The "Matthew effect" in R&D public subsidies: The Italian evidence

DOI:10.1016/j.techfore.2013.03.008

(Article begins on next page)

THE "MATTHEW EFFECT" IN R&D PUBLIC SUBSIDIES: THE ITALIAN EVIDENCE

Cristiano Antonelli
Dipartimento di Economia, Università di Torino
and BRICK, Collegio Carlo Alberto.

Francesco Crespi
Corresponding author:
crespi@uniroma3.it

Dipartimento di Economia, Università Roma Tre
and BRICK, Collegio Carlo Alberto.

Abstract

This paper explores the causes and effects of persistence in the discretionary allocation of public subsidies to R&D activities performed by private firms and elaborates a crucial distinction between *vicious* Matthew-effects and *virtuous* Matthew-effects. The latter identifies the role of dynamics increasing returns based upon accumulation of competence stemming from learning, learning to learn and knowledge cumulability. On the contrary *vicious* Matthew-effects lead to substitution of private funds with public ones and represent an additional source of 'government failure' which has not been specifically addressed by previous literature. The empirical results show that past grants increase the probability to access further funding. Both the descriptive and econometric evidences confirm the persistent character of R&D subsidies, providing indication that some mechanisms related to a Matthew effect is at work for the observed firms. Moreover, the results suggest that the stable pattern in the access to R&D public subsidies by firms is associated with a 'picking the winner' strategy adopted by public authorities, which, positively contributed to the effectiveness of the policy instrument.

KEY-WORDS: R&D SUBSIDIES; PERSISTENCE; TECHNOLOGY POLICY, MATTHEW EFFECTS

JEL CLASSIFICATION: **H25, H32, L52**

1. Introduction

A large literature has identified the case for a substantial market failure in the identification of the correct amount of resources that markets are able to allocate in the generation of technological and scientific knowledge (Nelson, 1959; Arrow, 1962a). Moreover, the broader perspective adopted by the innovation systems literature has expanded the range of legitimate justification and scope for public intervention in this field to different types of system failures (see Smith, 2000; Georghiou and Metcalfe, 1998; Edquist, 2001). Following these arguments, significant amounts of public funds have been spent on programs to stimulate not only the generation of new scientific knowledge in research institutions, but also the funding of innovative activities by private firms (OECD, 2007).

However, the actual impact of R&D subsidies on firm's innovative activities is not obvious and it is possible that public subsidies crowd-out private investment (David and Hall, 2000; David et al., 2000; Hall and van Reenen, 2000; Bloom et al., 2002). A number of explanations have been provided for the potential ineffectiveness of public R&D incentives. In particular, it has been argued that public subsidies are potential sources of 'government failures' that might be as large or even larger than the 'market failure' they are supposed to correct (Nelson, 1980). The following arguments appear to be relevant for understanding such claims. The first is related to the problem of asymmetric information and the consequent difficulty of policymakers and program officials to know which firms to favour (Grossman, 1991; Stiglitz and Wallsten, 2000). Moreover, interest group theories argue that the possibility of receiving some kind of public support gives industries and other interest groups an incentive to invest large resources in unproductive rent-seeking activities such as lobbying (see e.g. Tollison, 1997). Therefore, irrespective of the information problems governments have, politicians try to maximise votes and to allocate subsidies optimally from a political point of view, by responding to the requests of interest groups (see e.g. Peltzman, 1976; Olson, 1982; Mitchell and Munger, 1991; Magee, 1997). In addition to this, the efficiency of public support for R&D activities may be further harmed if bureaucrats seek to maximize their own utility and the distribution scheme is consequently designed to achieve the goal of the bureaucrat himself (Link, 1977).

The procedures of allocation of public subsidies matter in this context. The allocation of public subsidies to R&D activities takes place either with automatic procedures, typically associated with tax expenditures, or with discretionary beauty contest procedures based upon the assessment of the quality of the research programmes[1]. The main theoretical as well as practical difference between subsidizing R&D by tax credits rather than by a direct grant is that the former is neutral with respect to industry or sector and, most important, the characteristics of the firm. The most important advantage of tax credit programs relative to direct grants is that they minimize the discretionary decisions involved in project selection for direct government grants (Bozeman and Link, 1984). However, much literature has criticized automatic procedures, mainly based upon tax incentives, and praised the positive effects of discretionary procedures based upon the actual screening of the research projects. The former risk, in fact, to provide support to an array of activities that often do not actually consist in research activities performed by firms that are not actually able to carry out properly research programmes and to make an effective use of the subsidies. The risks of opportunistic behaviour moreover seem to be very high. Firms label some expenses as finalized to research activities while they actually fund other kinds of business activities vaguely related to research: the effective control of public authorities is almost impossible. In parallel, the lobbying activities of firms exert relevant pressure on government authorities in order to obtain changes in the definitions of what counted as R&D as to broadening allowable costs (Alt et al., 2010).

Moreover, according to David et al.(2000), private firms are likely to use any tax credits to first fund projects with the highest private rate of return. For this reason, they argue that tax credit users are likely to concentrate their research efforts on projects with short term prospects. These are not necessarily the projects that would most deserve public support, which should concentrate on projects with the largest gap between social and private returns. The availability of tax credits is therefore unlikely to increase the probability that the users will undertake projects with high social and low private rate of return. Hence, even though tax credits represent an agile way of providing public support to R&D and to reduce problems related to 'government failure', they do not appear to be the most efficient tool to correct the 'market failure' (Shane, 2009).

Discretionary beauty contest procedures based upon the assessment of the quality of the research programmes to allocate R&D grants, are potentially better suited to fill the gap

[1] The notion of beauty contest has been applied in a variety of contexts with some shifts from the original Keynesian formulation. In this paper we follow Klemperer's (2000) definition of beauty contest as a procedure for the allocation of public resources consisting in an administrative selection mechanism based upon committees of experts that are requested to assess the merits of competing firms' business plans. Such procedures are widely used for the allotment of spectrum in telecommunications and broadcasting and for the selection of research projects.

between the private and social returns to innovation not only for the higher chances to select and hence support better research projects, but also because this allocation procedure of public subsidies can help identifying and supporting potential complementarities among innovative projects (Milgrom and Robets, 1995; Mohnen and Roller, 2005). As a matter of fact many countries do rely on discretionary selection procedures, even though this may come at a cost. These are criticized for the high risks that selection committees become 'prisoners' of interest groups. The growing evidence on the persistence in their allocation to past recipients now available has engendered much perplexity upon the actual reliability of selective procedures and their limitations. The persistence in the allocation is considered a direct clue of the lock-in of the selection committees that become 'prisoners' of the interest groups constituted by the former assignees of R&D subsidies.

In the present paper we claim that it is important to qualify the persistence, whether it is actually and necessarily dysfunctional, or it may be even fruitful from a dynamic efficiency viewpoint and, hence, that it is necessary to enquire about the causes and the effects of persistence in the provision of public subsidies. In doing so we apply to research policy the notion of Matthew effect drawn from the sociology of science to assess the causes and effects of the persistence in the assignment of R&D subsidies (Merton, 1968; Arora and Gambardella, 1997; Rigney, 2010).

Merton's analysis of the Matthew effect has been first elaborated in the context of the sociology of science, but deserves a wide application well beyond its original scope of application. It can be considered one of the first and most perceptive insights about the working of non-ergodic processes and their implications for the analysis of social dynamics. It contrasts, in fact, the automatic association of non-ergodicity with the reduction of welfare conditions. It shows that non-ergodic processes may have pathological effects of lock-in as well as positive effects in terms of learning processes. The identification of two possible Matthew effects can be considered as one the most important building blocks of the distinction, within non-ergodic processes, between of path and past dependence (David, 1985 and 1997).

In order to highlight the relevance of this issue, we propose the distinction between *virtuous* and *vicious* Matthew effects. The former consist in the persistence of the provision of subsidies to firms that have been actually able to use previous subsidies to effectively increase their R&D activities. The latter include the cases of persistence in the assignment of public subsidies based on sheer reputation, even to firms that have actually reduced their commitment to research after receiving previous subsidies. The *vicious* case identifies an additional potential source of 'government failure' in the provision of R&D grants, which has not been discussed by previous literature on the subject. On the contrary in the *virtuous* case public authorities can be right in confirming their preferences for firms that have taken advantage of previous grants simply because their projects embody a larger amount of inputs, higher levels of competence and expertise and hence are simply of a higher and better quality. In this context we claim that Matthew effects would be consistent and would complement a strategy of 'picking the winners' in the provision of public subsidies to R&D, by replacing pure arbitrary criteria that might be adopted by selection committees in the absence of such a constraining strategy and, consequently, increasing the efficiency of public support to firms' innovative activities (Cantner and Kösters, 2009).

The relevance of these arguments is empirically tested on a sample of 750 Italian manufacturing firms observed in the period 1998-2003, by analysing transition probabilities between states and by developing an original econometric model to identify the determinants of firm's access to R&D grants. This model is designed to assess whether it is possible to identify a *virtuous* effect consistent with a 'picking the winners strategy', that is past grants increase the innovative performance of benefited firms and consequently the probability to access further funding, or a *vicious* effect so that the past success in receiving public support increases the probability of gaining access to public funding independently from firms' innovative competence and results. This issue is further investigated through an evaluation impact analysis based on the Propensity Score Matching method. This allows us to assess the effect of public grants on firm's R&D intensity providing complementary evidence on the nature of the identified persistence.

The remainder of the paper is structured as follows. Paragraph 2 discusses the notion of Matthew effect and applies it to R&D subsidies; section 3 describes the data, the empirical strategy and shows the analysis based on transition matrixes; paragraphs 4 and 5 discuss respectively the econometric methodologies applied in the analysis and the obtained results; finally, the last section draws the main conclusions and policy implications emerging from the study.

2. The Matthew effect in R&D subsidies

Discretionary procedures to select public subsidies to R&D projects proposed by private firms are based upon the working of Committees of experts appointed by the Ministry and other Intermediary Agencies. The Committees select the projects according to their scientific and technological relevance and to their assessment of the capability of firms to actually perform and finalize the research programmes. It is a typical beauty contest characterized by major information asymmetries: the members of the Committees have limited information upon the actual capabilities of the firm to conduct the specific research programmes that are being proposed. Moreover, the work by Committees might be influenced by the pressures exerted by interest groups which invest large resources in unproductive rent-seeking activities.

For these reasons many criticisms have emerged and the basic question concerns the limitations of the procedure and the possible biases in the selection mechanism. However, in this context little attention has been devoted to the determinants and the effects of persistence in the provision of public subsidies. Such considerations appear to be relevant in the light of the argument based on the Mertonian 'Matthew effect', according to which the public assessment of the quality of scientific research is related to previous accomplishments. As Merton noted: "…eminent scientists get disproportionately great credit for their contributions to science while unknown scientists tend to get disproportionately little credit for comparable contributions" (Merton, 1968:57). While in the economics of science the 'Matthew effect' hypothesis has received considerable attention (Arora and Gambardella, 1997; Arora et al., 1998; Medoff, 2006), the relevance of this argument has not been properly elaborated in the economics of innovation policy. Following a typical recombinatory process we believe that the transfer and application of the issues and methodological results of the Matthew effect away from the economics of science into the economics of innovation policy can yield interesting results.

At a first sight it is possible to directly and quite abruptly apply the quote from Merton to the specific case of the provision of public subsidies. A 41st chair effect risks to take place in the provision of public subsidies and valiant research programmes presented by unknown firms risk to be deprived of the deserved public support with very negative effects in terms of waste of resources and misallocation of public money. Following this line of analysis the criticisms to the selection procedures based upon the perceived quality of both the research projects and the firms performing them, is enriched by the argument that members of the selection committees would be too much influenced by the scientific and technological reputation of the candidates, rather than by the sheer quality of the projects. Actually the reputation of the candidates would become a reliable proxy for the quality of the projects. Such reputation would be strongly influenced by previous awards and specifically by the inclusion in precedent assignment tournaments. The claim is that firms that have already received a selective subsidy based upon discretionary procedures in the past have disproportionately higher chances to be selected again, simply because of their acquired reputation, and not because of a correct assessment of their actual efforts. According to these criticisms a *vicious* Matthew effect, i.e. a dysfunctional persistence, would take place in the selective allocation of public subsidies based upon beauty contests.

However, in order to clarify whether the Matthew effect is exclusively dysfunctional, the careful reading of the original text by Robert Merton is necessary and it reveals that the issue is far from being univocal. As a matter of fact Merton elaborates two distinct arguments. Ex-post we can term the first an information economics argument and a knowledge economics the second. This distinction leads us to articulate the separation between *vicious* and *virtuous* Matthew effects.

The first argument has been already considered and consists in a typical issue elaborated in information economics: search costs and information asymmetries do matter. Authors (members of selection committees) read and cite (praise) better the work of eminent scientists (established firms that were recipients of previous subsidies) because their reputation helps screening the backlog of redundant information (excess number of applicants). Reputation reduces search costs and information asymmetries. Authors (members of selection committees), facing new articles (projects) that are supposed to be original and innovative, are more ready to trusts established scientists (firms) rather than un-known ones. Once more, and yet for a different reason, they will cite (praise) more the articles (projects) proposed by established scientists (firms that have already won previous tournaments). The second argument stems from the careful reading of Robert Merton's text: "The recognition accorded scientific achievements by the scientist's pier is a reward in the strict sense identified by Parson. As we shall see, such recognition can be converted into an instrumental asset as enlarged facilities are made available to the honoured scientists for further work. Without deliberate intent on the part of any group, the reward system thus influences the 'class structure' of science by providing as stratified distribution of chances, among scientists, for enlarging their role as investigators" (Merton, 1968:57). Merton makes very clear that the reward system influences the chances and the opportunities of recognized scientists *without any deliberate intent on the part of any group*. Nobody is a prisoner of an interest group in his analysis, and persistence takes place simply because of the enlarged facilities made available to past recipients of academic awards

This second argument is well supported by the arrovian economics of knowledge (Arrow, 1962a, 1962b, 1969; David, 1994) on three different and yet complementary counts: a) authors (firms) who have been selected in previous tournaments are the persistent recipients of beauty contest allocations because they had the opportunity to enlarge their role as investigators in terms of increased access to scarce research resources and the opportunity to concentrate and specialize in conducting their research. In this case past recipients should have performed larger flows of R&D activities, although partly funded by public grants; b) past recipients had the opportunity to learn to learn (Stiglitz, 1987). No surprise hence that in a successive tournament their scientific production, be articles for scientists or research projects for firms, will be actually and intrinsically better. c) knowledge exhibits intrinsic cumulability both at the individual, organization and system levels. New knowledge is the result of the recombination of existing bits of knowledge: hence the larger the knowledge base under the command of each firm (author) and the larger the chances to generate new technological (scientific) knowledge (Weitzman, 1996 and 1998). This amounts to argue that in the economics of R&D activities a positive relationship between the stock of existing competence and the output in terms of technological knowledge, for a given amount of current efforts, is at work. Consequently, in this second case the persistence effects do not necessarily identify an economic dysfunctionality. On the contrary, in this case a *virtuous* Matthew effect can be justified by the economics of knowledge. Readers and committees members might be perfectly right in confirming their preferences for scientists and firms that have taken advantage of previous awards, simply because their products embody a larger amount of inputs, higher levels of competence and expertise and hence are simply of a higher and better quality.

The proposed distinction between the two types of Matthew effects appears to be relevant in the light of recent advancements in the literature on public subsidies to firm's innovative activities. These studies showed that a possible way to reduce 'government failures' in the allocation of subsidies and to increase the efficiency of public support to private companies is to follow a 'picking-the-winner strategy' (Shane, 2009; Cantner and Kösters, 2009). In so doing program agencies choose firms that are more experienced and capable or firms that command already high levels of technological competence and/or are well advanced on a promising strategic and technological path. Evidence for a policy focus on high potential and best-equipped firms has been recently found for example in the German case (Aschhoff, 2010; Hussinger, 2008; Cantner and Kösters, 2009), highlighting the advantages of adopting such a strategy. In this context, beside other information, government agencies can consider previous success in receiving selective R&D grants as an indicator signalling the quality of the firms proposing the projects.

Summing up, the identification of persistence in the allocation of R&D subsidies to private firms by means of discretionary selection procedures is not sufficient to claim that perverse dysfunctional processes are at work. The identification of the factors behind the persistence and of its effects both at the firm and the system level, in terms of actual dynamic efficiency, is necessary to qualify it from an economic and social viewpoint. The distinction between 'reputation persistence' based on sheer informational externalities and 'competence persistence' based on the internal accumulation of higher skills and expertise and the broadening of the research base determined by the assignment of previous subsidies is crucial to assess the dynamic efficiency of the procedure. Following these arguments our hypotheses can be synthesized as it follows.

First, we expect that Matthew effects are relevant and hence that significant persistence is at work in the allocation of discretionary public subsidies. Second, we claim that Matthew effects can be of two types. In the case of a pure reputation *vicious* effect we expect that in the allocation of R&D subsidies only the achievement of past grant is relevant in explaining the current access to public funds. On the contrary, we expect that in the *virtuous* case the current distribution of R&D subsidies is shaped by previous allocations as well as by other characteristics of firms and, in particular, those related to firms' competence and commitment to innovative activities. In this context the Matthew effect would be consistent with a 'picking the winners' strategy, with potential benefits in the effectiveness of the adopted policy instrument.

3. Descriptive analysis and empirical strategy

3.1 Empirical strategy

Consistently with the theoretical discussion, in our empirical analysis we follow three different but complementary approaches. The first aims at the identification of firm-level persistence in the access to R&D subsidies by means of Transition Probability Matrixes (TPM). The second explores the determinants of firm-level persistence in gaining public support by means of a probit model and qualify the allocation strategy pursued by public authorities in granting subsidies. Finally, the third applies a propensity score matching method to evaluate the impact of public subsidies on firms' innovative investments. While the initial TPM approach is expected to provide only summary evidence on the persistence of firms' access to R&D subsidies along time, the probit analysis aims at identifying the actual role of past subsidy history in determining the admission to subsequent support programs when relevant contingent factors are taken into account. In this way it will be possible to test the relevance of the Matthew effects and to obtain a first indication on the nature of the identified persistence, by verifying if it is consistent with a 'picking the winner strategy' adopted by granting committees. Moreover, the probit model will offer the statistical basis for an evaluation impact exercise which will allow us to obtain complementary insights on whether it is possible to identify a *virtuous effect*, that is past grants increase the innovative performance of benefited firms and consequently the probability to access further funding, or a pure *reputational effect* so that the past success in receiving public support increases the probability of gaining access to public funding independently from firms' innovative results.

3.2 Database description

The analysis is based on a dataset derived from the questionnaire surveys developed originally by the investment bank Mediocredito Centrale (MCC, now Unicredit), regarding a representative sample of Italian manufacturing firms with more than 11 employees. The original MCC database comes from two different questionnaire waves, each of them collecting contemporary and retrospective (previous three years) data from samples of more than 4000 firms. In order to obtain a dataset for our study, we merged two waves (covering years from 1998 to 2003). For the purposes of our analysis we restricted the sample to firms which invest in R&D activities and which have been observed in both the two waves of the survey. We finally cleaned the dataset by eliminating outliers and cases of M&As, ending up with a balanced dataset of 752 manufacturing firms observed two times over a 6-year period[2]. The questionnaire survey collects information about firm structure and behaviour, including investment and innovation activities, internationalization

[2] The source of information used for our analysis did not allow us to obtain a longer longitudinal time-spam of the set of data, which would be desirable for studying persistence. While this aspect should be kept in mind in the interpretation of our empirical results, we claim that this study represents one of the first attempts to systematically identify patterns of persistence in R&D subsidies and analyze their nature and impacts. Further qualifications of our results based on richer datasets are left to future research.

strategies, financial characteristics and public support. In particular, the survey allows to distinguish between tax credit instruments (mainly allocated through automatic procedures erga omnes and ex-post) and public grants (typically awarded by means of *ex-ante* discretionary evaluation mechanisms). For the purpose of our analysis we then exploited the information on the latter instrument. As the paper will discuss in detail, the richness of the information contained in the database and the possibility to observe both supported and non supported firms for two times in the considered period offers a high satisfactory information base to account for the role of firm's past subsidy history in the analysis of the determinants of R&D subsidies and in the evaluation of their effectiveness.

Table 1 exhibits the sectoral composition of the sample, while Table 2 provides the basic descriptive statistics of the sample. The share of firms that accessed R&D subsidies were respectively 13.56% in the period 1998-2000 and 22.61% in the period 2001-2003. In the period 2001-2003, the companies included in the sample had an average number of employees equal to 139. Firms not receiving R&D subsidies are smaller than those that are granted a subsidy (115 employees vs. 222). This evidence is confirmed when turnover is taken into account, with an average turnover for subsidized firms of about 59 Millions of Euros and of about 33 Millions of Euros for non subsidized companies.

Subsidized firms are also more capital intensive, with a capital labour ratio value of about €5582 per worker against €5262 for non-subsidized ones. The same pattern holds for R&D investments and human resources devoted to R&D activities. Firms receiving grants are, on average, more R&D intensive than non benefiting ones (5242 Euros per worker invested in R&D vs. 2744 Euros), and employ a higher percentage of total workers in R&D activities (11.06% vs. 8.46%). However, as it will be subsequently clarified, such difference cannot be considered as an effect of R&D subsidies since it may simply reflect the selective nature of the group of funded firms.

[Insert Table 1 here]

[Insert Table 2 here]

3.3 Descriptive analysis based on Transition Probability Matrixes

In this section we provide descriptive evidence on the extent of firm-level persistence in the access to R&D subsidies, using transition probability matrixes. This statistical tool allows to analyse the sequence of subsidized and non-subsidized states by means of transition probabilities:

(1)

where, each term of the (2X2) TPM will be the conditional probability , or the probability of moving from state j to state i[3].

The analysis of the diagonal terms, based on estimated transition probabilities (Roper and Dundas, 2008; Antonelli et al., 2012), allows the identification of specific patterns of persistence. In the case of a 2-dimensional matrix there is evidence of persistence if the sum of the main diagonal terms is more than 1.

[Insert Table 3 here]

This applies to our data representing a first indication of the presence of some form of inter-temporal stability in the access to R&D subsidies that has to be qualified by looking in more details at our empirical findings (see Table 3). In particular, for the whole sample, while the probability of accessing public funding at time t for non-subsidized companies at t-1 is only 0.19, the probability of obtaining R&D subsidies in period t for subsidized firms in period t-1 is 0.45, that is more than the double. Symmetrically, the "negative" state dependence appears to be very strong in our sample, with 81% of non-subsidized companies in t-1 still not gaining access to public subsidies at time t.

---

[3] Let P_{ij} and $\hat{P}_{ij}$ denote the population and sample probabilities of a transition of a company from the status i to the status j. This transition process can also be seen as the outcome of a binomial distribution. Hence, standard errors of the estimated transition probabilities can be calculated as a binomial standard deviation: $\sqrt{P_{ij} * (1 - P_{ij}) / N}$ where N equals the number of companies in status i. As N increases $\hat{P}_{ij}$ tends to P_{ij}. In the matrixes that will be presented in our analysis the binomial process has just two possible outcomes hence the estimated standard error is the same for the elements of each row in the 2X2 matrix.

The distinction between two (equally sized) groups of companies classified by dimension (Table 4) offers further insights to the analysis, highlighting that an higher level of state dependence in accessing public funds for R&D investments concerns companies with the largest number of employees. In this latter case, while the probability of accessing public funding at time t for non-subsidized companies at t-1 is 0.22, the probability of obtaining R&D subsidies in period t for subsidized firms in period t-1 is 0.48. The same probability is 0.40 for companies belonging to the group of smallest firms.

[Insert Table 4 here]

Finally, Table 5 presents the analysis of the TPMs based on two (equally sized) subsamples ordered in terms of firms' R&D personnel intensity, which shows that the overall degree of state dependence in accessing R&D subsidies increases with the percentage of R&D personnel over total employees. In the case of companies belonging to the top 50% in terms of R&D personnel intensity strong "positive" state dependence is found, with a probability of obtaining grants in period t for subsidized firms in period t-1 equal to 0.5. Conversely, the "negative" state dependence decreases with the percentage of R&D personnel, with the share of non-subsidized companies in t-1 still not gaining access to public subsidies at time t falling from 0.85 (Low group) to 0.76 (High group).

[Insert Table 5 here]

The analysis conducted so far provides strong preliminary indications that suggest state dependence in firm's access to public funds for R&D investments, with differentiated patterns of persistence across crucial dimensions such as size or the intensity of R&D capabilities. It should be clear that such findings provide only a preliminary support about the relevance of persistence in the access to public R&D subsidies by firms. In fact they suggest the presence of some form of inter-temporal stability in getting public funds for firms' innovative activities. However, they do not provide, yet, a solid indication on how much of the observed persistence would be related to operating mechanisms related to either *vicious* or *virtuos* Matthew effects in the access to public support for R&D. The observed persistence can clearly be influenced by an array of complementary factors, and the evidence provided in Tables 4 and 5 offers precise hints in this direction. The econometric analysis in the next section aims specifically at controlling for those factors in order to test the robustness of this result and possibly to isolate the kind of Matthew effect at work effects.

4. Econometric analysis

4.1 The probit model

In this section we present the econometric model that tests the determinants of the access to R&D public support with special attention to firm's past subsidy history. The analysis is based on a probit model in which the dependent variable is affected by a set of exogenous control variables and by the lagged realization of the dependent variable. The presence of the lagged outcome variable allows us to test the hypothesis of true state dependence. In this way we aim at capturing the effect on firms' current subsidy status of the event of being subsidized or not at time t-1.
In our econometric analysis we estimate a probit model of the event (Y=1) of receiving a public R&D subsidy that can be represented as follows:

$$\Pr(Y_{it} = 1 \mid X_{it-1}, Y_{it-1}) \qquad (2)$$

where $X_{i,t-1}$ is a vector of observable firm i's characteristics at t-1 and Y_{it-1} the event of being subsidized or not at time t-1[4].

Control variables beside firms' past R&D subsidy history have been selected in this study according to the literature that has analysed this probability (Busom, 2000; Wallsten, 2000; Arvanitis et al., 2002; Almus and Czarnitzki, 2003; Duguet, 2004; Blanes and Busom, 2004; Görg, H. and E. Strobl, 2007; Hussinger, 2008). Previous research has found that several firm characteristics, such as group membership, size, financial structure, past R&D and innovation efforts, export activity, industry context are correlated with public funding of R&D. The majority of these studies, beyond the heterogeneity of the support programs considered, showed that well established large firms who planned their innovation activity

[4] Given the structure of our data for *t* has to be intended the years 2001-2003 and for *t-1* the years 1998-2000.

and had previous R&D experience were the main beneficiaries of subsidies. This has been interpreted as a clue that public authorities adopted a 'picking the winner strategy' in granting the subsidies.

In more detail the control variables used in our model specifications are the following:

Firm age: Well established companies, with previous experience in the application process for public funding can be better placed in the competition for public funding. Moreover old firms may have had better opportunities with respect to new and young firms to establish contacts with and influence the support-granting authorities.

Firm size (lagged): Evaluation studies suggest that larger firms are more likely to be subsidized than smaller firms. This is in part due to the positive relationship between firm size and innovation activities which has been extensively debated in the literature, showing that large firms benefit from economies of scale and scope, have a better organizational structure and suffer less from capital market imperfection (Cohen and Klepper, 1996). In the probit model, firm size is measured as the log of total number of employees.

Past Innovative Behaviour Indicators: If policymakers follow a "picking the winner" strategy in allocating the public R&D funds, the probability of the receipt of public R&D funding is affected by the existing R&D staff and equipment and the innovative history of the firm. Research has shown that previous innovation activities, proxied by patents or by the presence of R&D departments, are positively related to the probability of being subsidized (Wallsten, 2000; Hussinger, 2008). Previous research activities influence the granting of subsidies because the firms that do more R&D are the ones that are the most likely to apply for subsidies. It is in fact to be expected that those firms with previous R&D experience which systematically plan their activities, detailing them in a plan, will find making the request for subsidies easier. In the model the innovative background is approximated by the percentage of R&D personnel over total employee and by a dummy variable indicating whether the firm introduced any innovation at time t-1 or not[5].

[5] We acknowledge that the static nature of this variable limits its potential to capture the dynamics of knowledge accumulation processes. However, given the structure of the dataset and the necessity to use lagged covariates in order to reduce potential problems of endogeneity in our estimates, we were not able to include in the model variables expressed as rates of change, which would be more appropriate.

Export activity (lagged): Firms that export their products are usually exposed to strong international competition, and are likely to strengthen their competitiveness through innovation. Furthermore, one of the goals of R&D funding schemes may be to strengthen the competitiveness of firms in international markets. Thus, export activities can represent a signal for the allocation decision of the public R&D funds if policymakers are believed to be inclined to subsidize R&D projects with potentially high international market success (Blanes and Busom, 2004).

Other characteristics of the firm: We have considered other variables that might have an important discriminatory power between subsidised and non-subsidised firms. The relationship of these variables with innovation activities has been widely documented in the literature. In particular, the econometric specifications account for **group membership**, since firm belonging to a group may be better equipped to apply for a subsidy because resources at the corporate level, such as information, expertise and funds, are made available to the applicant; **credit rationing** (proxied by the percentage of firms declaring of having asked for additional funds being denied at t-1); the intensity of fixed capital investments measured as the log of fixed capital investments per employee at t-1. Finally, following the taxonomy introduced by Pavitt (1984), **industry dummies** have been considered in order to control for sectoral technological specificities.

In the following Table 6 we report the definition of the variables that will be used in the different specifications of the model on the persistence of R&D subsidies.

[Insert Table 6 here]

With respect to our hypotheses, if the probit model shows that the variable associated with the past allocation of subsidies remains statistically robust after the introduction of several firms specific control variables, it will be possible to interpret this result as an evidence of true state dependence supporting the view that Matthew effects are relevant. Moreover, the eventual significance of other control variables will provide us with a first indication on the nature of Matthew effects in action. In particular, if sheer reputation effects are dominant the variable associated with previous subsidies allocation should be the most (if not the only) statistically robust variable entering the model. More importantly, in the case of a *vicious* Matthew effect the variables associated with firms' efforts devoted to innovative activities are expected to be irrelevant. On the contrary, if the *virtuous* Matthew effect prevails we expect that beside previous achievements in subsidy allocation other characteristics of the firms are taken into account by grant authorities. In particular, that related to performed R&D activities by firms are expected to turn out to be positive and statistically significant in this latter case.

4.2 The impact evaluation analysis

The probit model previously described can also be used as the first step of an impact evaluation analysis on public R&D subsidies. This allows us to obtain a second indication on the nature of the identified persistence in grant allocation. In particular, we will interpret the eventual detection of additionality results in R&D investments as a signal that the *virtuous* Matthew effect prevailed. In contrast, the absence of additionality or the presence of crowding out effects will be considered as an indication that the *vicious* Matthew effect was dominant.

In any empirical analysis designed to test the effect of public grants (treatment) on the targeted subjects (treated), it has to be taken into account that the receipt of a subsidy is not random, but rather is subject to different selection processes, both on firm's and government's side as discussed before. Several econometric methods have been developed in order to get reliable results in the presence of such selection bias (Cerulli, 2010). Among these, the approach based on matching methods, has been successfully applied to the evaluation of public R&D funding in the field of industrial economics. Such matching methodology has been widely used in recent years as estimation technique and is also applied in this study (Heckman et al., 1999, Blundell and Costa Dias, 2000; Almus and Czarnitzki, 2003; Hussinger, 2008).

The crucial research issue in this type of analyses is to measure the effect of public R&D support on firms' innovation performances in the absence of counterfactual evidence, so that it is not possible to forecast the result of firms' innovation performances in the absence of subsidies. The solution that can be adopted in such circumstances is to use the results of non-treated firms, with similar characteristics, to estimate the possible effect on treated companies had they not participated in public funded R&D programmes. The basic idea of matching is then to balance the sample of subsidy recipients and comparable non-recipients by selecting the best twin from the control group for each subsidized firm, so that the means of the outcome are comparable between the two groups. In this way, the differences in the means of the outcome variable between the treated and the selected control groups can be then attributed to the treatment (Rosenbaum and Rubin, 1983; Heckman et al. 1998).

In the ideal case, the best twin for a subsidized firm is the firm identical in all relevant characteristics. However, when the number of matching criteria is large, it would be very difficult to find any such observation. A solution to this problem is represented by the "propensity score" matching (PSM) method, proposed by Rosenbaum and Rubin (1983) who demonstrated that it is possible to reduce the multi-dimensionality of the matching procedure through the use of a synthetic mono-dimensional propensity score. The procedure consists in estimating the propensity score which is the probability of accessing R&D subsidies for the whole sample and find pairs of treated and non-treated that have the same probability value of participation. Usually, a 'nearest neighbour' matching is performed, so that the control observation with the estimated probability value closest to the participant is selected. However, in the proposed evaluation impact exercise we will check the robustness of our results by using different matching estimators.

To estimate the causal effect of R&D subsidies, the PSM requires that the Conditional Independence Assumption (CIA) be met. The CIA implies that all the characteristics which influence both treatment and potential outcome have to be observed. While it cannot be tested whether the CIA is fulfilled or not, given the broad range of variables in our dataset, it is reasonable that we have enough information on the firms to sufficiently approximate the treatment and the outcome so that this condition holds.

In addition, the assumption on common support and the stable unit treatment value assumption (SUTVA) have to be fulfilled in order to identify the average treatment effect. The common support demands that firms with the same characteristics have a positive probability of being both treated and not treated. This condition assures that for each treated observation a similar control can be found and can be directly imposed to our data when calculations are performed. The SUTVA requires that the treatment of a particular firm must not influence the outcome of other firms and its validity cannot be tested empirically (Rubin, 1990).

Finally, four important characteristics of the database used for the empirical analysis appear to be relevant for the effectiveness of the evaluation method adopted (Heckman et al., 1998). First, the information on both supported and not-supported firms derives from the same survey; second, the data contains a rich set of variables on firms' structure and behaviour relevant to modelling the participation decision; third, the goodness of matching is facilitated by the presence of a large number of non-treated companies in the sample; finally, we could reduce problems due to endogeneity by using lagged variables as regressors which can satisfy more easily the weak exogeneity assumption with respect to the dependent variable.

5. Empirical results

Table 7 shows the results for different specifications of the probit model regarding the determinants of firms' access to public R&D subsidies. Globally, the predictions of the probit models are good with about 80% of concordant predictions. The levels of the likelihood ratio chi-square always suggesting that our models, as a whole, are statistically significant. Results in general show that, even after controlling for a number of firm and industry level characteristics, the probability of observing a subsidized company in period t is still positively and significantly affected by its R&D subsidy history. Hence, the estimated models confirm the picture emerged from the analysis on TPMs highlighting the presence of state dependence in the access of public R&D grants by firms, which, however, turns out to be shaped by specific firms' idiosyncratic characteristics.

The introduction of a number of different control variables allows us to test the robustness of the relationships identified between past and current realization of the dependent variable. Among the relevant factors, the level of R&D capabilities, as measured by the share of internal R&D personnel over total employee, significantly enhances the probability of subsequent access to public R&D subsidies. Moreover, the variables associated with the size and the age of the observed companies appear to have a certain (but not strongly robust) influence on the success in grant applications. Finally, the dummies associated with the Pavitt classes are also jointly significant in all specified models, confirming the importance of controlling for differentiated patterns of persistence in accessing public grants among different groups of economic sectors.

With respect to our research hypotheses these results have important implications. The stable significance of the coefficient associated with past R&D subsidies confirms the results of TPM analysis and supports the view that persistence in the provision of public subsidies is at work, The significance of the variable associated with the intensity of R&D capabilities previously accumulated, along with that related to past grants can be interpreted as a first indication that the hypothesis that a *vicious* Matthew effect is not confirmed by the data. The strength of firms' technological capabilities in fact would not be significant if the persistence was purely reputational because the past conditions related to grant's assignment would play an exhaustive causal role. On the contrary, the detected persistence can be explained by the accumulation of expertise, tacit and codified knowledge by firms that had access to larger resources to conduct research in the past, also because of the previous allocation of public subsidies. Finally, our results show that well established, larger and R&D intensive firms are perceived as more promising to be successful with their R&D projects and are, consequently, more likely to receive public R&D funding. We interpret this result as evidence that the distribution policy of public agencies favoured firms guaranteeing the technical viability of the subsidised projects. This suggests that public authorities followed a "picking the winner" strategy by encouraging firms with the best chances to successfully conduct the proposed R&D projects. As already stated, the adoption of such a strategy does not assure that the selected projects are necessarily the best, however, it may represent a practical way to reduce the 'government failure' costs associated with the selective assignment of public subsidies.

Such aspects can be further investigated through the evaluation impact analysis based on the Propensity Score Matching method described in the previous section. Table 8 reports the non-parametric estimation results of average treatment effect obtained through different matching estimators: nearest neighbour matching, Caliper matching and Kernel estimator[6]. These allow us to assess the effect of public grants on firm's R&D intensity and to evaluate the possible negative allocative distortions on productive resources generated by subsidies. Given that public resources are raised via socially costly revenue mechanisms, society will be worse off if the total R&D investment remains unaltered (Jaffe, 2002). In this context it seems plausible to state that the case of full crowding-out can be interpreted as a clear sign that a pure reputation (vicious) Matthew effect prevails. On the contrary,

[6] While the *Caliper* matching avoids the risk of bad matches if the closest neighbour is distant, the *Kernel* estimator makes it possible to match each treated with more than one comparable non-treated. In this last case, we also used bootstrapped standard errors, so that the estimated variance of the treatment effect include the variance due to the derivation of the propensity score, the determination of common support and the order in which treated individuals are matched. The bootstrapping is based on 50 replications of the original sample.

evidence of additionality may signal the prevalence of a virtuous mechanism, where Matthew effects are consistent with a 'picking the winners' strategy, with potential benefits in the effectiveness of the adopted R&D policy instrument.

Table 8 displays the average treatment effect (ATT)[7] obtained with different matching estimators by considering both subsidized firms and the control group of counterfactual. The ATT are calculated both for the overall R&D expenditure and for private R&D investments. With respect to the former, the average subsidized firm has significantly greater R&D expenditure per employee compared to a twin-firm not supported by public subsidies. This results holds independently from the model and the matching estimator adopted. Regarding the complementarity issue, i.e. whether grants induce firms to further increase private R&D investment as a response to public funding, we found that the differences between granted and non granted firms are not sufficiently statistically robust. We conclude that the analyzed data do provide supporting evidence on the additionality of public R&D subsidies which do not appear to substitute private R&D investments, although, consistently with other analyses on different Italian data (e.g. Evangelista, 2007) we cannot confirm the full complementarity between publicly and privately funded R&D.

From a policy perspective this result implies that the considered policy is not (fully) distorsive, since it seems to support marginal R&D projects, which are expected to be privately low profitable and would be not pursued without a subsidy. In this respect the adopted strategy of 'picking the winners' appears to be capable of assuring a satisfying level of efficiency of the policy instrument. Moreover, such evidence represents a further indication that the identified persistence in grants' allocation is not necessarily related to a *vicious* Matthew effect. In contrast, a *virtuous* Matthew effect emerges as prevailing, so that the observed past dependence can be explained by the accumulation of expertise, tacit and codified knowledge by firms that had access to larger resources to conduct research in the past, because of the previous allocation of public subsidies.

6. Conclusions and policy implications

Public policy plays a key role in supporting R&D activities. Because of limited appropriability firms are likely to under-invest in the performance of R&D activities with substantial social losses in terms of inadequate supply of technological knowledge. A

[7] Since the outcome variable is expressed in euro per worker the result is straightforward to interpret.

variety of policy tools have been applied to contrast the undersupply of technological knowledge ranging from the direct involvement of public authorities in the generation of technological and scientific knowledge within Universities and other public research centres, the procurement of technology intensive products, to the provision of subsidies to private firms performing R&D activities. A sharp debate contrasts the advocates of the merits of the provision of such public subsidies by means of automatic procedures, typically associated with tax expenditures directed to all firms able to exhibit their undertaking in R&D activities with the supporters of the advantages of discretionary allocation of grants based upon beauty contest procedures.

The sources of 'government failures' in the case of discretionary procedures have been widely discussed in a large literature mainly aimed at identifying the problems related to asymmetric information and interest group behaviours. This literature has based much criticism upon the growing evidence about the persistence in the allocation of R&D grants to the same firms. The discretionary allocation of R&D subsidies would be responsible of a pathological persistence in the selective discrimination process that would take place because past recipients have disproportionate access to public support with respect to other firms that never received such a grant, simply because of reputational effects.

In our view this critique elaborates on the wrong argument that all persistence is necessarily pathological. The actual causes of persistence deserve a more careful assessment. Persistence in the allocation of discretionary subsidies cannot be interpreted automatically as a proof of a pathological process, as it can be the result of the positive effects of previous awards on the competence and capability at time t of the recipients of awards at time t-1. The detailed analysis of the theoretical basis of the mertonian Matthew effects has enabled us to elaborate and substantiate analytically the distinction between *virtuous* and *vicious* Matthew effects. This distinction is quite important and deserves further investigation. Careful reading of Merton seminal contribution reveals that persistence in science and hence in research is not necessarily associated with perversion and sub-optimality.

The vicious Matthew effect is clearly at work when the recipients of public subsidies reduce the amount of private funding and actually substitute their internal funds with the public subsidies. *The vicious* Matthew effect applies to the cases of persistence in the assignment of public subsidies based on sheer reputation, even to firms that have actually reduced their commitment to research after receiving previous subsidies. *The virtuous* Matthew effect consists in the persistence of the provision of grants to firms that have been actually able to use previous subsidies to effectively increase their competence, their internal stock of technological knowledge and the flows of current R&D activities. Indeed persistence is at work: current behaviour is influenced by past awards, but such persistence reflects dynamic increasing returns in the generation of technological knowledge. The recent advances in the economics of knowledge confirm that the generation of new knowledge is characterized by the intrinsic cumulability of knowledge so that new knowledge is generated by means of the recombination of the existing stock of knowledge. The larger is the stock of knowledge possessed by each agent and the larger is the output of current R&D activities. The recurrent allocation of new grants to past recipients simply reflects the higher efficiency and better conduct of past recipients that have been able to take advantage and exploit past successes and build upon higher current performances. In this respect, the *virtuous* Matthew effect is likely to increase the dynamic efficiency of a system and it is fully consistent with a 'picking the winners strategy' that supports the innovative capability of firms better able to accumulate technological competence and actually more innovative.

The relevance of these arguments has been tested by implementing a three stages strategy of empirical analysis based on the exam of transition probabilities between states, the development of an original model on the determinants of firm's access to R&D grants and on an evaluation impact analysis adopting the Propensity Score Matching method. Both the descriptive and econometric evidences show that past grants increase the probability to access further funding and suggest that the access to public subsidies for R&D activities is indeed characterised by significant persistence. Our results reject the claim that discretionary procedures of allocation engender automatically perverse effects of persistence and exclusion. They show in fact that persistence is at work and yet it is not necessarily dysfunctional. On the opposite the empirical analysis provides some support to the hypothesis that a 'good' persistence is at work, i.e. a *virtuous* Matthew effect in the Italian experience, which would be coherent with the adoption of a 'picking the winner strategy' by public authorities.

Automatic subsidies risk to provide benefiting firms with an artificial competitive edge and, consequently, have the potential to keep inefficient recipients alive and inducing a crowding out of non-subsidized firms. In order to minimize these distortions, subsidies should therefore be targeted at truly "good" firms. Moreover, while the evaluation of the potential outcome of a specific project might be particularly difficult to assess for public agencies, the general assessment of firms' quality seems to be a task that can be performed more easily. It is a matter of looking at their performance in the past. Thus, the observation of persistent flows of R&D or patenting activities and the high level of human capital might represent crucial, objective indicators that public agencies may consider in taking their decisions. Within this context, firms that exhibit both a record of innovative investments and innovative performances above the average in the past might be more likely to be successful in the new innovative venture and hence should be selected in the program. Obviously, the adoption of a 'picking-the-winner strategy' cannot assure an optimal allocation of public resources so that the selected projects are necessarily the best. Moreover, the persistence in the assignment of public R&D subsides could nonetheless create (in a more long-term perspective) problems of lock-in and stickiness to existent technological paths, at micro as well as at system level. In this respect, a systemic approach to innovation policy should consider complementary instruments aimed at preserving diversity in the national R&D business structure. However, a 'picking-the-winner strategy' strategy may represent a viable way through which public authorities can reduce the 'government failure' costs associated with the selective assignment of public subsidies to R&D activities performed by private firms. When the decisions of selection committees are at least partially constrained by the adoption of objective criteria based on firm's past performance, the tendency of assuming totally arbitrary choices, that might be affected by the lobbying activities of interest groups and by the maximising behaviour of policy makers or bureaucrats, could be reduced.

Finally, it should be stressed that while the three stages research strategy designed and implemented in this paper appears to offer an effective framework of empirical analysis for the issue at stake, additional research is needed to further substantiate our results. In particular, the availability of data with a more deep longitudinal structure would allow for a better identification of persistence patterns in the allocation of R&D grants and a more accurate appreciation of the role played by knowledge cumulativeness and dynamic increasing returns. In addition, the possibility to collect detailed information on specific grant schemes and the associated selection procedures, would represent a relevant step further in the comprehension of the mechanisms and consequences related to granting authorities decision process.

Acknowledgements

The authors acknowledge comments and suggestions by two anonymous referees, Paolo Liberati and the participants to the SIEPI Conference held in Rome in January, 2011. This paper contributes the research project 'Policy Incentives for the Creation of Knowledge: Methods and Evidence' (PICK-ME), funded by the European Union D.G. Research with the Grant number 266959 to the within the context Cooperation Program / Theme 8 / Socio-economic Sciences and Humanities (SSH). The support of the Collegio Carlo Alberto, the University of Torino, and the Roma Tre University is also gratefully acknowledged. The usual disclaimers apply.

References

[40] Almus, M., Czarnitzki D., The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany, *J. Bus. Econ. Statist.* 21(2) (2003) 226-236.

[18] Alt, J., Preston I, Sibieta L., The Political Economy of Tax Policy, in: Mirrlees J., Adam S., Besley T., Blundell R., Bond S., Chote R., Gammie M., Johnson P., Myles G., Poterba J. (eds), *Dimensions of Tax Design: the Mirrlees Review*, Oxford University Press, Oxford, (2010) 1204-1279.

[36] Antonelli C., Crespi F., Scellato G. (2012), Inside Innovation Persistence: New Evidence from Italian Micro-data, *Struct. Change Econ. Dynam.*, (Forthcoming).

[26] Arora A., David, P.A., Gambardella, A., Reputation and competence in publicly funded science: Estimating the effects on research group productivity, *Ann. Econ. Statist.* 49/50 (1998) 163-190

[23] Arora, A., Gambardella, A., Public policy towards science: Picking stars or spreading the wealth ? *Revue Econ. Ind.*, 79 (1997) 63-75.

[2] Arrow, K. J., Economic welfare and the allocation of resources for invention, in Nelson, R. R. (ed.) *The rate and direction of inventive activity: Economic and social factors,* Princeton University Press for N.B.E.R., Princeton (1962a) 609-625.

[28] Arrow, K. J., The economic implications of learning by doing, *Rev. Econ. Stud.* 29 (1962b)155-173.

[29] Arrow, K. J., Classificatory notes on the production and transmission of technical knowledge, *Amer. Econ. Rev.* 59 (1969) 29-35.

[39] Arvanitis, S. and Hollenstein, H. and Lenz, S. (2002), The Effectiveness of Government Promotion of Advanced Manufacturing Technologies (AMT) : An Economic Analysis Based on Swiss Micro Data, Konjunkturforschungsstelle der Eidgen¨ossischen Technischen Hochschule Z¨urich, Working Papers 54.

[34] Aschhoff, B., Who Gets the Money? The Dynamics of R&D Project Subsidies in Germany, *Jahrbücher für Nationalökonomie und Statistik* 230(5) (2010) 522-546.

[42] Blanes, J. V., Busom, I., Who participates in R&D subsidy programs? The case of Spanish manufacturing firms. *Res. Pol.* 33 (2004) 1459-1476.

[7] Bloom, N., Griffith, R., Van Reenen, J., Do R&D tax credits work? Evidence from a panel of countries 1979-1997, *J. Pub. Econ.* 85 (1) (2002) 1-31.

[48] Blundell, R., Costa Dias, M., Evaluation Methods for Non-Experimental Data, *Fisc. Stud.* 21(4) (2000)427-468.

[17] Bozeman, B., Link, A. N., Tax incentives for R&D: a critical evaluation, *Res. Pol.* 13(1) (1984) 21-31.

[37] Busom, I., An Empirical Evaluation of the Effects of R&D Subsidies, *Econ. Innovation New Tech.* 19 (2000)111-48.

[25] Cantner U., Kösters, S., Picking Winners? Empirical Evidence on the Targeting of R&D Subsidies to Start-ups, Jena Economic Research Papers, 2009-093.

[46] Cerulli, G., Modelling and Measuring the Effect of Public Subsidies on Business R&D: A Critical Review of the Econometric Literature, *Econ. Rec.* 86(274) (2010) 421-449.

[44] Cohen W. Klepper A., A reprise of size and R&D, *Econ. J.* 106 (1996) 925-951. Dasgupta, P., David, P.A., Toward a new economics of science, *Res. Pol.* 23 (1994) 487–521.

[30] David, P. A., Clio and the economics of QWERTY, *American Economic Review* 75, (1985) 332-37.

David, P.A., Positive feedbacks and research productivity in science: Reopening another black box, in Granstrand O. (ed.), *Economics and technology*, Elsevier, Amsterdam (1994) pp. 65-89.

[4] David P.A., Hall. B.H., Heart of darkness: Modeling public-private interactions inside the R&D black box. *Res. Pol.*, 29(9) (2000) 1165–84.

David, P. A., Path dependence: A foundational concept for historical social science, *Cliometrica: Journal of Historical Economics and Econometric History* 1, (2007) 91-114

[5] David, P.A., Hall, B.H. and Toole, A.A., Is public R&D a complement or a substitute of private R&D? *Res. Pol.*, 29(4) (2000) 467–529.

[41] Duguet, E., 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 Econ. Politique*, 114(2) (2004) 263-292.

Edquist, C., Innovation Policy: A Systemic Approach, in: D. Archibugi *and* B.-Å. Lundvall (eds), *The Globalizing Learning Economy*, Oxford, Oxford University Press, (2001) 219–37.

[52] Evangelista, R., Rilevanza e impatto delle politiche dell'innovazione in Italia. I risultati delle indagini CIS, *Econ. Politica Industriale* n. 1, (2007) 103-124.

Georghiou, L., Metcalfe, J.S., Equilibrium and evolutionary foundations of technology policy, *STI Review* – Special Issue on New Rationale and Approaches in Technology and Innovation Policy, vol. 22. OECD, Paris (1998).

[43] Görg, H., Strobl E., The Effect of R&D Subsidies on Private R&D, *Economica* 74 (2007)215–234.

[9] Grossman, G., Promoting new industrial activities: A survey of recent arguments and evidence, *OECD Econ. Stud*, No. 14, (1991) 87-125.

[6] Hall B.H., van Reenen J., How effective are fiscal incentives for R&D? A review of the evidence, *Res. Pol.*, 29, n. 4-5 (2000) 449-469.

[49] Heckman, J.Ichimura H., Todd P., Matching as an Econometric Evaluation Estimator, *Rev. Econ. Stud.*, Blackwell Publishing, vol. 65(2) (1998) 261-94.

[47] Heckman J.J, Lalonde R.J., Smith J.A., The economics and econometrics of active labor market programs, in: *Handbook of Labor Economics*, Vol. IV, Ashenfelter O, Card D (eds). North-Holland: Amsterdam, (1999)1866–2097.

[35] Hussinger, K., R&D and Subsidies at the Firm Level: An Application of Parametric and Semi-Parametric Two-Step Selection Models, *J. Appl. Econometrics* 23 (2008)729-747.

[51] Jaffe, A. B., Building programme evaluation into design of public research support programmes, *Oxford Rev. Econ. Pol.* 18(1) (2002) 22-34.

Klemperer P. (ed.), *The Economic Theory of Auctions,* Edward Elgar, Cheltenham, UK, (2000).

[16] Link, A. N., On the efficiency of federal R&D spending: A public choice approach, *Public Choice* 31(1) (1977)129-133.

[15] Magee, S. P., Endogenous protection: The empirical evidence. In Mueller, D. C., 1997, Perspectives on public choice: A handbook. Cambridge University Press, New York (1997).

[27] Medoff, M.H., Evidence of a Harvard and Chicago Matthew effect, *J. Econ. Methodology*, 13(4) (2006) 485-506.

[22] Merton, R.K., The Matthew effect in science, *Science* 159 (1968)56-63.

[20] Milgrom. P., Roberts. J., Complementarities and fit: strategy. structure and organizational change in manufacturing, *J. Acc. Econ*. 19 (1995) 179–208

[14] Mitchell W.C., Munger, M.C., , Economic model of interest groups: An introductory survey, *Amer. J. Polit. Sci.* 35(2) (1991)512-546.

[21] Mohnen. P., Röller. L.H., Complementarities in innovation policies, *Europ. Econ. Rev.* 49 (2005) 1431-1450

[1] Nelson R.R., The simple economics of basic scientific research, *J. Pol. Econ.*, 67 (1959) 297-306.

[8] Nelson, R. R. (1980), Balancing market failure and government inadequacy: the case of policy towards industrial R&D. Working Paper 840, Department of Economics, Yale University.

[13] Olson, M., *The rise and decline of nations: Economic growth, stagflation, and social rigidities*, Yale University Press, New Haven (1982).

[3] OECD, *Science, Technology and Industry Scoreboard 2007*, Paris, OECD (2007).

[45] Pavitt, K., Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory, *Res. Pol.* 13 (1984) 343-73.

[12] Peltzman, S, Toward a more general theory of regulation, *J. Law Econ.*, Vol. 19, August, (1976) 211-240.

[24] Rigney, D., *The Matthew effect*, *How advantage begets further advantage*, Columbia University Press, New York(2010).

[35] Roper, S., Hewitt-Dundas, N., Innovation persistence: Survey and case-study evidence, *Res. Pol.* 37 (2008)149-162.

[49] Rosenbaum P., D. Rubin, The central role of the propensity score in observational studies for causal effects. *Biometrika* 70, (1983) 41-55.

[50] Rubin, D.B., Formal mode of statistical inference for causal effects, *Journal of Statistical Planning and Inference* 25(3) (1990) 279-292.

[19] Shane, S. A., Why encouraging more people to become entrepreneurs is bad public policy, *Small Bus. Econ.*, 33(2) (2009) 141-149.

Smith, K.,. Innovation as a systemic phenomenon: rethinking the role of policy enterprise & innovation. *Manag. Studies* 1, (2000), 73–102.

[31] Stiglitz, J.E., Learning to learn localized learning and technological progress, in Dasgupta, P. and Stoneman, P. (eds.), *Economic policy and technological performance*, Cambridge University Press, Cambridge (1987).

[10] Stiglitz, J. E. and Wallsten, S. J., Public-Private Technology Partnerships – Promises and Pitfalls. In: Vaillancourt Rosenau, P.(ed.). Public-Private Policy Partnerships. Cambridge, Mass.: The MIT Press, (2000) 37-58.

[11] Tollison, R. D., "Rent seeking". Chapter 23 in Mueller, D C, Perspectives on public choice: A handbook. Cambridge University Press, New York (1997).

[38] Wallsten, S., The effect of government-industry R&D programs on private R&D: the case of the small business innovation research program, *Rand J. Econ.* 31(1) (2000) 82-100.

[32] Weitzman, M. L., Hybridizing growth theory, *Amer. Econ. Rev.* 86, (1996) 207-212.

[33] Weitzman, M. L., Recombinant growth, *Quart. J. Econ.* 113, (1998) 331-360.

TABLES

Table 1 Sectoral composition of the sample

NACE Rev. 1 Sectors	Number of firms	%
FOOD PRODUCTS AND BEVERAGES	48	6.38

TEXTILES	50	6.65
WEARING APPAREL, DRESSING AND DYING OF FUR	29	3.86
LEATHER, LEATHER PRODUCTS AND FOOTWEAR	29	3.86
WOOD AND PRODUCTS OF WOOD AND CORK	18	2.39
PULP, PAPER AND PAPER PRODUCTS	10	1.33
PRINTING AND PUBLISHING	7	0.93
COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	1	0.13
CHEMICALS AND CHEMICAL PRODUCTS	51	6.78
RUBBER AND PLASTICS PRODUCTS	42	5.59
OTHER NON-METALLIC MINERAL PRODUCTS	32	4.26
BASIC METALS	10	1.33
FABRICATED METAL PRODUCTS, except machinery and equipment	74	9.84
MACHINERY AND EQUIPMENT, N.E.C.	177	23.54
OFFICE, ACCOUNTING AND COMPUTING MACHINERY	6	0.8
ELECTRICAL MACHINERY AND APPARATUS, NEC	42	5.59
RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	30	3.99
MEDICAL, PRECISION AND OPTICAL INSTRUMENTS	29	3.86
MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS	13	1.73
OTHER TRANSPORT EQUIPMENT	9	1.2
MANUFACTURING NEC	45	5.98
TOTAL	752	100

Table 2 Summary statistics for the sample (years 2001-2003).

	Total Sample		Access to R&D Subsidies			
			Yes		No	
	Mean	**st dev**	**Mean**	**St. dev.**	**Mean**	**St. dev.**
Number of employees	139.69	520.35	222.06	948.21	115.63	293.08
R&D per employee (Euro)	3308.51	4896.34	5241.93	6396.20	2743.76	4204.22
Share of employees in R&D (%)	8.46	8.96	11.06	9.72	7.71	8.59
Turnover (MEuro)	39.04	271.85	59.08	344.61	33.19	246.64
Fixed capital investments/Emp. (Euro)	5334.325	6506.06	5582.54	6369.79	5261.82	5648.95
Export	83.00%		85.12%		82.38%	
Access to R&D Subsidies (1998-2000)	13.56%					
Access to R&D Subsidies (2001-2003)	22.61%					

Table 3 Transition probabilities between period T and T-1 along years 1998-2003. Full sample.

T-1 \ T	Yes	No
Yes	0.451 (0.0493)	0.549 (0.0493)

No	0.191 (0.0154)	0.809 (0.0154)

Standard Errors in parentheses

Table 4 Transition probabilities between period T and T-1 along years 1998-2003 by size classes.

	T-1 \ T	Yes	No
Group of smallest companies	Yes	0.400 (0.0828)	0.600 (0.0828)
	No	0.165 (0.0202)	0.835 (0.0202)
	T-1 \ T	Yes	No
Group of largest companies	Yes	0.478 (0.0610)	0.522 (0.0610)
	No	0.219 (0.0234)	0.781 (0.0234)

Standard Errors in parentheses

Table 5 Transition probabilities between period T and T-1 along years 1998-2003 by class of R&D personnel intensity

	T-1 \ T	Yes	No
Lowest 50%	Yes	0.361 (0.0801)	0.639 (0.0801)
	No	0.150 (0.0194)	0.850 (0.0194)
	T-1 \ T	Yes	No
Highest 50%	Yes	0.500 (0.0615)	0.500 (0.0615)
	No	0.235 (0.0240)	0.765 (0.0240)

Standard Errors in parentheses

Table 6 Definition of variables.

R&D_SUB	Dummy variable that equals one if the company has access to public R&D subsidies
SIZE	Log of the number of employees
AGE	Company's age.
INNOV	Dummy variable that equals one if the company performs any innovation activity

R&D_EMP	Share of R&D personnel over total employee (%)
EXPORT	Dummy variable that equals one if the company exports
INV_EMP	Log of the fixed investments per employee performed by the company
GROUP	Dummy variable that equals one if the company belongs to a group
CRED_RAT	Dummy variable that equals one if the company declared having asked for credit being denied
DEG_EMP	Share of personnel with university degree over total employee (%)
PAVITT	Dummy variables for industry Pavitt classes

Table 7 Probit model. Dependent variable: Access to public R&D subsidies (R&D_SUB)

	Model (1)	Model (2)	Model (3)	Model (4)
R&D_SUB (t-1)	0.61***	0.61***	0.61***	0.61***
	(0.144)	(0.144)	(0.144)	(0.145)
AGE	0.01*	0.01*	0.01*	0.01*
	(0.003)	(0.003)	(0.003)	(0.003)
SIZE (t-1)	0.09*	0.09*	0.09*	0.09*
	(0.052)	(0.054)	(0.055)	(0.055)
R&D_EMP (t-1)	0.01**	0.01**	0.01**	0.01**
	(0.006)	(0.006)	(0.006)	(0.006)
CRED_RAT (t-1)	-0.03	-0.03	-0.04	-0.04
	(0.141)	(0.141)	(0.142)	(0.142)
GROUP (t-1)	-0.05	-0.05	-0.05	-0.05
	(0.131)	(0.131)	(0.131)	(0.131)
INV_EMP (t-1)		-0.00	-0.00	-0.00
		(0.016)	(0.016)	(0.016)
EXPORT (t-1)			-0.07	-0.07
			(0.148)	(0.149)
INNOV (t-1)				-0.01
				(0.124)
PAVITT	Yes	Yes	Yes	Yes
Constant	-1.65***	-1.65***	-1.61***	-1.61***
	(0.297)	(0.303)	(0.313)	(0.313)
N. of firms	752	752	752	752
LR chi2	49.01***	49.01***	49.24***	49.25***

Robust Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.10

Table 8 Estimation of the ATT with the Nearest Neighbour Matching method, Nearest Neighbour Matching with Caliper and with Kernel method (Bootstrapped S.E.)

Matching Method	Nearest Neighbour Matching	Nearest Neighbour with Caliper	Kernel with Bootstrapped S.E

Outcome Variable	Model	ATT	t-test	ATT	t-test	ATT	z-test
R&D /EMPLOYEE	I	1981.8	2.94***	1861.5	2.77***	2104.3	3.59***
PRIVATE R&D/EMPLOYEE	I	593.9	0.94	517.2	0.82	781.2	1.72*
R&D /EMPLOYEE	II	2024.5	3.07***	1905.1	2.90***	2104.5	3.90***
PRIVATE R&D/EMPLOYEE	II	598.9	0.97	522.2	0.85	781.5	1.88*
R&D /EMPLOYEE	III	2209.4	3.51***	2125.9	3.40***	2117.1	4.33***
PRIVATE R&D/EMPLOYEE	III	704.6	1.05	669.3	1.00	537.9	1.05
R&D /EMPLOYEE	IV	1671.2	2.33***	1694.4	2.35***	2140.3	4.54***
PRIVATE R&D/EMPLOYEE	IV	490.0	0.74	539.5	0.81	825.1	2.00**

*** $p<0.01$, ** $p<0.05$, * $p<0.10$