R&D policy evaluation: the effects of R&D subsidies in Italy

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Abstract: In a context of scarce resources, exacerbated by the economic crisis, financing investment and structural changes in slowly growing economies, such as Italy, is very challenging. It becomes fundamental to engage in evaluation exercises in order to understand what policies are working and for whom. The paper offers an evaluation exercise on the major instruments used to promote R&D and innovation activities of Italian firms. We concentrate in particular on the incentives provided by Law 46/82 (and revisions) and we look at the effects they have on firms expenditures on R&D and on new employment generation. Unlike previous studies, we consider the effects of such incentives also when other similar policies are at work. We also look at the effects for different subgroups of firms. Results suggest that a rethinking of the system of incentives would be appropriate to limit an inefficient overlapping of instruments. They also highlight that the additionality of R&D investment is verified for some categories of firms. Starting from these results, further and continuous research is needed on this subject, in order to build a robust set of evidence to inform the policy making process.

Keywords: R&D subsidies; innovation; policy evaluation; additionality; heterogeneity; Italy; Law 46/82.

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1 Introduction[1]

Modern economies, even when based on a free-market organisation, make use of public policies for several purposes. Mainstream economic literature traditionally justifies such interventions with the market failure argument. Other strands of literature, ranging from the *developmental state* to evolutionary approaches, signal the use of industrial development policies for objectives that go beyond the correction of market failures. The recent economic crisis has reduced the capacity of governments to invest and to support their economies. Budget constraints, together with legal restrictions to industry incentives imposed by the European Union, have reduced the ability of governments to mitigate the effect of the crisis. At the same time these constraints represent an opportunity for governments to identify and eliminate weak instruments and to focus on specific and enforceable incentives. In this context, the research on policy evaluation can be viewed as an institutional practice as well as a coherent set of techniques and it becomes fundamental. Too often policy evaluation is studied and developed within academic circuits, with few linkages with policy makers and scarce effects on voters' choices (Barbieri and Santarelli, 2010; Barbieri, 2010). On the contrary, policy evaluation can offer important solutions to the government failure dilemma.

The word 'evaluation' means different things in different contexts. Although the literature normally refers to it as a 'judgement on the effects' of a policy (Shadish et al., 1991), there is no consensus on the comparison term that should be used to measure such effects. When talking about ex-post evaluation, the question "what would have happened without policy intervention?" is crucial. Social experiments, techniques of the so-called quasi-experiments and interviews to the beneficiaries of policy interventions are traditionally three ways to address this question. Quasi-experiments have increasingly gained consensus within policy evaluation as a scientific reference method to carry out policy evaluation when social experiments are not feasible. As it can be argued (see among others Smith, 2004), quasi-experiments have limitations: sometimes the counterfactual situation is just impossible to identify, or the combination of available data with conventional statistic and econometric tools implies unrealistic assumptions. Although these can be arguments against the quasi-experimental approaches, the question of what would happen without policy intervention remains crucial. This paper wishes to

stress the need for research to move forward in this direction, looking for ways to take into account the numerous complexities that policy intervention implies.

In this scenario and with this aim, the research presented in this paper investigates the effects of the Italian Law n.46/1982 (hereafter Law 46/82), which regulates the major incentive programs that support the Research and Development (R&D) and innovation of Italian firms (Ministero dello Sviluppo Economico, 2009). In particular, we study the effects of these incentives on firms' R&D expenditures and on the number of workers in R&D. To this aim we refer to a well-established methodology: the difference in difference technique (DD). We also utilise a less diffuse form of such an approach (difference in difference in difference, DDD) in order to take into account that firms might receive other incentives for their R&D activities (in addition to those of Law 46/82), from the national and the regional governments. In this way we try to overcome a usual limit of evaluation analyses, which often overlook the co-presence of similar incentives. Moreover, we try to go beyond another shortcoming of the usual evaluation procedures, which tend to calculate an average effect, ignoring systematic differences among different typologies of recipients. In this paper, in fact, we investigate the effects of Law 46/82 for homogeneous sub-groups of firms, with the aim to deepen our knowledge on the specific kind of firms that benefit the most from this policy intervention. Our results suggest a possible inefficient overlapping of instruments aiming at similar goals. A positive effect of the law seems to emerge for large firms, although a deeper look at the specific manufacturing sectors reveals that the precise industrial production needs to be taken into account. The paper is structured as follows: Section 2 recalls the main theoretical considerations on R&D and innovation policies; Section 3 summarises the debate on the effects of subsidies to R&D; in the fourth section the main features of Law 46/82 are described with reference to the Italian scenario; Section 5 describes the data used in the estimates, whereas Section 6 explains the econometric strategy applied. The seventh section discusses the results and the eighth concludes.

2 Theoretical considerations on R&D and innovation incentives

The theoretical reasons why public intervention is needed when speaking of innovation have been long since established. The traditional conceptual framework belongs to the neoclassical approach; then an articulated evolutionary approach to the problem has been also developed.

The seminal contribution belongs to Arrow (1962), who underlines the non-perfect appropriability of knowledge and the need for government intervention to avoid an underinvestment in R&D by private actors. Patents are the fundamental policy instruments to obtain this result. Nevertheless, as large part of innovation is not patented, other instruments of public intervention are frequently adopted, particularly in the form of monetary subsidies.

Additionality is a key point in evaluating a public intervention: it means that a firm which benefits from a public subsidy, in a general sense *does* more and better than it would have done without the intervention. We use such a generic definition because different kinds of additionality may be identified: following Georghiou (2002) we may identify an input additionality, an output additionality and a behavioural additionality. There is input additionality if the firm, receiving the incentive, spends a greater amount

of money (typically in R&D) than it would have done in absence of such incentive. In a strict sense, there is no input additionality if such an increase is smaller than the amount of the subsidy. Input additionality is not verified also if the firm uses the subsidy for an activity that it would have carried out anyway and the internal resources originally destined to such activity are diverted to other projects. The Nordhaus' model (1969) predicts that a public subsidy may induce the firm to undertake inefficient projects (whose expected costs exceed benefits).

Output additionality occurs when firms obtain an innovative output (product or process) that would not have been realised without the public support.

There is also a behavioural additionality, a concept introduced by the evolutionary approach to innovation. It takes place when the innovation policy changes the behaviour of the firm, in terms of 'objective' decisions (scale, scope, timing investment, etc.), permanent strategic behaviour (e.g., the firm moves into new areas of activity) or it increases the acquired competences, up to what Bach and Matt (2002) call 'cognitive capacity additionality'. In this paper, we focus on the input additionality: we try to verify if firms that have received the incentives established in Law 46/82 have increased their R&D expenditure and personnel, with respect to a hypothetical situation where such public intervention is absent. Among the different kinds of additionality, this is perhaps the easiest to verify, as it is, at least in principle, clearly quantifiable and the cause-effect nexus are more direct.

Our paper also deals with a less traditional theme: the evaluation of the effects of a specific incentive in the presence of other incentives directed to similar goals. In fact the presence of multiple incentives to innovation, that is, as we will see, a characteristic of the Italian scenario, creates theoretical and practical problems when trying to evaluate the effect of a specific incentive.

If an incentive A has typically an effect X and an incentive B has typically an effect Y, a firm that receives both incentives may simply have an effect X + Y. But there are many good reasons to hypothesise another effect. The global effect may be less than X + Y if there is an overlapping of the two incentives, that is of the fields or kind of projects they may finance; in such a case part of the projects of the firm may be covered *de facto* by two incentives: we only have partial additionality. It is also possible an effect greater than X + Y if there is a behavioural additionality: with the incentive A the firm tries to do something it would not have done without it; then the firm learns to do that kind of research: the incentive has the 'normal' effect X plus 'something else' (in terms of experience); this 'surplus' allows the firm to obtain more than the 'normal' benefit (Y) if it utilises a second incentive (B). Indeed, another case is actually possible: if a firm receives the incentive A alone, the effect is X, when the firm receives the two incentives together, the effect is smaller than X; if this happens it is a sign of a severe distortion in the system of incentives.

3 The debate on the effects of subsidies to R&D and innovation

The literature on the effects of public subsidies on firms' innovation activities is extremely wide. However, there are several thorough reviews that help synthesise the main features of the studies available on the topic (see in particular David et al., 2000 and Klette et al., 2000).

Most of the available studies measure the effects of public incentives on firms' R&D expenditures. In other words they question the degree of substitutability or complementarity between private and public investment in R&D and they choose to use, as a measure of the outcome, the variable that determines innovation (R&D expenditures) rather than innovation itself (Griliches, 1990). As already mentioned, one of the reasons of such a preference is that the causal relationship between public incentives and expenditures in R&D is more direct than the one between incentives and the final innovation performance of the firm. At the same time, investigating the relation between government incentives and firms' spending is also a necessary first step to understand the effectiveness of R&D policies over innovation results.

Studies analysing input additionality have used either cross-section data (Wallsten, 2000; Busom, 2000; Almus and Czarnitzki, 2003; Aerts and Czarnitzki, 2004; Aerts and Schmidt, 2008; Heijs and Herrera, 2004; Kaiser, 2004; Lööf and Heshmati, 2005), time series data (particularly in aggregated analysis, see Levy and Terleckyj, 1983; Lichtenberg, 1987) or panel data (Lichtenberg, 1987; Toinovanen and Niininen, 1998; Lach, 2002; Suetens, 2002; Görg and Strobl, 2007; Duguet, 2004; González et al., 2005). The methods used are typical of the quasi-experiment approach and range from multiple regressions with different estimation methods to matching methods and the use of instrumental variables, according to the type of data available and to the type of bias that needs to be taken into account.

These studies (as noted also by Almus and Czarnitzki, 2003) point at a general positive effect of the public investment on private R&D expenditures, thus suggesting a complementarity between the two, at least at the country and industry level. However, when going into the details of firm-level studies, the results are not homogeneous. Some studies find evidence of substitution effects between public and private R&D investment (Wallsten, 2000; Busom, 2000; Heijs and Herrera, 2004; Kaiser, 2004; Lach, 2002; Suetens, 2002; Lichtenberg, 1987; Toinovanen and Niininen, 1998). Others reject the crowding out hypothesis (Aerts and Czarnitzki, 2004; Almus and Czarnitzki, 2003; Duguet, 2004; González et al., 2005; Görg and Strobl, 2007; Lööf and Heshmati, 2005; Aaerts and Schmidt, 2008). The reason for these diverging conclusions could be searched in the use of different estimators and approaches (Aaerts and Schmidt, 2008). But even more important, one could argue that there are no priors concerning the effects of public incentives to R&D, since it is most probably the single instrument, the way it is designed and implemented together with the specific context where it is adopted, that determine a positive or a negative (or null) effect.

Coming to the effect of the specific policy that we are investigating, a first study on the effects of FAR (Fund for Applied Research, which is regulated by art.1–13 of Law 46/82) was produced by Merito et al. (2007) with matching procedures and data from Ministry of University and Research, Amadeus-Bureau van Dijk and Delphion-Thomson. The results do not show any positive effect of the law on sales, employment or labour productivity, while they suggest a short term effect on patent applications. A second contribution by Potì and Cerulli (2010) (on data from Ministry of University and Research and Italian National Institute of Statistics) combines a system of equations with matching procedures. The former are used to model the behaviour of the public agency and the one of supported firms and non-supported firms, and they are used to estimate the effects of subsidies on R&D investment. The latter are used to estimate the effects of incentives on patents. The authors find that FAR has stimulated additional investment in

R&D and better innovation performances (measured by patents). These results refer in particular to large firms. The second part of the law (art. 14–19 which regulates the FIT – Fund for Technological Innovation) has also been studied: De Blasio et al. (2009) re-create a natural experiment thanks to an unexpected shortage of funds. The authors adopt a regression discontinuity approach and conclude that there are no effects on firms' tangible or intangible asset investment. The Ministry of Economic Development, on the other hand, following a qualitative approach with direct interviews to the beneficiaries, concludes that the FIT produces additional investment, with 65% of the firms declaring that without the incentives they would not have invested or they would have invested less than observed (Ministero dello Sviluppo Economico, 2008).

3.1 Dealing with firm heterogeneity

As we anticipated, our analysis tries to go beyond the so-called ATET (Average Treatment Effect on the Treated), which is the effect produced *on average* by the policy on the group of selected beneficiaries. It is the parameter retrieved by most of the contributions analysed in the previous section, with few exceptions (i.e. Görg and Strobl, 2007; Lach, 2002; González et al., 2005). In this section we want to recall that an identical average effect can result both from an even distribution of similar effects among beneficiaries or from the sum of very diverse positive and negative effects. If there is considerable heterogeneity of effects among recipients, one single parameter can be little informative, or even misleading, in terms of policy prescriptions. Moreover, analyses that produce as a result an average effect on beneficiaries can be little helpful to policy makers and other stakeholders, since they tend to either accept the incentives as they are or to suggest that incentives should be fully abandoned. In this way little room is left for improvements and rationalisation.

When dealing with public policy evaluation, there is a question therefore of how homogeneous we think the response of beneficiaries is. The evolutionary approach to innovation policy (see among others Metcalfe, 1995; Nelson, 2009; Malerba, 2009; Bach and Matt, 2005) concentrates on the reasons that make firms heterogeneous actors. These studies open the black box and investigate firms' behaviour in an evolutionary and dynamic perspective, as opposed to the static and equilibrium one of the neoclassical approach. Firms are seen as complex entities that continuously adapt to a changing environment and their choices are taken in a scenario of uncertainty, asymmetric information and bounded rationality. Firms' behaviour towards external actors (policy makers, customers, rivals, workers etc.) depends to a large extent on their capacities to accumulate knowledge and exploit learning economies. However, this same capacity depends upon the characteristics of the environment in which firms operate and, more important, it depends on the way all actors interact and exchange knowledge. It is important to highlight that in an evolutionary perspective any notion of representative behaviour is redundant and the variations between firms become crucial (Metcalfe, 1995). Each firm has a unique history, which makes it difficult to make general hypotheses on the way a whole sample of different firms might respond to the same policy incentive.

At the same time the evolutionary approach investigates the role of policy makers. Just like firms, policy makers operate in a context of uncertainty and asymmetric information. It is unrealistic to assume that they have a superior understanding of markets

or technologies. Policy makers' strategies can fail just as firms' technology strategies do. All they can do is to learn and to adapt in the light of experience (Metcalfe, 1995). It is clear that, also from an evolutionary perspective, policy evaluation becomes crucial for policy makers. And it is also clear that evaluation should allow some heterogeneity in the response of firms to policy incentives.

Such heterogeneity, as mentioned, has been fairly investigated from the theoretical point of view. From an empirical perspective it is being considerably analysed when studying the impact of R&D expenditures on innovation and more in general on firms' performance (among others Damijan et al., 2011; Falk, 2010; Coad and Rao 2008; Hölzl 2009; Stam and Wennberg, 2009).

However, when coming to the specific issue of additionality of R&D subsidies, the different strands of literature have not yet been integrated. Heterogeneity and multiple treatments can imply complex models of estimation (Smith, 2004), which often discourage a diffuse debate on these aspects. Moreover, the lack of crucial data, such as the amount of R&D subsidies received, makes it often difficult to apply methods such as quintile regressions, which seem to be appropriate for the investigation of heterogeneity among firms (Serrano-Velarde, 2008). When quintile regression is not applicable, a prior identification of sub-group of firms is required. Sissoko (2011) suggests to compute the distance to the technology frontier, assuming that firms far from the frontier are more likely to benefit from R&D support. As a whole, there seems to be room in the literature for further investigation on firms' heterogeneous response to R&D subsidies. In particular, in an evolutionary perspective the idea of 'optimal instrument' and 'best policy' has to be abandoned. The co-presence of different tools, each one affecting firms in a different way according to the specific 'failure' they try to overcome, has to be envisaged. And evaluation processes should help identify not only 'what works' in general, but 'for whom a specific policy tool works best'. Therefore, we suggest that, when more complex methods are not viable, a first investigation of firm heterogeneity can be based on estimations for sub-group of firms. This step, in our view, should become common practice in the evaluation of policy measures directed to firms.

4 R&D subsidies in the Italian scenario

The Italian economy is characterised by a low level of private investment in R&D. Only 40% of the R&D expenditures is private. The comparative figure of other European countries (Sweden, Germany, Finland, Ireland and Spain) is 70%. Moreover R&D incentives only represent 13% of government incentives, compared to 15% for Germany, 16% for Spain and 23% for France (Ministero dello Sviluppo Economico, 2009).

Among R&D government incentives to firms, Law 46/82 is the longest lasting and most important policy measure in Italy (Ministero dello Sviluppo Economico, 2008). Two different parts can be distinguished within the Law, the first one concerning art. 1–13, the second one art.14–19.

The first part of the law (art.1–13) regulates the special fund for applied research. The focus is particularly on applied research, on technology transfer to medium and small

enterprises and on research collaborations between the public and the private sector[2]. Up to 50% of the costs of the projects may be covered by such fund. In 2001 the fund established in this part of the law became part of a wider fund (Fund to Facilitate Research, FAR), as a consequence of a process of legislative simplification. We took this reform into account when evaluating the effect of the first part of the Law 46/82.[3]

The second part of the law (art.14–19) creates the FIT. According to the law's words, this fund has the goal to "finance programs concerning activities of planning, experimentation, development and pre-industrialisation". Under this fund firms receive financial support at a cut rate, up to a period of fifteen years.

Under several aspects the law assures favourable conditions to small and medium firms. Actions of technology transfer, for instance, are financed only if undertaken by SMEs.

It must be underlined that, notwithstanding the legislative simplification we mentioned above, Italian firms continue to have the chance to benefit from a number of public subsidies, particularly at the local level; this peculiarity of the Italian system increased in the last decade as a consequence of a significant process of legislative decentralisation, particularly in favour of the Regions (Rolfo and Calabrese, 2005).[4]

It seems important to spend a few words on the selection procedures of the benefited firms and describe, in particular, how the laws deal with the theme of additionality, which is central in the theoretical analysis of the public funding for innovation.

As regards the Fund to Facilitate the Research (FAR), three kinds of procedures are possible: evaluative, negotiated and automatic[5].

In the first case some criteria are expressly required and verified by a committee: innovative character, originality and industrial utility; technical and economic capacity to carry out the project. The additionality criterion is expressly required only for large firms, in line with the EU regulation[6].

The negotiation procedure regards public competitions for projects of R&D and training: the ministry individuates specific thematic areas of intervention and selects the best projects.

The evaluation phase of the projects is completely overcome with the automatic procedure of intervention: when a firm carries out some specific activities (hiring of qualified research personnel, provision of scholarships for PhD students, assignments of specific research contracts) it may apply for some established forms of funding, that will be automatically granted, according to the chronological order of the demands, up to a pre-defined budget limit.

As regards the second part (art.14–21) of the law, the incentives are assigned through an evaluative procedure, with no reference to the theme of additionality[7].

Summing up, we found that the additionality is rarely expressly considered in the laws we are analysing. Particularly with the automatic procedure there is a clear risk of non-additionality. Of course the automatic procedure is administratively simpler and increases the likelihood of weak firms to win awards. Some studies done by the Ministry of Economic Development in 2008 (Ministero dello Sviluppo Economico, 2008) confirmed these considerations. A high percentage of firms that utilised the automatic incentives declare that they would have anyway done the same actions, even in the absence of the public support; this percentage is much lower when the evaluation procedure is involved; on the other side, the automatic procedures have been greatly appreciated, particularly by small firms, exactly because they are easy to access, while the main complaint against the evaluation procedure is its length.

5 Data and summary statistics

The database used for the analysis is composed by the 7th, 8th and 9th Capitalia Surveys[8] on manufacturing firms with more than 10 employees. Each wave includes about 4500 observations: these are composed by a stratified sample of the population of firms with less than 500 workers and by all Italian firms with more than 500 employees. Each wave refers to a period of three years, respectively 1995–1997, 1998–2000 and 2001–2003. Questionnaires were kept very similar among the waves to ensure comparability. The stratified sampling has been realised to cover macro-regions (North-East, North-West, Centre, South), dimensions (11–20, 21–50, 51–250, 251–500, more than 500 employees) and Pavitt classification (Supplier-Dominated, Scale-Intensive, Specialised Suppliers and Science-Based). Each stratum has been determined following the Neyman's formula[9], in order to be representative of the whole population.

Table 1 Sample composition

Variable\Period	*Wave 7 1995–1997*	*Wave 8 1998–2000*	*Wave 9 2001–2003*	*Waves 7–8 1995–2000*	*Waves 8–9 1998–2003*	*Waves 7–9 1995–2003*
Num. of firms (rotation panel)	4,497	4,680	4,284	9,177	8,960	13,457
Num. of firms (balanced panel)	4,497	4,680	4,284	1,316	2,127	663
%Large firms	10.52	6.77	11.37	8.61	8.97	9.49
%Part of a group	24.88	20.34	32.33	22.57	26.07	25.67
%Pavitt1 supplier-dominated	44.07	52.78	51.96	52.39	48.51	49.61
%Pavitt2 scale-intensive	24.86	17.84	16.81	21.10	17.16	19.73
%Pavitt3 specialised Suppliers	26.46	24.10	26.68	25.26	25.33	25.71
%Pavitt4 science-based	4.60	5.64	4.55	5.13	5.12	4.95

Notes: The rotation samples are obtained by summing the observations of different waves. All percentages are calculated on the rotation sample.

The database resulting from the merger of the three waves is composed by more than 13,000 observations. Within this database, a balanced panel of more than 600 firms can be observed across the three waves (see Table 1, 2nd line) and two balanced panels, one of 1,316 firms and the other of 2,127 firms, can be observed respectively between the 7th and 8th waves and between 8th and 9th waves. There is high attrition in the sample (i.e., loss of data across different waves), as O'Higgins and Nese (2007) noted, which can potentially result in an attrition bias in the regression estimates. Appropriate tests on the variables as in Verbeek and Nijman (1992) and Wooldridge (2002) have been introduced in the analysis (see Section 7) to deal with this aspect.

The Capitalia dataset is composed mainly by small and medium firms, in line with the structure of the Italian productive system. Large firms represent only about 10% of the sample (Table 1, 3rd line). The Pavitt classification was preferred to others because it distinguishes enterprise specialisation without splitting the sample into excessively

minute sub-samples. Moreover, it is relevant to analyse the effect of incentives on R&D for firms that employ different levels of technology. Most firms in the sample belong to the Pavitt 1 category (supplier-dominated), whereas the percentage of science-based firms represents only a minor part of the survey, about 5% (Table 1, from 4th to 7th line)

The Capitalia database contains information on both firm characteristics and incentives received. On the one hand, it is possible to know firms' R&D expenditures, how they finance investments and the number of workers in R&D. On the other, the database distinguishes between different typologies of incentives to R&D and between the two parts of Law 46/82. This bulk of information in the Capitalia Survey is a unique instrument for the evaluation of Law 46/82 and other R&D incentives.

Table 2 Percentage of firms granted with a law for R&D/with Law 46/82

Variable\time	*Wave 7 1995-1997*	*Wave 8 1998–2000*	*Wave 9 2001–2003*	*Waves 7–8 1995–2000*	*Waves 8–9 1998–2003*
% Firms that received a subsidy for R&D (from Law 46/82 or other laws)	11.32	14.94	19.79	13.16	17.26
% Firms that received a subsidy from Law 46/82	4.47	5.47	11.11	4.98	8.17
% Firms that received a subsidy from Law 46/82 first part	2.22	2.31	1.54	2.27	1.94
% Firms that received a subsidy from Law 46/82 second part	3.34	4.29	10.20	3.82	7.12
% Firms receiving a subsidy from Law 46/82 (first or second part) that received even another subsidy for R&D	62.69	66.41	40.55	65.77	49.59
% Firms receiving Law 46/82 (first part) that received even another subsidy for R&D	89	88.89	74.24	88.94	83.33
% Firms receiving Law 46/82 (second part) that received even another subsidy for R&D	64.67	68.16	41.65	66.67	50

Notes: All percentages are calculated on the rotation sample.

The percentage of firms that received any R&D incentive (including Law 46/82) in the survey increased from 11% to 20% in the three waves (Table 2, first line). The number of firms receiving an incentive under Law 46/82 is not so wide: incentives under the first part of the law are granted to about 2% of the firms, whereas the second part of the law benefits more than 3% of the firms (Table 2, lines 2nd, 3rd and 4th). Even if the number of firms receiving incentives under Law 46/82 is scant, most of them obtain at least another R&D incentive, as it is displayed in Table 2 (lines 5th, 6th and 17th). In wave 7 and 8, almost 90% of firms that received incentives from the first part of Law 46/82

received also another incentive for R&D; this percentage declines in wave 9 (about 75%). The overlapping between the second part of the law and the other R&D incentives is a bit lower and also declining in wave 9.

Table 3 Percentage of firms granted with Law 46/82/other incentives for R&D; by Pavitt category and firm size

Pavitt	*Size*	*Law 46/82 Wave 7*	*Law 46/82 Wave 8*	*Law 46/82 Wave 9*	*Other R&D incentives Wave 7*	*Other R&D incentives Wave 8*	*Other R&D incentives Wave 9*
Supplier dominated	All firms	2.37	3.28	8.45	6.26	9.03	9.66
Supplier dominated	Large	9.93	15.08	20.88	12.06	23.02	12.64
Supplier dominated	SMEs	1.79	2.65	7.34	5.81	8.28	9.39
Scale intensive	*All firms*	*3.94*	*4.28*	*10.83*	*8.14*	*8.92*	*9.58*
Scale intensive	*Large*	*11.32*	*14.08*	*26.42*	*14.47*	*23.94*	*9.43*
Scale intensive	*SMEs*	*2.71*	*3.35*	*8.14*	*7.09*	*7.50*	*9.61*
Specialised	All firms	7.31	8.69	15.40	15.04	20.57	21.08
Specialised	Large	24.81	29.35	29.73	28.68	44.57	27.03
Specialised	SMEs	5.18	6.85	13.27	13.83	18.44	20.20
Science-based	*All firms*	*11.11*	*15.91*	*17.44*	*19.32*	*32.20*	*20.51*
Science-based	*Large*	*22.73*	*46.43*	*31.37*	*34.09*	*50.00*	*15.69*
Science-based	*SMEs*	*7.98*	*12.29*	*12.50*	*15.34*	*30.08*	*22.22*
All kinds	Large	15.64	21.77	25.87	19.45	31.86	16.63
All kinds	SMEs	3.16	4.29	9.22	8.50	11.74	12.75
All kinds	All firms	4.47	5.47	11.11	9.65	13.10	13.19

Notes: All percentages are calculated on the rotation sample.

Table 3 shows the percentage of firms, in the three waves, that received subsidies from Law 46/82 or from other laws, divided by Pavitt category and firm size. From this table it emerges that incentives for R&D are much more diffused among large firms than small-medium firms; this difference is particularly significant for subsidies from Law 46/82. Marked differences also exist across the four Pavitt categories: there are low percentages of granted firms among supplier-dominated and scale-intensive firms,

significantly higher percentages among specialised and science-based firms. No clear and systematic differences may be found between the distribution, across sectors and size, of Law 46/82 and other R&D incentives. These data confirm that the co-presence of different R&D incentives, supporting the same target firms, needs to be taken into account.

6 Econometric analysis

6.1 Methodology: difference-in-difference estimator

The advantage of having repeated observations for each unit of analysis is that one can observe the behaviour of firms that did not have any incentive and then received it at some point in time, and compare it with that of firms that never received the incentive.

In this study we refer to the 'difference in difference' approach as an instrument to take into account possible biases due to the non-random selection of beneficiaries (Heckman et al., 1998; David et al., 2000; Klette et al., 2000). In particular, given the nature of our data, we use the DD estimator in the fixed effect form as in Imbens and Wooldridge (2009)[10]. Difference-in-differences estimators have been used widely in policy evaluation since Ashenfelter and Card (1985). The analysis is carried out over two consecutive time periods (each period covers three years) and the beneficiaries are firms that received the incentive in the second period but not in the first one[11]. We do not take into account firms that received the incentive in the first period, because they potentially incorporate already an effect of the incentive on R&D expenditures. In this approach the selection mechanism for receiving the subsidy is allowed to be dependent on time-invariant unobserved characteristics. The usual example is of subsidised individuals, or firms in our case, that are 'more able' or 'more motivated' to take part to the program than excluded firms, provided that such an advantage affects their outcome in every period in the same way. In the context of firm incentives to R&D, several analyses have chosen the DD method of estimation to take into account the bias potentially emerging when the selection of beneficiaries is based on unobservable factors (see for instance Holemans and Sleuwaegen, 1988). The fixed effect form we apply also allows to control for possible heterogeneities of the beneficiaries, meaning other individual effects depending on time-invariant firms characteristics (such as geographical location and industrial sector). Moreover, we add other control variables in the model in order to capture effects that cannot be refereed to the single firm and differences in the growth trend of beneficiary firms and non-beneficiary ones. The main limit of such an approach, beyond the assumption of fixed effects, is that it is dependent from the functional form that the evaluator chooses to specify[12].

The estimation of the effects of Law 46/82 is carried out on both R&D expenditures and on R&D employment, analysing the Law as a whole as well as its two different components (FAR and FIT). The DD estimations take the following form:

$$\text{R\&D expenditures}_{it} = \alpha + \beta_1 \,\text{Wave}_t + \beta_2 \,\text{Law } 46/82_{it} + Z_{it}\gamma + c_i + u_{it} \tag{6.1}$$

$$\text{R\&D employment}_{it} = \alpha + \beta_1 \,\text{Wave}_t + \beta_2 \,\text{Law } 46/82_{it} + Z_{it}\gamma + c_i + u_{it} \tag{6.2}$$

In the above specified equations β_1 captures the time effect; β_2 is the DD estimator that captures the effect of the policy: the variable Law $46/82_{it}$, in fact, is equal to 1 when firm

i receives the incentive at wave *t* and 0 otherwise. The variable Z_{it} summarises all controls; further details on the variables and the way they are calculated can be found in Table A.1 (Appendix).

6.2 Co-presence of R&D incentives and firm heterogeneity: difference-in-difference-in-difference estimator

The above specified equations allow to compute an average effect of the policy on the beneficiaries of Law 46/82. However, there still are a number of crucial issues that are missed in the estimations of equations (6.1) and (6.2).

First of all, there is a need to take into account the possible scenario where firms receive more than one incentive, by different government sources and authorities (Barbieri et al., 2010). As shown in Section 5 this is indeed a common scenario.

The counterfactual situation for non-beneficiaries of Law 46/82 is seldom 'a complete absence of incentives', but it is rather likely (and it is the case in Italy) that firms face a choice among many different incentives, at the national and regional level. Many firms benefit from other R&D incentives in addition to Law 46/82, while other firms only have one of this options and still other firms have none. As it is shown in the result Section 7, when other R&D incentives are included in the analysis the results change substantially.

Secondly, we try to go beyond the ATET, taking into consideration the heterogeneity of the firms, particularly under the aspects of size and sector.

We provide a contribution in this direction by including in the analysis other incentives in R&D and by estimating the effect of Law 46/82 for subgroups of firms.

In particular, in order to take into account other R&D incentives, we calculate the DDD (difference in difference in differences) estimator (Wooldridge, 2007; Imbens and Wooldridge, 2009). To this aim, a new variable is created (Other R&D incentives), that is equal to 1 if a firm receives other R&D incentives, different from those offered by Law 46/82, at time *t* (and 0 otherwise). The interaction between the two policy variables is also introduced in the equation (we call this variable DDD estimator). Equations (6.3) and (6.4) provide the details of the DDD estimation:

$$\begin{aligned} \text{R\&D expenditures}_{it} = {} & \alpha + \beta_1 \,\text{Wave}_t + \beta_2 \,\text{Law } 46/82_{it} \\ & + \beta_3 \,\text{Other R \& D incentives}_{it} \\ & + \beta_4 \,\text{DDD estimator}_{it} + Z_{it}\gamma + c_i + u_{it} \end{aligned} \tag{6.3}$$

$$\begin{aligned} \text{R \& D employment}_{it} = {} & \alpha + \beta_1 \,\text{Wave}_t + \beta_2 \,\text{Law } 46/82_{it} \\ & + \beta_3 \,\text{Other R \& D incentives}_{it} \\ & + \beta_4 \,\text{DDD estimator}_{it} + Z_{it}\gamma + c_i + u_{it} \end{aligned} \tag{6.4}$$

The coefficient β_1 captures the time effect; β_2 measures the effect of Law 46/82 if the firm does not receive any other R&D incentive; β_3 highlights the effect of other incentives to R&D if the firm does not receive incentives under Law 46/82; β_4 shows the interaction effect of Law 46/82 and other R&D incentives (how much the effect of Law 46/82 is increased by the presence of other R&D incentives; how much the effect of other R&D incentives is increased by the presence of Law 46/82). This implies that the effect of Law 46/82 must be derived by the observation of both coefficients β_2 and β_4[13]. Details of the new variables can be found in Table A.1 of the Appendix.

This analysis clarifies the advantages of the DDD model *versus* the DD model: the first one takes into account the presence of other incentives to R&D, avoiding the 'omitted variable' problem of the DD model; moreover, the interaction term of the DDD model allows to observe possible multiplicative effects of different subsidies. We compute the DDD estimation also for sub-group of firms in order to capture possible heterogeneous responses to the policy measures.

The comparison between the two techniques (DDD vs. DD) and between different estimators (average effect on the whole sample vs. sub-group of firms) is important. It shows clearly how the results of evaluation exercises can change when shifting from general models to more specific ones that zoom into the peculiar features of policy tools and industrial contexts.

6.3 Variables description

The relevant dependent variables are, as mentioned, the logarithms of expenditures in R&D (R&D expenditures) and the logarithms of number of workers within the R&D sector (R&D employment).

Given that the database allows distinguishing the two parts of Law 46/82, the regressions look at the whole effect of Law 46/82 as well as at the distinct effects of the FAR and the FIT. All control variables are provided by the Capitalia database, except for the number of bank branches in the firm's town of residence, which is provided by the Bank of Italy[14]. Control variables were introduced for two specific reasons. On the one hand, they allow to take into account some relevant confounding factors: first of all firms' size (*Workers and Log_Sales*) that affects the ability to manage R&D and that captures the effects of macroeconomic cycles or shocks; secondly, the participation to consortia that represents an alternative channel for small companies to foster R&D (*R&DConsortia*). On the other hand, incentives work as an alternative method of financing. Firms with reduced capacity of interactions with banks can have more difficulties in finding sources to invest in R&D and this justifies controlling for a few financial indicators (*Self-financing in R&D and Bank branches*).

The variable Law 46/82 has different specifications depending on whether it is analysed as a whole or in its two parts and on the considered period of observation. The term Law 46/82 has *de facto* six different specifications that are explained in detail in Table A.1 of the Appendix. To simplify the reading of the results, all these specifications take the same name in the regression tables.

The variable referring to other R&D incentives is defined in a similar way and details can also be found in Table A.1 (Appendix). The last policy variable (DDD estimator) is the product of Law 48/82 and other R&D incentives and it represents the combined effect of the different R&D policies.

7 Results

Before commenting on the results, a few remarks on the specification tests carried out in the analysis are mandatory. Data description in Section 5 has shown possible biases in the results coming from a possible attrition problem in the data. The Verbeek and Nijman test[15] has been used to control for this possibility and it shows that the loss of

observations that we detect is not dependent from any variable in the regressions, but it is rather due to casual factors. We can therefore exclude the presence of attrition bias. The results of the attrition test are displayed in the regression tables (see Table A.2). Regressions are also run taking into account heteroskedasticity, which is corrected through robust estimations[16].

The results of the DD estimation (Table A.2 of the Appendix) show a general positive effect of the law on both R&D expenditures and R&D employment. However, only a few cases satisfy the conventional significance threshold (90%) that excludes the possibility of a null or even negative effect. In particular, the first part of the law appears to have positive and significant effects on R&D expenditures, but only in the first period of observation. On the other hand, the second part of the law displays positive and significant effects on R&D employment, but again only in the first period of observation (Waves 7 and 8).

When moving onto the DDD estimations, where other R&D incentives are taken into account, the results change considerably (Table A.3 of the Appendix). In particular, whereas the other R&D incentives always display positive and significant results, the coefficient of Law 46/82 (that gives the effect of the law in absence of other R&D incentives) loses significance in all the different specifications and periods of observation. Moreover, although never significant, the DDD estimator often appears with a negative sign; this means that the effect of receiving Law 46/82 in presence of other R&D incentives is smaller than the effect of receiving it alone[17]. These results suggest that multiple treatment is an issue that needs to be carefully investigated. In this case it appears that the first positive effects of the law detected in the DD estimation were in fact due to other R&D incentives and that there might be an inefficient overlapping of instruments to support R&D investments.

In addition, these estimations return an average effect that is equal for all kinds of firms. As already mentioned, the homogeneity of effects is probably an unrealistic assumption in this case and it is worth looking at subgroups of firms that share similar characteristics. The idea is to have a clearer picture of the type of firm that might benefit the most from FAR and FIT. Tables A.4 and A.5 of the Appendix provide a separate estimation of the DDD model for large firms and for medium and small enterprises (SMEs). Again, some slight changes in the results appear. In particular, a positive effect of the first part of the law can be detected for large firms on both R&D expenditures and employment, but only for the period between the waves 7 and 8[18]. On the other hand, a negative effect appears for SMEs on both expenditures and number of workers in R&D, but again limited to the first part of the Law and to the first period. We recall that the Law 46/82 is much more utilised by large firms than small-medium ones (see Section 5) and this is consistent with such results. The second part of the Law does not appear to have effects on either SMEs or large firms. Both the first and the second part of the Law seem to have no effects whatsoever in the second period of observation (that is after the reform of 2001).

It is worth noting that, when considering the sub-sample of large firms, the effects of other R&D incentives also seem to lose some significance (in particular in the second period of observation), whereas they remain always positive and highly significant for SMEs.

Even in this disaggregated analysis the interaction term (DDD estimator) is never significant, signalling that neither among large nor among small-medium firms the

co-presence of different incentives has a multiplicative effect; on the contrary, the sign continues to be frequently negative.

We tried to go beyond an analysis of the aggregate effect of the Law 46/82 also by investigating the effects of the law in each of the four group of firms identified by the Pavitt taxonomy. Then, within each Pavitt group we estimated the effects for large firms and for SMEs. The results are shown in Tables A.6–A.9.

It is difficult to identify a sub-group of firms where the Law 46/82 results with no doubt effective in each of the considered periods; nevertheless, we may identify some interesting 'partial' effects.

1 In the first Pavitt group (supplier dominated) the second part of the Law 46/82 (FIT) has a positive effect on the number of R&D employees of large firms in the 2001–2003 period.

2 In the second Pavitt group (scale intensive), some positive effects of the law on large firms can also be observed; in this case the effect is on R&D expenditures, again by FIT in the 2001–2003 period, but also by FAR in the first period.

Among the firms belonging to the third and fourth Pavitt group (respectively: specialised suppliers and science-based), more intensively innovative, the incentives for R&D are more diffused, particularly among large firms, as seen in Section 5. Nevertheless, even in these groups it is possible to find only partial positive effects of Law 46/82.

3 In the third Pavitt group (specialised suppliers) the first part of the law has a significant effect, in the second considered period, both on expenditures and employees in R&D. It is worth noting that this effect is concentrated on small-medium firms.

4 In the fourth Pavitt group (science-based), where R&D is particularly important, there is a positive and significant effect of the law in the second period. This is observable for both parts of the law on R&D employment. In this case the positive effect is observed for the whole sample of firms and for SMEs (limited to FIT). Due to lack of variability it was not possible to estimate the regression for large firms.

These last results seem important: as they concern the period 2001–2003, they give some positive signs on the effect of the legislative reform in 2001, particularly on the most research-intensive firms.

We reported above the few cases where the coefficient of Law 46/82 resulted positive and significant. Indeed, it has also to be observed that this coefficient is sometimes significantly negative. As concerns the DDD estimator, its coefficient is seldom significant; the prevalence of the negative sign continues to be observed in these regressions. We believe that this aspect should be carefully considered by policy makers that wish to rationalise and re-organise the system of R&D incentives in Italy.

As regards the effect of other R&D incentives, it has to be remarked their significant positive effect in all the specification concerning the small-medium firms of the first and third Pavitt group. The effectiveness of the other R&D incentives, emerged in many of our analyses, suggests to deepen the analysis on these incentives in further works. In particular, it is necessary to go beyond their aggregation and identify the effect of each one, or at least of the most important ones.

8 Conclusions

In this paper we have recalled the importance of policy evaluation in the definition of industrial policy strategies, we have reviewed the theoretical reasons why government should support private expenses in R&D and reported the results of the main attempts to evaluate this kind of policies. Then we focused our attention on the Italian system of incentives to R&D and innovation, underlining how it is exposed to potential overlapping problems. We focussed in particular on the effects of a specific Law – 46/1982. An investigation on the average effect of the law (and its two main operating funds FAR and FIT) shows no significant effect on firms' R&D expenses or employment once other R&D incentives are at work. These results appear particularly discouraging if considered that the other R&D incentives appear, with few exceptions, positive and significant. Moreover, the combined effect of Law 46/82 and other R&D incentives appears most of the time with a negative sign.

These average results are in part mitigated once we consider possible heterogeneous responses of firms to policy incentives. When large firms are analysed separately from SMEs some positive results emerge for large firms, while negative effects appear for small firms. These findings are not systematic and are only limited to the first period of observation. Moreover, these results are particularly discouraging if considered that the other R&D incentives appear, with few exceptions, positive and significant. Indeed, even this kind of analysis suffers from a high level of aggregation. In fact, when the Pavitt classification is taken into consideration and crossed with the distinction by firm size, some interesting results emerge and we are able to offer more precise policy indications. In particular there are some positive signals about the effects of the Law 46/82 after its re-organisation in 2001. The analysis by sub-groups of firms suggests that it would probably be worth concentrating incentives under Law 46/82 on these specific types of firms: large supplier dominated and scale intensive firms (particularly through FIT), specialised SMEs suppliers (particularly through FAR) and science-based firms (through both funds).

Two general warnings emerge from our study. First of all, when a specific public intervention is adopted in presence of similar policies, there is a need to take explicitly into consideration the context, to isolate the effects of the different policy instruments and to study their combined effects. This is important to formulate policy suggestions that can help avoid useless overlapping of incentives. Secondly, there is a need in the evaluation practice to go beyond the use of mean effects, particularly when the response of beneficiaries is likely to be heterogeneous, as it is in the case of firms. Identifying the specific groups where the policy is effective may reduce the entity of public expenditure and increase its effectiveness.

References

Aerts, K. and Czarnitzki, D. (2004) 'Using innovation survey data to evaluate R&D policy: the case of Belgium', *ZEW Discussion Paper* 04-55, Mannheim. Also appeared as Research Report OR 0439, K.U. Leuven, Dept. of Applied Economics.

Aerts, K. and Schmidt, T. (2008) 'Two for the price of one?: Additionality effects of R&D subsidies: a comparison between Flanders and Germany', *Research Policy*, Vol. 37, No. 4, pp.806–822.

Almus, M. and Czarnitzki, D. (2003) 'The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany', *Journal of Business and Economic Statistics*, Vol. 21, No. 2, pp.226–236.

Ashenfelter, O. and Card, D. (1985) 'Using the longitudinal structure of earnings to estimate the effect of training programs', *The Review of Economics and Statistics*, Vol. 67, No. 4, pp.648–60.

Arrow, J.K. (1962) 'Economics welfare and allocation of resources for innovation', in Nelson, R. (Ed.): *The Rate and Direction of Inventive Activity,* Princeton University Press, Princeton (NJ).

Bach, L. and Matt, M. (2002) 'Rationale for science and technology policy', in Georghiou, L., Rigby, J. and Cameron, H. (Eds.): *Assessing the Socio-Economic Impacts of the Framework Programme*, report to DG research, available at http://les.man.ac.uk/PREST/Download/ASIF_report.pdf (accessed on 20/09/2010).

Bach, L. and Matt, M. (2005) 'From economic foundations to S&T policy tools: a comparative analysis of the dominant paradigms', in Llerena, P. and Matt, M. (Eds.): *Innovation Policy in a Knowledge Based Economy: Theory and Practice*, pp.17–46, Springer-Verlag Berlin Heidelberg.

Barbieri, E. (2010) 'The evaluation of policies for knowledge transfer: some emerging issues', *International Journal of Healthcare Technology Management*, Vol. 11, No. 4, pp.263–282.

Barbieri, E., Iorio, R. and Lubrano-Lavadera, G. (2010) 'Incentivi alla Ricerca & Sviluppo in Italia: una indagine sugli effetti della legge 46/82', *L'Industria*, Vol. XXXI, No. 2, pp.327–358.

Barbieri, E. and Santarelli, E. (2010) 'La Valutazione delle Politiche Industriali', in Bianchi, P. and Pozzi, C. (Eds.): *Le Politiche Industriali alla Prova del Futuro*, Il Mulino, Bologna (in stampa).

Bertrand, M., Duflo, E. and Mullainatha, S. (2004) 'How much should we trust differences-in-differences estimates?', *Quarterly Journal of Economics*, Vol. 119, No. 1, pp.249–275.

Blundell, R., Macurdy, T. and Meghir, C. (2007) 'Labor supply models: unobserved heterogeneity, nonparticipation and dynamics', in Heckman, J.J. and Leamer, E.E. (Eds.): *Handbook of Econometrics*, North-Holland, Amsterdam.

Busom, I. (2000) 'An empirical evaluation of the effects of R&D subsidies', *Economics of Innovation and New Technology*, Vol. 9, No. 2, pp.111–148.

Centro Studi Capitalia (1998) 'VII indagine sulle Imprese Manifatturiere, 1995–1997', Capitalia, Rome.

Centro Studi Capitalia (2001) 'VIII indagine sulle Imprese Manifatturiere, 1998–2000', Capitalia, Rome.

Centro Studi Capitalia (2004) 'IX indagine sulle Imprese Manifatturiere, 2001–2003', Capitalia, Rome.

Coad, A. and Rao, R. (2008) 'Innovation and firm growth in high-tech sectors: a quantile regression approach', *Research Policy*, Vol. 37, No. 4, pp.663–648.

Damijan, P.J., Kostevc, C. and Rojec, M. (2011) 'Innovation and firms' productivity growth in Slovenia: sensitivity of results to sectoral heterogeneity and to estimation method', in Nijkamp, P. and Siedschlag, I. (Eds.): *Innovation, Growth and Competitiveness, Advances in Spatial Science*, pp.165–194, Springer-Verlag Berlin Heidelberg.

David, A.P., Hall, H.B. and Toole, A.A. (2000) 'Is public R&D a complement or substitute for private R&D? A review of the econometric evidence', *Research Policy*, Vol. 29, No. 4, pp.497–529.

De Blasio, G., Fantino, D. and Pellegrini, G. (2009) *Evaluating the Impact of Innovation Incentives: Evidence from an Unexpected Shortage of Funds*, mimeo.

Duguet, E. (2004) 'Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non experimental data', *Revue d'Economie Politique,* Vol. 114, No. 2, pp.263–292.

Falk, M. (2010) 'Quantile estimates of the impact of R&D intensity on firm performance', *Small Business Economics*, published online 11th July 2010.

Georghiou, L. (2002) 'Impact and additionality of innovation policy', in Boekholt, P. (Ed.): *Innovation Science Technology – Innovation Policy and Sustainable Development: Can Public Incentives Make a Difference?*, IWT-Studies, IWT-Observatory, Brussels.

Görg, H. and Strobl, E. (2007) 'The effect of R&D subsidies on private R&D', *Economica,* Vol. 74, No. 294, pp.215–234.

González, X.J., Jaumandreu and C. Pazó (2005) "Barriers to innovation and subsidy effectiveness", *RAND Journal of Economics,* Vol. 36, No. 4, pp. 930–950.

Griliches, Z. (1990) 'Patent statistics as economic indicators: a survey', *Journal of Economic Literature*, December, Vol. 28, No. 4, pp.1661–1707.

Heckman, J.J., Ichimiura, H., Smith, J. and Todd, P.E. (1998) 'Characterizing selection bias using experimental data', *Econometrica*, Vol. 66, No. 5, pp.1017–1098.

Holemans, B. and Sleuwaegen, L. (1988) 'Innovation expenditures and the role of government in Belgium', *Research Policy*, Vol. 17, No. 6, pp.375–379.

Heijs, J. and Herrera, L. (2004) 'The distribution of R&D subsidies and its effect on the final outcome of innovation policy', working paper Instituto de Análisis Industrial y Financiero 46, Madrid.

Hölzl, W. (2009) 'Is the R&D behaviour of fast growing SMEs different? Evidence from CIS III data for 16 countries', *Small Business Economics*, Vol. 33, No. 1, pp.59–75.

Imbens, G.W. and Wooldridge, J.M. (2009) 'Recent developments in the econometrics of program evaluation', *Journal of Economic Literature*, Vol. 47, No. 1, pp.5–86.

Kaiser, U. (2004) 'Private R&D and public R&D subsidies: microeconometric evidence from Denmark', CEBR Discussion Paper, No. 19, Denmark.

Klette, T.J., Moen, J. and Griliches, Z. (2000) 'Do subsidies to commercial R&D reduce market failures? Microenomic evaluation studies', *Research Policy*, Vol. 29, pp.471–495.

Lach, S. (2002) 'Do R&D subsidies stimulate or displace private R&D? Evidence from Israel', *Journal of Industrial Economics*, Vol. 50, No. 4, pp.369–390.

Levy, D.M. and Terleckyj, N.E. (1983) 'Effects of government R&D on private R&D investment and productivity: a macroeconomic analysis', *Bell Journal of Economics*, Vol. 14, No. 2, pp.551–561.

Lichtenberg, F.R. (1987) 'The effect of government funding on private industrial research and development: a re-assessment', *The Journal of Industrial Economics*, Vol. 36, No. 1, pp.97–104.

Lööf, H. and Heshmati, A. (2005) 'The impact of public funding on private R&D investment. New evidence from a firm level innovation study', CESIS working Paper 06, Sweden.

Malerba, F. (2009) 'Increase learning, break knowledge lock-ins and foster dynamic complementarities: evolutionary and system perspectives on technology policy in industrial dynamics', in Foray, D. (Ed.): *The New Economics of Technology Policy*, pp.33–45, Edward Elgar, Cheltenham, UK.

Merito, M., Giannangeli, S. and Bonaccorsi, A. (2007) 'Gli incentivi per la ricerca e lo sviluppo industriale stimolano la produttività della ricerca e la crescita delle imprese? Evidenza sul caso italiano', *L'Industria – Rivista di Economia e Politica Industriale*, Vol. XXVIII, No. 2, pp.221–242.

Metcalfe, J.S. (1995) 'The economic foundations of economic policy: equilibrium and evolutionary perspectives', in Stoneman, P. (Ed.): *Handbook of the Economics of Innovation and Technological Change*, Blackwell Handbooks in Economics, pp.409–512.

Ministero dello Sviluppo Economico (2008) 'Strumenti automatici e valutativi nelle politiche di incentivazione alle imprese', Settembre 2008.

Ministero dello Sviluppo Economico (2009) 'Relazione sugli interventi di sostegno alle attività economiche e produttive', June 2009.

Moulton, B. (1990) 'An illustration of a pitfall in estimating the effects of aggregate variables on micro unit', *Review of Economics and Statistics*, Vol. 72, No. 2, pp.334–338.

Nelson, R.R. (2009) 'Building effective innovation systems versus dealing with market failures as ways of thinking about technology policy', in Foray, D. (Ed.): *The New Economics of Technology Policy*, pp.7–16, Edward Elgar, Cheltenham UK.

Nordhaus, W.D. (1969) 'Invention growth and welfare', MIT Press, Cambridge (MA).

O'Higgins, N. and Nese, A. (2007) 'Panel attrition in the Capitalia panel', *International Review of Economics*, Vol. 54, No. 3, pp.383–403.

Potì, B. and Cerulli, G. (2010) 'Valutazione di Impatto', in Potì, B. (Ed.): *Modelli e metodologie per la valutazione dell'impatto del finanziamento pubblico alla ricerca industriale*, Final Report FIRB Project, Rome.

Rolfo, S. and Calabrese, G. (2005) 'Triple helix in Italy: from national to regional approach', Paper presented at the *5th Triple Elix Conference*, 18–21 May, Turin.

Serrano-Velarde, N. (2008) *Crowding Out at the Top: The Heterogeneous Impact of R&D Subsidies on Firm Investment,* mimeo.

Shadish, W.R., Cook, T.D. and Leviton, L.C. (1991) *Foundations of Program Evaluation: Theories of Practice*, Sage Publications, Newbury Park.

Sissoko, A. (2011) 'R&D subsidies and firm-level productivity: evidence from France', *Ires Discussion Paper*, 2011-2, Leuven.

Smith, J. (2004) 'Evaluating local economic development policies: theory and practice', in OECD (2004) *Evaluating Local Economic and Employment Development*, Organization for Economic Cooperation and Development, Paris.

Stam, E. and Wennberg, K (2009) 'The roles of R&D in new firm growth', *Small Business Economics*, Vol. 33, No. 1, pp.77–89.

Suetens, S. (2002) 'R&D subsidies and production effects of R&D personnel: evidence from the Flemish region', CESIT Discussion Paper 2002/03, Antwerp.

Toivanen, O. and Niininen, P. (1998) 'Investment, R&D, subsidies and credit constraints', Working Paper, Department of Economics MIT and Helsinki School of Economics.

Verbeek, M. and Nijman, T. (1992) 'Testing for selectivity bias in panel data models', *International Economic Review*, Vol. 33, No. 3, pp.681–703.

Wallsten, S.J. (2000) 'The effects of government-industry R&D programs on private R&D: the case of the small business innovation research program', *RAND Journal of Economics*, Vol. 31, No. 1, pp.82–100.

Wooldridge, J.M. (2002) 'Econometric analysis of cross section and panel data', MIT Press, Cambridge, MA.

Wooldridge, J.M. (2007) 'What's new in econometrics? Lecture 10, differences-in-differences estimation', NBER Summer Institute, available at http://www.nber.org (accessed on 15/06/2010).

Notes

1 This paper is the result of a strict collaboration among the authors. Anyway sections 1, 3, 3.1 and 6.1 may be mainly attributed to Elisa Barbieri; Sections 2 and 4 to Roberto Iorio; Sections 5 and 6.3 to Giuseppe Lubrano Lavadera. Sections 6.2, 7 and Conclusions have been jointly written.

2 The financed research must be conducted in external public or private laboratories, authorised by the government.

3 The Legislative Decree n. 297/1999, which became effective in 2001, unified many of these programs, precisely: Law 46/82; Law 488/1992 (the part concerning research); Law 346/1988; Law 196/1997 (art.14); Law 449/1997 (art.5) in a unique Fund to Facilitate Research (FAR).

4 Other laws that offer subsidies for innovation, as revealed by the firms of our sample, are: Law 140/1997, that grants fiscal benefits to PMI on research and innovation expenditures; D.L.357/1994 and its subsequent legislative modifications (so called 'law Tremonti') that reduces taxes for profits reinvested in instrumental goods; Law 598/1994 (so called 'law Barsani') that grants low interest rates to SMEs that invest in research and innovation.

5 In illustrating the three procedures we followed a web page of the site of the Ministry of University and Research (http://www.miur.it/0003Ricerc/0139FAR_-_/0159Il_nuo/index_cf3.htm), which makes a comment to the Ministerial Decree n.593/2000; this decree made the Legislative decree n.297/1999 effective, substituting the first part (art.1–13) of the Law n.46/82.

6 Large firms are all the firms that do not meet at least one of the criteria to be defined as small-medium enterprises (SEMs). SMEs in turn are defined according to these three criteria: number of employees lower than 250; annual revenues not exceeding 40 million Euros; no ownership control by a large firm exceeding 25% of the capital.

7 The financed firms must declare that they are not benefiting from other specific public funds for programs with the same object and goals (precisely those established by Law n.1089/1968 and Law n.675/1977). Anyway an overlap of incentives still remains possible, as several other incentives exist and they are not mutually exclusive with Law 46/82.

8 Centro Studi Capitalia (Former Mediocredito Centrale) (1998, 2001, 2004).

9 The Neyman's Formula is an optimal distributive method that assigns the number of observations in a stratum while minimising the variance in the sample. It is obtained applying the following formula: $n_h = n * (N_h S_h / \sum N_h S_h)$, where: n_h = size of the stratum h; n = sample size, N_h = size of the population for the stratum h; S_h = size of appropriate class of stratum h.

10 For further reference see also Blundell et al. (2007) and Wooldridge (2007).

11 Alternatively we could have run the regression on the three periods, but in this case we should have assumed a constant effect of the law throughout nine years, which we guessed unrealistic (Bertrand et al., 2004).

12 Non-parametric matching methods, for instance, do not suffer from this limit. However, fixed effects estimation is preferred to deal with a selection mechanism based on observable variables if panel data are available. For further details see Abadie (2002), Dehejia and Wahba (1999)

13 The combined effect of Law 46/82 and other incentives to R&D is therefore given by $\beta_2 + \beta_3 + \beta 4$. It follows also that $\beta_2 + \beta_4$ is the effect of Law 46/82 if the firm receives also other R&D incentives and $\beta_3 + \beta_4$ is the effect of the other R&D incentives if the firm receives also Law 46/82 (Barbieri et al., 2010). In terms of counterfactual, the effect of law 46/82 is evaluated with respect to two situations: 1) firm receiving only incentives from law 46/82 vs. firm not receiving any incentive ($\beta 2$); 2) firm receiving incentives from law 46/82 and other incentives in R&D vs. firm receiving other incentives in R&D but not from law 46/82 ($\beta 2 + \beta 4$).

14 http://www.bancaditalia.it/statistiche

15 Verbeek and Nijman (1992) cited in Wooldridge (2002). Following them, we introduce in the regression a dummy variable, *nextwave*, that is equal to 1 if an observation is present also in the following wave. With a simple test (Nextwave), we test the hypothesis that P(Y|Nextwave,X) = P(Y|X). If the hypothesis is verified, the loss of observations is not related to variables in the regression but it is probably due to casualness.

16 This correction is made through the cluster method, which takes into account aggregate variables in the individual (single firm) estimations. A simple robust estimator in fact can under-estimate the error as noted by Moulton (1990).

17 The negative sign of the DDD estimator may of course be interpreted in the symmetrical way: the effect of receiving other incentives to R&D in presence of incentives from Law 46/82 is smaller than the effect of the same incentives in absence of Law 46/82. In some cases even the sum of the two coefficients is negative, meaning that a firm receiving Law 46/82 and other incentives spends less in R&D (or has less R&D employees) than an equivalent firm receiving only other incentives.

18 In this section, when we call about significant (positive or negative) effects of the Law 46, we refer to the coefficient of Law 46, that is the effect of the law in absence of other R&D incentives. Indeed, the interaction term (DDD term) in most cases is not significant or in some cases it was not possible to estimate, because of lack of variability. In these cases it is not possible to distinguish the effect of Law 46/82 in the two scenario (presence and absence of other R&D incentives). In a few cases the opposite happens: the coefficient for DDD estimator is significant, while the coefficient for Law 46/82 is not.

Appendix

Table A.1 Variables: definitions and calculations

Dependent variables	
R&D expenditures	ln (1 + total R&D expenditures in the wave)
R&D employment	ln (1 + average number of workers in R&D in the wave)
Time variable	
Wave	different meaning in different periods:
	Regressions in the waves 7–8: = 1 if the observation is in the VIII wave; = 0 if the observation is in the VII wave
	Regressions in the waves 8–9: = 1 if the observation is in the IX wave; = 0 if the observation is in the VIII wave
Policy variables	
Law46/82	different meaning according to the different regressions:
	Regression Law 46/8-wave 7–8: =1 if the firm receives incentives from any part of the law in the VIII wave; = 0 otherwise
	Regression Law 46/8-wave 8–9: = 1 if the firm receives incentives from any part of the law in the IX wave; = 0 otherwise
	Regression Law 46/8-Part I-wave 7–8: = 1 if the firm receives incentives from the first part of the law in the VIII wave; = 0 otherwise
	Regression Law 46/8-Part I-wave 8–9: = 1 if the firm receives incentives from the first part of the law in the IX wave; = 0 otherwise
	Regression Law 46/8-Part II-wave 7–8: = 1 if the firm receives incentives from the second part of the law in the VIII wave; = 0 otherwise
	Regression Law 46/8-Part II-wave 8–9: = 1 if the firm receives incentives from the second part of the law in the IX wave; = 0 otherwise
Other R&D incentives	different meaning according to the different regressions:
	Regression Law 46/8-wave 7–8: =1 if the firm receives other incentives but law46/82 in the VIII wave; = 0 otherwise
	Regression Law 46/ 8-wave 8–9: = 1 if the firm receives other incentives but law46/82 in the IX wave; = 0 otherwise
	Regression Law 46/8-Part I-wave 7–8: = 1 if the firm receives other incentives but the first part of the law46/82 in the VIII wave; = 0 otherwise
	Regression Law 46/8-Part I-wave 8–9: = 1 if the firm receives other incentives but the first part of the law46/82 in the IX wave = 0 otherwise
	Regression Law 46/8-Part II-Wave 7–8: = 1 if the firm receives other incentives but the second part of the law46/82 in the VIII wave; = 0 otherwise
	Regression Law 46/8-Part II-Wave 8–9: = 1 if the firm receives other incentives but the second part of the law46/82 in the IX wave; = 0 otherwise
DDD estimator	Law46/82*Other R&D incentives
Control variables	Z_i
Workers	Average number of workers in the wave
Log_sales	ln (1 + total sales in the wave)
Self-financing in R&D	Amount of self-financed R&S expenditures in the wave
Bank branches	Number of bank branches in the town of firm’s residence
R&D consortia	(= 1 if the firm is Part of an R&D Consortium; = 0 Otherwise)

Table A.2 *Difference –in– Differences*. Effects of Law 46 (total, part I and part II). Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients (standard errors in parenthesis)

	Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
	Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
	R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*
Wave	1.19***	0.17***	0.16	0.07**	1.30**	0.19***	0.20	0.07**	1.25***	0.17***	0.17	0.06**
	(0.22)	(0.03)	(0.18)	(0.02)	(0.22)	(0.03)	(0.17)	(0.02)	(0.22)	(0.03)	(0.18)	(0.02)
Law 46/82	2.10**	0.30**	0.76	0.11	2.27*	0.22	1.86	0.28	1.42	0.25*	0.52	0.14
	(0.69)	(0.10)	(0.56)	(0.09)	(1.06)	(0.12)	(1.39)	(0.21)	(0.76)	(0.11)	(0.55)	(0.09)
Log_sales	0.50	0.08	0.18	0.07	0.49	0.09	0.10	0.07	0.51	0.10	0.16	0.07
	(0.48)	(0.06)	(0.42)	(0.05)	(0.48)	(0.06)	(0.40)	(0.05)	(0.48)	(0.06)	(0.41)	(0.05)
Workers	–0.00	0.00	–0.00	0.00	0.00	0.00	–0.00	0.00*	–0.00	0.00	–0.00	0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Self-financing in R&D	0.01**	0.00**	0.02***	0.00	0.01**	0.00*	0.02***	0.00	0.01**	0.00**	0.01***	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Bank branches	–0.01	–0.00	0.01	0.00	–0.01	–0.00	0.01	0.00	–0.01	–0.00	0.01	0.00
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.0)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
R&D consortia	0.64	–0.05	0.86	–0.06	0.66	–0.09	1.80	0.06	0.60	–0.05	0.80	–0.05
	(2.42)	(0.20)	(1.12)	(0.23)	(2.49)	(0.19)	(1.17)	(0.17)	(2.43)	(0.20)	(1.00)	(0.21)
_Costant	–4.68	–1.04	0.68	–0.70	–4.79	–1.05	2.14	–0.64	–4.89	–1.23	1.23	–0.78
	(7.98)	(2.65)	(7.02)	(1.78)	(8.00)	(2.66)	(6.77)	(1.72)	(7.90)	(2.69)	(6.98)	(1.78)
Hausman test FE vs RE	24.62***	65.98***	36.24***	60.86***	17.87*	61.64***	27.43***	38.54***	26.03***	59.37***	34.18***	53.89***
NEXTWAVE	0.47	–0.51	–0.24	–0.31	0.52	–0.26	–0.22	–0.29	0.59	–0.34	–0.23	–0.31
N	7,380	7,153	7,181	6,892	7,462	7,232	7,323	7,024	7,425	7,197	7,234	6,936
Adjusted R-squared	0.054	0.085	0.022	0.029	0.052	0.076	0.019	0.026	0.049	0.081	0.018	0.028
Log likelihood	-14,221.5	1,535.9	-14,610	270.0	-14,500	1,514.8	-15,000.4	95.13	-14,356	1,479.2	-14,760.2	213.3

Notes: * Significance: * $\alpha < 5\%$; ** $\alpha < 1\%$; *** $\alpha < 0.1\%$
Hausman values of χ^2 and significance.
T-test values for the attrition variable NEXTWAVE and significance

Table A.3 *Difference -in-Difference-in Difference (DDD)***.** Effects of Law 46 (total, part I and part II). Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients (standard errors in parenthesis)

	Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
	Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
	R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*
Wave	0.87***	0.12***	0.10	0.06**	0.87***	0.12***	0.11	0.06**	0.87***	0.12***	0.11	0.06**
	(0.23)	(0.03)	(0.19)	(0.02)	(0.23)	(0.03)	(0.20)	(0.02)	(0.23)	(0.03)	(0.19)	(0.02)
Law 46/82	0.37	0.16	0.41	0.12	0.41	0.27	2.58	–0.17	0.41	0.07	0.00	0.07
	(1.01)	(0.18)	(0.93)	(0.12)	(0.71)	(0.30)	(4.66)	(0.17)	(1.30)	(0.20)	(0.93)	(0.12)
Other R&D incentives	5.44***	0.57***	4.83***	0.36***	4.69***	0.52***	3.24***	0.29***	5.26***	0.54***	4.73***	0.34***
	(0.64)	(0.09)	(0.65)	(0.08)	(0.56)	(0.08)	(0.53)	(0.07)	(0.61)	(0.09)	(0.66)	(0.08)
DDD estimator	–1.32	–0.14	–1.56	–0.09	–1.58	–0.34	–2.58	0.67	–1.64	0.05	–0.89	0.09
	(1.48)	(0.24)	(1.40)	(0.24)	(1.69)	(0.34)	(5.14)	(0.48)	(1.71)	(0.26)	(1.41)	(0.24)
Log_sales	0.20	0.07	0.36	0.07	0.22	0.07	0.37	0.08	0.24	0.07	0.36	0.07
	(0.50)	(0.06)	(0.41)	(0.05)	(0.50)	(0.06)	(0.41)	(0.05)	(0.49)	(0.06)	(0.41)	(0.05)
Workers	–0.00	0.00	–0.01*	–0.00	–0.00	0.00	–0.01	–0.00	–0.00	0.00	–0.01*	–0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Self-financing in R&D	0.02***	0.00***	0.02***	0.00*	0.02***	0.00***	0.02***	0.00*	0.02***	0.00***	0.02***	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Bank branches	–0.01	–0.00	0.01	0.00	–0.01	–0.00	0.01	0.00	–0.01	–0.00	0.01	0.00
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
R&D consortia	1.54	–0.03	–1.61	–0.11	1.61	–0.03	–1.19*	–0.09	1.52	–0.03	–1.58	–0.10
	(2.34)	(0.15)	(0.89)	(0.37)	(2.39)	(0.15)	(0.60)	(0.36)	(2.35)	(0.16)	(0.87)	(0.37)
_Costant	–0.41	–0.75	–2.93	–0.83	–0.50	–0.75	–2.96	–0.86	–0.84	–0.78	–2.84	–0.83
	(8.23)	(0.95)	(6.86)	(0.78)	(8.22)	(0.95)	(6.98)	(0.77)	(8.21)	(0.95)	(6.86)	(0.78)
Hausman test FE vs RE	33.55***	77.17***	56.34***	115.81***	33.81***	66.44***	47.07***	100.64***	35.20***	68.59***	56.77***	118.46***
NEXTWAVE	0.53	–0.24	–0.32	0.50	0.37	–0.37	–0.33	–0.35	0.44	–0.17	–0.32	–0.34
N	7,123	6,904	6,761	6,519	7,123	6,904	6,761	6,519	7,123	6,904	6,761	6,519
Adjusted R-squared	0.147	0.136	0.085	0.055	0.137	0.131	0.071	0.055	0.144	0.138	0.087	0.057
Log likelihood	–13,113.3	1,999.5	–13,288.0	857.7	–13,157.0	1,978.1	–13,341.8	8,57.7	–13,126.2	2,007.0	–13,283.1	864.7

Notes: * Significance: * $\alpha < 5\%$; ** $\alpha < 1\%$; *** $\alpha < 0.1\%$
Hausman values of χ^2 and significance.
T-test values for the attrition variable NEXTWAVE and significance

Table A.4 *Difference -in-Difference-in Difference (DDD)*. Effects of Law 46 (total, part I and part II) *for Small-Medium firms*. Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients (standard errors in parenthesis)

	Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
	Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
	R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*
Wave	0.78***	0.12**	0.15	0.07***	0.79***	0.12***	0.15	0.07**	0.78***	0.12***	0.15	0.07**
	(–0.23)	(–0.03)	–0.19	–0.02	(0.23)	(0.03)	(0.19)	(0.02)	(0.23)	(0.03)	(0.19)	(0.02)
Law 46/82	0.25	0.10	1.16	0.09	–0.59*	–0.11***	2.46	–0.19	0.39	0.05	0.73	0.05
	(–1.17)	(–0.19)	(1.04)	(0.10)	(0.23)	(0.03)	(4.63)	(0.17)	(1.37)	(0.21)	(1.02)	(0.10)
Other R&D incentives	5.17***	0.49***	4.92***	0.34***	4.70***	0.45***	3.70***	0.26***	4.97***	0.46***	4.80***	0.31***
	(–0.69)	(–0.10)	(0.67)	(0.08)	(0.61)	(0.09)	(0.56)	(0.06)	(0.66)	(0.09)	(0.68)	(0.08)
DDD estimator	–0.33	–0.05	–2.12	–0.12	–1.69	–0.03	–2.23	0.62	–0.23	0.13	–1.16	0.04
	(–1.72)	(–0.26)	(1.60)	(0.21)	(1.71)	(0.17)	(5.25)	(0.58)	(1.90)	(0.29)	(1.61)	(0.23)
Log_sales	0.33	0.09	–0.06	0.01	0.31	0.09	–0.04	0.01	0.34	0.09	–0.07	0.00
	(–0.48)	(–0.06)	(0.36)	(0.04)	(0.48)	(0.06)	(0.37)	(0.04)	(0.48)	(0.06)	(0.36)	(0.04)
Workers	0.05***	0.00**	0.04**	0.01***	0.05***	0.01**	0.04**	0.01**	0.05***	0.01**	0.04**	0.01***
	(–0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
Self-financing in R&D	0.01**	0.00*	0.02***	0.00**	0.01**	0.00*	0.02***	0.00**	0.01**	0.00*	0.02***	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Bank branches	0.01	0.00	0.02*	0.00	0.01	–0.00	0.02	0.00	0.01	0.00	0.02*	0.00
	(–0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
R&D consortia	1.44	0.02	–1.71	–0.11	1.40	0.00	–1.39	–0.09	1.45	0.03	–1.68	–0.10
	(–2.85)	(–0.17)	(0.99)	(0.36)	(2.88)	(0.17)	(0.77)	(0.35)	(2.87)	(0.17)	(0.97)	(0.36)
_Costant	–5.58	–1.42	0.15	0.07***	–5.17	–1.40	0.70	–0.04	–5.78	–1.43	1.15	0.01
	(–7.80)	(–1.01)	(0.19)	(0.02)	(7.81)	(1.01)	(6.00)	(0.68)	(7.79)	(1.01)	(5.84)	(0.68)
Hausman test FE vs RE	29.73***	56.63***	38.51***	108.38***	33.20***	55.89***	33.00***	89.92***	28.96***	50.31***	38.30***	110.71***
NEXTWAVE	0.06	0.06	0.33	0.33	0.03	0.03	0.32	0.32	0.05	0.05	0.33	0.33
N	6,554	6,381	6,206	6,091	6,554	6,381	6,206	6,091	6,554	6,381	6,206	6,091
Adjusted R-squared	0.17	0.16	0.094	0.073	0.156	0.156	0.084	0.072	0.163	0.163	0.095	0.074
Log likelihood	–11,692.1	2,751.7	–1,2159.7	1,544.3	–11,728.2	2,732.8	–12,192.9	1,542.1	–11,703.4	2,758.6	–12,155.6	1,547.5

Notes: * Significance: * $\alpha < 5\%$; ** $\alpha < 1\%$; *** $\alpha < 0.1\%$
Hausman values of χ^2 and significance.
T-test values for the attrition variable NEXTWAVE and significance

Table A.5 *Difference -in-Difference-in Difference (DDD)*. Effects of Law 46 (total, part I and part II) *for Large firms*. Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients (standard errors in parenthesis)

	Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
	Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
	R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*
Wave	0.20	–0.01	–0.85	–0.18	0.20	–0.02	–0.89	–0.15	0.28	–0.01	–0.79	–0.15
	(1.19)	(0.22)	(1.49)	(0.34)	(1.19)	(0.22)	(1.50)	(0.35)	(1.19)	(0.22)	(1.50)	(0.34)
Law 46/82	3.80	0.60	–2.62	–0.01	6.28*	1.17***	0.37	0.24	0.44	0.04	–2.93	–0.34
	(2.06)	(0.45)	(3.06)	(0.94)	(2.63)	(0.22)	(1.82)	(0.63)	(1.15)	(0.22)	(3.27)	(1.13)
Other R&D incentives	7.15***	1.39***	2.21	0.99*	5.60***	1.29***	0.34	0.79	7.15***	1.36***	2.19	0.98*
	(1.87)	(0.37)	(1.41)	(0.49)	(1.63)	(0.33)	(1.96)	(0.54)	(1.69)	(0.34)	(1.41)	(0.49)
DDD estimator	–6.01*	–0.46	4.08	0.67	–4.56	–0.49	NO	NO	–3.67	0.12	3.71	0.83
	(2.90)	(0.62)	(3.07)	(1.19)	(3.94)	(0.36)			(2.13)	(0.45)	(3.21)	(1.27)
Log_sales	–4.27	–0.11	–1.41	1.27	–3.96	–0.10	–1.53	1.24	–4.29	–0.10	–1.13	1.39
	(2.31)	(0.11)	(3.50)	(0.84)	(2.41)	(0.11)	(3.56)	(0.82)	(2.32)	(0.11)	(3.51)	(0.86)
Workers	–0.00	–0.00	–0.01	–0.00	–0.00	–0.00	–0.01	–0.00	–0.00	–0.00	–0.01	–0.00
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Self-financing in R&D	0.06**	0.01**	0.03	–0.00	0.06**	0.01**	0.04	–0.00	0.06**	0.01**	0.03	–0.00
	(0.02)	(0.00)	(0.03)	(0.01)	(0.02)	(0.00)	(0.02)	(0.01)	(0.02)	(0.00)	(0.03)	(0.01)
Bank branches	–0.04	–0.01	0.02	0.01	–0.04	–0.01	0.01	0.00	–0.04	–0.01	0.01	0.00
	(0.02)	(0.00)	(0.02)	(0.01)	(0.02)	(0.00)	(0.02)	(0.01)	(0.02)	(0.00)	(0.02)	(0.01)
R&D consortia	2.45	–0.93	NO	NO	2.97	–0.75	NO	NO	2.77	–0.91	NO	NO
	(3.53)	(0.87)			(2.91)	(0.82)			(3.73)	(0.87)		
_Costant	93.38*	4.06	40.32	–22.40	87.22	3.83	42.71	–21.63	94.57*	3.98	35.96	–24.15
	(43.91)	(2.36)	(65.11)	(15.05)	(45.73)	(2.36)	(66.03)	(14.65)	(44.17)	(2.33)	(65.12)	(15.30)
Hausman test FE vs RE	18.62*	9.68	13.80	6.21	20.15*	8.39	15.02*	5.25	20.99*	9.83	14.37	6.37
NEXTWAVE	0.88	0.88	0.05	0.05	0.75	0.75	0.04	0.04	0.67	0.67	0.05	0.05
N	569	523	555	428	569	523	555	428	569	523	555	428
Adjusted R-squared	0.236	0.228	0.213	0.111	0.229	0.222	0.182	0.084	0.248	0.232	0.213	0.118
Log likelihood	–1,170.7	–146.7	–1,037.9	–199.5	–1,173.5	–148.8	–1,049.3	–206.6	–11,66.1	–145.3	–1,038.1	–198.0

Notes: * Significance: * $\alpha < 5\%$; ** $\alpha < 1\%$; *** $\alpha < 0.1\%$
Hausman values of $\chi 2$ and significance
T-test values for the attrition variable NEXTWAVE and significance
"NO" means that it has not been possible to estimate that coefficient

Tables A.6 *Difference -in-Difference-in Difference (DDD)*. Effects of Law 46 (total, part I and part II) among *Pavitt 1 (supplier-dominated)* firms classification/by firm size**.** Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients. *Only policy variables and significant (at 5%) coefficients are shown.*

		Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
		Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
		R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employm ent*
Pavitt 1 all firms	Law 46/82												
	Other R&D incentives	6.86***	0.67***	5.25***	0.39***	6.15***	0.62***	3.51***	0.30**	6.49***	0.64***	5.29***	0.37**
	DDD estimator			–3.98*			–0.63*	–8.01*	0.31**			–3.66*	
	N	3,540	3,435	3,582	3,460	3,540	3,435	3,582	3,460	3,540	3,435	3,582	3,460
Pavitt 1 small and medium firms	Law 46/82												
	Other R&D incentives	6.68***	0.64***	5.58***	0.36**	5.91***	0.57***	3.62***	0.26**	6.26***	0.61***	5.61***	0.33**
	DDD estimator			–4.32*		–5.74***	–0.66*	–8.10*	0.35**			–3.96*	
	N	3,340	3,248	3,368	3,288	3,340	3,248	3,368	3,288	3,340	3,248	3,368	3,288
Pavitt 1 large firms	Law 46/82				1.69***		NO		NO				1.69***
	Other R&D incentives	8.91**				7.68***	0.98*		1.56*	8.67***		5.61***	
	DDD estimator				NO		NO		NO			–3.96*	NO
	N	200	187	214	172	200	187	214	172	200	187	214	172

Notes: Significance: *α < 5%; ** α <1%; ***; α<0.1***
"NO" means that it has not been possible to estimate that coefficient; it has been reported only if, in the same regression, at least one of the other policy variables is significant.

Tables A.7 *Difference -in-Difference-in Difference (DDD)*. Effects of Law 46 (total, part I and part II among *Pavitt 2* (*scale-intensive*) firms classification/by firm size**.** Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients. *Only policy variables and significant (at 5%) coefficients are shown*.

		Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
		Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
		R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*
Pavitt 2 all firms	Law 46/82							–11.50***	–0.68***				
	Other R&D incentives			5.12***	0.27*			3.32***		3.72*		3.83*	
	DDD estimator				1.24**			NO	NO				1.27**
	N	1,468	1,423	1,203	1,155	1,468	1,423	1,203	1,155	1,468	1,423	1,203	1,155
Pavitt 2 small and medium firms	Law 46/82			–6.16*				–11.69**					
	Other R&D incentives		0.64***	4.13**	0.36**		0.57***		0.26**		0.61**		0.33**
	DDD estimator			12.51***	1.35***		–0.66*	NO	0.35**			12.60***	
	N	1,302	1,268	1,077	1,060	1,302	1,268	1,077	1,060	1,302	1,268	1,077	1,060
Pavitt 2 large firms	Law 46/82	18.51***		8.09***	–1.41*	18.77***	NO	NO				8.09***	–1.41*
	Other R&D incentives		1.85***		4.13***		1.57**	10.07***		7.96*	1.85**		4.13***
	DDD estimator	–19.56***	NO	NO	NO	NO	NO	NO		NO	NO	NO	NO
	N	166	155	126	95	166	155	126	95	166	155	126	95

Notes: Significance: *α < 5%; ** α <1%; ***; α<0.1***
"NO" means that it has not been possible to estimate that coefficient; it has been reported only if, in the same regression, at least one of the other policy variables is significant.

Tables A.8 *Difference -in-Difference-in Difference (DDD)*. Effects of Law 46 (total, part I and part II) among *Pavitt 3* (*specialised*) firms classification/by firm size. Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients. *Only policy variables and significant (at 5%) coefficients are shown.*

		Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
		Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
		R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*
Pavitt 3 all firms	Law 46/82							10.21***	0.20*				
	Other R&D incentives	4.54***	0.36*	4.49***	0.34*	4.52***	0.44**	2.93**	0.32*	4.35***	0.33*	4.67***	0.33*
	DDD estimator						NO						
	N	1,762	1,706	1,667	1,609	1,762	1,706	1,667	1,609	1,762	1,706	1,667	1,609
Pavitt 3 small and medium firms	Law 46/82							10.83***	0.16*				
	Other R&D incentives	4.48***	0.37*	4.90***	0.37*	4.84***	0.41**	4.65***	0.29*	4.37***	0.33*	5.08***	0.36*
	DDD estimator					NO	NO	–8.82*					
	N	1,603	1,563	1,501	1,483	1,603	1,563	1,501	1,483	1,603	1,563	1,501	1,483
Pavitt 3 large firms	Law 46/82			–15.99**				NO				–15.99**	
	Other R&D incentives			–5.72*		4.05*	2.09*	–10.28**		3.72*		–5.72*	
	DDD estimator			21.93**		NO	NO	NO				21.93**	
	N	159	143	166	126	159	143	166	126	159	143	166	126

Notes: Significance: *α < 5%; ** α <1%; ***; α<0.1***
"NO" means that it has not been possible to estimate that coefficient; it has been reported only if, in the same regression, at least one of the other policy variables is significant.

Tables A.9 *Difference -in-Difference-in Difference (DDD)*. Effects of Law 46 (total, part I and part II) among *Pavitt 4* (*science-based*) firms classification/by firm size. Waves 7–8 and 8–9. Dependent variables R&D expenditures (log) and R&D employment (log). Fixed-effect coefficients. *Only policy variables and significant (at 5%) coefficients are shown.*

		Law 46/82				*Law 46/82 – Part I (FAR)*				*Law 46/82 – Part II (FIT)*			
		Wave 7–8		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*		*Wave 7–8*		*Wave 8–9*	
		R&D expenditures	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*	*R&D expenditures*	*R&D employment*
Pavitt 4 all firms	Law 46/82		1.18***		0.81**				0.57**		–2.21**		0.59**
	Other R&D incentives				0.55**		1.13***				0.61*		0.56**
	DDD estimator		–2.15**		NO	12.48***			NO		NO		
	N	353	340	309	295	353	340	309	295	353	340	309	295
Pavitt 4 small and medium firms	Law 46/82		–2.43**		0.59***				NO		–2.43**		0.59***
	Other R&D incentives				0.55**				0.56**				0.55**
	DDD estimator		NO		NO				NO		NO		NO
	N	309	302	260	260	309	302	260	260	309	302	260	260

Notes: Significance: *α < 5%; ** α <1%; ***; α<0.1***
"NO" means that it has not been possible to estimate that coefficient; it has been reported only if, in the same regression, at least one of the other policy variables is significant.
It has not been possible to estimate the regression for the sub-group of large firms.