnaires could be a way to mitigate the problems arising from both the previous approaches. Nevertheless, to be workable, a questionnaire needs to be easy-to-fill for a firm and above all firms are not willing to provide private figures. In this sense ex-post evaluation based on targeted questionnaires are often rich of qualitative information, but poor of quantitative figures. They are really useful to address suitably behavioural rather than input and output additionality.

4.9 Policy full cost-benefit analysis

So far, very few efforts have been made in order to estimate a full cost/benefit analysis of an RDI supporting program. As it is an important task, it requires a clear-cut specification of the private and social costs and benefits associated to program under analysis. As for the public agency, elements such as monitoring and administration costs, reduction in tax revenues, as well as a potential decrease in other subsidies have to be appropriately set against the objective of generating firm R&D additionality. In other words, even when additionality is present, the overall success of the policy should be judged on the basis of the whole array of costs (benefits) generated directly and indirectly by the public intervention [see IPTS, (2002), pp.142–161].

4.10 General robustness

Some kind of 'sensitivity analysis' for policy effect's results seems of some relevance in the context of ex-post RDI policy evaluation. As results are thought of as essential figures for steering future policymaking, fairness in their reporting is needed. Recently, Cerulli and Potì (2012) have shown that different econometric methodologies can produce substantial differences in results, even when the comparison is made among methods that share similar identification assumptions. In particular, they observe, results on target-variables expressed in level (such as, R&D spending) are heavily more volatile across methods than target-variables expressed as ratio (such as, R&D per employees or R&D to turnover). It entails that reporting results from various methods, thus trying to explain their differences, should be an important part of any scientific effort aimed at communicate externally RDI policy conclusions. It goes without saying that a lot of work still needs to be done in this direction. Yet, the idea of building a sort of 'protocol' for a fairer reporting and communication of results should be favourably welcomed.

5 Conclusions

Although analyses of ex-post policy evaluation effect are becoming an integral part of several RDI policy designs throughout the World, and even if the scientific literature on the subject keeps on growing considerably, lots of work still remains to be done, especially along the lines traced by the open questions discussed above. But the message of this paper is also that these designs need to be better embedded in a more comprehensive structure. Indeed, policy objectives and implementation, R&D characteristics, agents' behaviours, factors and related indicators, econometric modelling and estimation of policy causal effects should not be thought of as 'isolated' aspects of an RDI supporting programme, but rather as interrelated and interdependent components whose quality of treatment – within a design of ex-post assessment – is possible only by taking into account their scope. Yet, so far the literature has not seemed to have provided sufficient evidence on this awareness. The majority of works are sometimes well-done econometric exercises of ex-post evaluation, but they are seriously lacking an in-depth knowledge of policy institutional aspects or they present poor theoretical speculation regarding agents' behaviours or factors leading to additionality. Indeed, what is at the heart of the question is that saying that a policy worked well as some (average) measure of additionality was found out, is nothing but a useless conclusion. A good ex-post evaluation exercise should strive to identify what causes actually have led to results. But it requires a more comprehensive approach to ex-post evaluation, where each element is suitably 'controlled for' within the whole chain of interrelations. Although in this paper we did not provide such an experimental exercise, we deem it a useful contribution to help designing more suitably RDI ex-post evaluation analyses for the future.

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Notes

1 For a broader examination of factors and the related indicators see Potì and Cerulli (2011).

2 An in-depth examination of the econometric techniques for estimating RDI policy effects, along with their comparative advantages and drawbacks, can be found in Cerulli (2010).

3 The MRR curve is a decreasing function of fixed (or R&D) investments as firms normally implement first projects with higher rates of return and then those with lower rates.

4 In many countries for instance, banks are entitled by the public agencies to provide the screening of firm/project financial quality. Although banks can have their own objectives in this concern, we assume in this context that they work only in the interest of the public agency.

5 See, for instance: Mansfield (1964), Howe and McFetridge (1976), Nadiri (1979), Cohen and Levinthal (1990) and David et al. (2000).

6 Observe that variables X_3 can be arbitrarily included into one of the two equations to complete the model.