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The determinants of the public R&D cofinancing rate
An empirical assessment on agricultural research projects in Italy

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Abstract

This paper empirically analyses how a public institution chooses the cofinancing rate in funding competitive agricultural R&D research projects. The public funding institution observes some objective features of the selected research projects and of the proponents. The paper puts forward some testable hypotheses about how the funding institution uses this available information to decide the cofinancing rate. An empirical model is then specified and estimated to test these hypotheses. The empirical application refers to the real case of the agricultural R&D program funded by an Italian region (Emilia-Romagna) over years 2001-2006. Results suggest that the cofinancing rate actually responds to the observed features but this response is not always consistent with the formulated hypotheses.

Keywords: *Public R&D Funding, Agricultural R&D*, *Censored-Normal Regression.*

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1. Introduction: objectives of the paper

In the last decades, the scientific debate on agricultural R&D public funding progressively shifted the attention from the optimal amount of expenditure to its optimal use or allocation, i.e., how to design funding mechanisms that optimally allocate the fixed or even diminishing amount of resources (Huffman and Just, 1994, 1999a, 1999b; Huffman et al., 2006; Pardey and Beintema, 2002; Pardey *et al*., 2006; Spielman and von Grebmer, 2004). At many different levels (regional, national, European) one funding mechanism has progressively emerged as one major stream of public support to research. It consists in granting public funds to research projects selected within a competitive procedure and, then, through a cofinancing agreement.

The increasing use of this funding mode in public agricultural R&D raised a lively debate about its underlying rationale. Some authors (Janssen, 1998) stress the advantages for a public funding institution associated to such modality. Others (Huffman and Just, 1994, 1999a and 2000; Huffman et al., 2006), on the contrary, provide arguments about its potential inefficiencies and failures. Most literature on this funding mechanism underlines that cofounding (or cofinancing) schemes aim at encouraging R&D investments by those research institutions or private companies that would not otherwise undertake or afford them (Wong and Singh, 2011). In this sense, within such schemes, the funding institution plays a complementary role in providing resources to run R&D activities but still takes the advantage of its financial contribution in order to select beneficiaries, projects, fields and types of innovations according to its own objectives.

An often disregarded aspect of this funding modality, however, is that it allows, at least in principle and more or less explicitly, the financier to choose the preferred cofinancing rate on the basis of observed features of the funded projects and proponents. If the cofinancing rate really is part of the contractual space, (i.e., it is established once a given R&D project has been approved for funding), the open question is why and how the financier chooses the cofinancing rate it considers appropriate. One argument could be that such decision is taken case-by-case (i.e., is case-specific) and, thus, it is independent from these observable characteristics. Empirically, following this argument, these characteristics are expected to be statistically insignificant with respect to the observed cofinancing rate. On the contrary, if a statistically significant effect of these characteristics emerges, we can conclude that there is an underlying rationale leading the financier in this kind of decision.

The present paper aims at providing empirical evidence in support to this latter interpretation by specifying and estimating an empirical relationship between the cofinancing rate granted by the public financier of agricultural research and some of these observable characteristics. Though the paper definitely has an empirical focus, we firstly discuss the main characteristics (i.e., purposes and functioning) of this R&D funding mechanisms and, then, put forward some hypotheses about the underlying theoretical rationale linking the cofinancing rate with the projects/proponents attributes (section 2). Then, this relationship is empirically assessed adopting an appropriate empirical model specification that allows assessing whether and how the cofinancing rate actually responds to some observed characteristics (section 3). This empirical model is estimated in the specific case of the agricultural R&D program funded by an Italian region (Emilia-Romagna) over years 2001-2006 (section 4). The concluding section draws some tentative conclusions about the empirical results and some conjectural explanations (section 5).

2. The research question: how is the cofinancing rate chosen?

2.1. Competitive grant funding and the use of the cofinancing rate

Several authors noticed that an increasing amount of public R&D funding is now allocated on the basis of a competition among alternative projects (*project funding* or *peer-reviewed competitive grant funding*) instead of (or in addition to) assigning budget on a regular base to research institutions that then allocate it discretionally (*program* or *institutional funding*). For instance, the European Union's scheme funding is based on competition among projects and the National Science Foundation in the USA also runs a large competitive grant system (Janssen, 1998). The easy justification of this shift in the funding modality is that, given the general shrinking of public resources (Huffmann and Just, 1999b), moving towards more competitive funding, therefore towards a contracting mode, would incentive researchers to remain more strongly tuned into the problems they are expected to deal with and public resources would consequently be more effective (Hess, 1992). The public funding institution looks for the capacity of the proponents to transform their good (in scientific terms) research ideas into results that are complaint with respect to the financier's own agenda.

At least in principle, as mentioned, there is another advantage of this funding mechanism that may, in fact, explain its adoption. Once the scientific value of a group of R&D projects has been appropriately assessed, the financier may still want to acknowledge more relevance and priority, thus more funding, to projects showing desirable attributes. Here, by *cofinancing rate* we intend the share (on the total cost of the selected project) granted by the funding institution to the research body that will carry out the R&D activities. Through a higher cofinancing rate, the financier aims at raising the degree of compliance of the projects/proponents. Thus, the selection of the cofinancing rate becomes the leverage through which the financier puts in pace his strategic or "political" choices beyond the pure scientific merit of the R&D projects.

From the perspective of the funding institution, therefore, the rationale of this funding mechanism can be ideally represented as a two-stage procedure (Figure 1). In the first stage, candidate projects are selected and the competition is run on the basis of the scientific merit as evaluated by independent peer-reviewers. During this stage, the funding institution, though apparently playing a passive role, also collects information on competing projects and researchers to make them disclose additional information and provide signals about themselves and their research projects that can be then used by the public funding institution in the following stage (Materia and Esposti, 2009a). In the second stage, the funding institution offers the researchers (or research institutions) whose projects have been selected (and their scientific quality validated), a contract. In practice, the content of this contract is the cofinancing rate which represents, for the funding institution, its *best response* to the information collected on projects and proponents during the first stage of the procedure.

2.2. The rationale behind the choice: theoretical motivations and the empirical issue

Evidently, Figure 1 represents an idealization of the funding mechanism and of the underlying logic of the financier. In fact, we could reasonably argue that in the practical experience the cofinancing rate, though being a free choice of the financier, is driven by factors, like habits, practices, conventions that makes the cofinancing rate be decided on a case-by-case basis without any regular effect attributable to the observable attributes of funded projects and proponents.

Understanding whether the public funding institutions really establishes the cofinancing rate given these observable characteristics and, thus, formulate its best response on this basis is the main objective of the present empirical investigation. Though proposing a formal theoretical model of how this best response is formulated is beyond the scope of this paper (see Materia and Esposti, 2009b), here we summarize and reinterpret the literature on this topic (Janssen, 1998; Tabor, 1998) by arguing that the financier looks at three basic attributes to prioritize R&D projects in order to maximize the compliance of their proponents to his own objectives.[1] In practice, among projects/proponents that succeeded in the first stage of the process, the financier will acknowledge different priority, thus will decide different cofinancing rate, according to these attributes: *scientific merit*, *relevance*, *risk* (that can be, in turn, distinguished in *complexity* and *reputation*).

Prioritization on the basis of the attribute of scientific merit is apparently of easy interpretation: the financier will want to reward better projects (according to the peer-reviewers' evaluation in the first stage of the process) with an higher cofinancing rate. The same univocal direction of prioritization can be also acknowledged to the attribute of relevance. This attribute expresses to what extent the R&D activity in question is oriented towards issues that the public funding body considers socially relevant. While the peer review process is expected to ensure the scientific quality of the proposals, it is not necessarily involved in fixing priorities or may not fully incorporate the financier's priorities.[2] Therefore, the decided cofinancing rate may reward projects that, provided that an acceptable scientific merit is granted, are closer to these priorities.

The other two attributes are both expression of the risk associated to this kind of mechanism. Though the scientific merit of the funded projects is guaranteed, in principle, by the peer-reviewing, in practice the funding body still has to face the risk of opportunistic or moral hazardous behaviours by the beneficiaries after receiving the grant. These behaviours consist in a lower effort than expected according to the contract in the second stage of the process, or in promising activities or results the beneficiary cannot actually afford, in the first stage (Materia and Esposti, 2009b).[3] Or, even more simply, it has to face the fact that more ambitious research project will more likely incur the risk of failure (Fortin and Currie, 2013).

The response of the funding public institution to this risk typically consists in looking for attributes that actually signals the magnitude of this risk. Two are the main attributes in this respect the financier may consider and they move in opposite direction. The first is the attribute of *complexity* of the R&D project which is essentially related to its size in terms of amount of resources involved, either funds or personnel, as well as administrative burden and costs in the overall management of

[1] Beside suggestions and arguments emerging from the literature on these aspects, here the identification of the main attributes guiding the choice of the cofinancing rate also comes from interviews made to officers and public managers at the institution under study here (Regione Emilia-Romagna) (Esposti et al., 2010) and from meetings with analogous decision makers of the other Italian regional institutions.

[2] For instance, in the case of agricultural research, for some public funding institutions "local" (or highly specific) research needs are real priorities and these needs are usually expressed by local farmers, consumers, agri-business firms or by their respective organizations.

[3] In fact, a potential risk of this funding mechanism, especially in smaller research systems, consists in the emergence, during the first stage of the process, of a "network of friends" (or colleagues) who indulge in informal decision making and favoritism and, eventually, circumvent principles of objectivity and neutrality. When a supposedly "competitive" grant scheme loses its objectivity and neutrality, it also loses its credibility.

the research activity. The financier may argue that a higher complexity is associated to a higher risk and this induces the financier to reduce the cofinancing rate. The second attribute taking risk into account is the *reputation* of projects' proponents. The attribute of *reputation* is particularly relevant whenever the financier is a public institutions as it ensures *ex ante* the accountability and credibility of the whole R&D funding process. At least in principle, the financier associates higher reputation of the proponent to a lower risk of the project she/he proposes.

Nonetheless, the response of the financier in terms of cofinancing rate decision to these two attributes and, therefore, to the level of risk they signal, is not easily predictable *ex ante* as it is affected by two contrasting needs. On the one hand, the financier may want to respond to higher risk by granting a lower cofinancing rate to penalize more risky projects/proponents[4] and enforce an higher co-responsibility on the funded research bodies. A lower cofinancing rate reduces the controlling effort (therefore, the costs) of the financier while leaving the funded institutions or researchers more flexibility and responsibility in being compliant with the declared research objectives. In large R&D projects, this flexibility is needed to possibly deviate from the original project design and ideas thus avoiding the "lock-in" effect. On the other hand, however, especially for those projects he considers of high relevance, the financier might decide to respond to higher risk with a higher cofinancing rate to maximize the control on R&D activities, the compliance of results to its objectives and, thus, to improve the credibility and transparency to the whole funding mechanism.

A final aspect that may affect the financier's decision on the cofinancing rate is the *budget constraint* it has to face. Strictly speaking, this is not an attribute of a project/proponent but still conditions the amount of resources the financier is willing to invest on a research project given the residual available funds and the project's cost.

Table 1a (second column) summarizes how, according to the discussion above, the funding institution is expected to adapt the cofinancing rate to these attributes (and the budget constraint) on the basis of the information it retrieves from the first stage of the process. Whether the expected response of the cofinancing rate according to these theoretical arguments is confirmed in the real world (i.e., with real data) becomes an empirical issue also because, as discussed, this expected response is often not univocal.

[4] Several empirical studies, for instance Fortin and Currie (2013), suggests that more complex projects are often associated to lower average returns to R&D investments.

2.3. From attributes to observable variables: towards testable hypotheses

Passing from these theoretical conjectures to the empirical assessment, however, is not straightforward as it implies that the abovementioned relevant attributes of any single project/proponent are observed. These attributes are, in fact, abstract and unobservable and have to be proxied by proper observable variables. What the financier can eventually observe of the selected R&D projects/proponents are their objective features and, given the inherent asymmetric information occurring in these cases, the signals the proponents want to give on the projects and on themselves. The financier is expected to interpret and use this available information to decide the proper cofinancing rate.

One might actually argue that, due to the imperfection and incompleteness of the information it handles, the financier eventually decides the cofinancing rate only on the basis of case-specific arguments. In fact, when many cases (funded projects and proponents) are observed, the real empirical challenge is to assess the presence of some regularities in how the funding institution makes this choice given the information and, consequently, draw some conclusions on how this information is interpreted in this respect.

Consider a financing institution facing a set of N R&D projects to be funded as they all have passed the first stage of the process, that is, the approval by a group of peers. For any i-th project (with $i=1,\ldots N$), the financier can observe three orders of variables. The first group of variables simply are the information disclosed during the first stage and consists in the following set of observable variables: the quality of the proposal and of the proponents as expressed by the *evaluation score* attributed by the peer-reviewers (S_i); the *duration* (D_i) and *cost* (C_i) of the project; the *nature of the proponent* (type of the research institution presenting and carrying out the project) (T_i).

The second order of variables are that kind of further information the financier can retrieve on any i-th project and beneficiary from the whole set of knowledge it holds and, in particular, from previous rounds of R&D funding. The *suitability* (SU_i) is an indicator built by the funding institution on the basis of an additional evaluation expressed by its own officers on the basis of the information coming from the first round and expressing, beyond the scientific merit, the degree of compliance of the proposal with the set of priorities established *ex ante* by the funding institution itself. The *history* of the relationship between the beneficiary and the financier can be expressed both as the number of successful proposals submitted by the same proponent in previous funding rounds or periods ($H1_i$) and the total funding received in these previous successful proposals ($H2_i$).

A final type of observable variable does not directly concern, as mentioned, the individual *i*-th project but the overall budget ceiling (B_t) that the funding institution has to manage and allocate across these N research projects and that may evidently vary over time (t = year) according to the financial conditions of the funding institution. This *budget constraint*, however, can also be referred to any individual project as the incidence of the respective total cost on the available budget in the year of interest (i.e., $B_i = C_i / B_t$).

The objective here is to empirically investigate how, given this available information, the financier decides the cofinancing rate, that is, to investigate the linkage between the cofinancing rate (r_i) and these observable variables, $r_i = f(\mathbf{X}_i)$, where $\mathbf{X}_i = (S_i, SU_i, D_i, C_i, T_i, H1_i, H2_i, B_i)$. Hypotheses about how r_i responds to any of these variables ($\partial r_i / \partial \mathbf{X}_i$) can be formulated by assuming that the financier interprets these observable variables as proxies or signals of the underlying and mostly unobservable attributes discussed in previous section (Table 1a).

First of all, evidently, the financier's cofinancing rate is expected to respond positively to a higher evaluation score, i.e. $\partial r_i / \partial S_i > 0$, and negatively to a higher *budget constraint*, i.e. $\partial r_i / \partial B_i < 0$. In the former case, however, we might also argue that the score achieved by a project during the final stage is not only an indicator of its scientific merit but also of its inherent risk of failure. If this interpretation of S prevails, we could eventually observe the opposite response of the financier, that is, $\partial r_i / \partial S_i < 0$.

Secondly, *relevance* can be proxied by the suitability indicator (SU_i) constructed on the basis of the specific evaluation expressed by internal expert officers after the first stage (see next section), the assumption being that the higher the suitability the higher the relevance; therefore it is expected that $\partial r_i / \partial SU_i > 0$.

Thirdly, being both expression of the size of the research project, duration (D_i) and cost (C_i) can be considered proxies of *complexity*. Variables D_i and C_i , however, show almost perfect collinearity as explained by the fact that project duration is almost proportional to project costs. So, one of these variables must be excluded. Here, D_i is maintained as proxy of complexity also because C_i is then used in the calculation of B_i. If this interpretation is correct, as discussed, r can react either positively or negatively, thus it can be either $\partial r_i / \partial D_i > 0$ or $\partial r_i / \partial D_i < 0$. Fourthly, reputation/credibility is expected to be expressed by the history of the relationship between the proponent and the financier ($H1_i, H2_i$). Even in this case, those variables being associated to the risk of project, the expected direction of the response is not univocal (either $\partial r_i / \partial H1_i, \partial H2_i$ >0 or <0).

Finally, T_i is a qualitative variable that affects how the different research institution typologies are perceived by the funding institution. Thus, the financier can associate T_i to all attributes and it simply behaves as a shifter of the response of *r* to any of these attributes. Consequently, its impact on r_i is unpredictable and we can expect either $\partial r_i / \partial T_i > 0$ or $\partial r_i / \partial T_i < 0$.

Table 1a summarizes this discussion about the linkage between the unobserved attributes and the observable variables (third column) and, consequently, the expected and testable relationship between these latter and the cofinancing rate (r_i) (forth column). Within this modelling framework, the empirical challenge thus becomes to put forward a general enough viable (i.e. estimable) specification of $r_i = f(\mathbf{X}_i)$ to test these hypotheses about the relationship between $\mathbf{X}_i$ and r_i.

In fact, this hypothesis testing can be ideally divided in two steps. The first general hypothesis to be empirically assessed is whether r_i significantly varies across heterogeneous projects and, therefore, its response to variations of $\mathbf{X}_i$ is statistically significant. Accepting this hypothesis would imply that, within this funding mechanism, the cofinancing rate really represents the response of the financier to the information disclosed on the funded projects and beneficiaries and, therefore, to the underlying attributes it allegedly signals. Secondly, once this first-level hypothesis is accepted, we can empirically test whether the response of r_i to $\mathbf{X}_i$ moves in the expected direction, i.e., that indicated in Table 1a. For those variables where no expectation can be formulated, the empirical investigation may provide evidence on which of the two opposite directions is eventually predominant in the decision of the funding institution under consideration.

2.4. Agricultural R&D cofinancing in Italian regions: a suitable case study

Though issues related to the functioning of the R&D funding mechanism under consideration are not evidently exclusive of public agricultural research (David, 2000), the empirical model is here developed and applied with specific reference to the agricultural case. The large prevalence of public funding in agricultural R&D (Huffman and Just, 1999b)[5] and the increasing use of cofinancing research contracts (Materia, 2008) make the sector particularly suitable for the present analysis. In the case of agriculture, this change raised a vivid debate due to the historically crucial role of public R&D funding in this sector both in developed and developing countries (Janssen, 1998; Huffman et al., 2006).

There is a further reason for focusing on agricultural R&D projects. Under this general heading, we usually find very heterogeneous R&D activities where heterogeneity comes from the highly diverse fields of application that inevitably imply highly heterogeneous scientific fields and disciplines. This heterogeneity is a typical trait of agricultural R&D as largely acknowledged in the literature in particular with reference to substantial differences occurring between crop and livestock research (Townsend and Thirtle, 2001). More recently, the advent of relatively novel scientific and technological challenges for the agricultural activity (from environmental issues to food quality and safety) has expanded further the already wide range of scientific disciplines involved in agricultural research.

In empirical analysis, this heterogeneity, rather than being a limitation, actually represents a major advantage. Though the available dataset is not, by itself, a panel, the presence of many heterogeneous R&D projects within a large cross-sectional sample still allows investigating (and testing for) the presence of differential behaviours across typologies. In other words, the agricultural R&D dataset allows the analyst incorporating the heterogeneity within the analysis and assessing the robustness of results in this respect.

Here, the empirical application concerns the agro-food R&D activity funded by *Regione Emilia-Romagna* (the institution administering one of the largest Italian region) over years 2001-2006 according to the cofinancing pluriannual programme promoted with Regional Law 28/98 (Materia, 2008).

Agricultural R&D funded by the regions is gaining an increasing relevance in Italy and it amounts to roughly 20-25% of total public agricultural R&D. The role of the regions as a pillar of the Italian system of agricultural research is now formally stated within the Italian Constitution that recognizes

[5] This is definitely the case in Italy. Alfranca and Huffman (2003) report that the Italian share of private agricultural research was about 25% in the nineties. Among other European countries, they report 60% for UK and 10% for Germany and Spain. Pardey et al. (2006), however, present slightly different data: in 2000, the private share was 71% in the UK, 54% in Germany, 54% in all OECD countries. With reference to 2000, Kirschke et al. (2011) indicate that the average private share is 54% in developed countries and only 6% in developing countries. More recently, on the basis of 2006-2008 OECD data, Wang et al. (2012) has reported much higher public shares of agricultural R&D in 13 Western European countries: 82% overall, 99% for Italy, 89% for Germany, 83% for Spain, 54% for the UK. For more details on Italian public agricultural R&D, its structure, evolution and returns, see Esposti (2002), Esposti and Pierani (2003 and 2006), Di Paolo and Vagnozzi (2014).

their autonomy in funding research and defining the priorities and strategies for its programming. Emilia-Romagna regularly is among the top three regions in terms of public agricultural R&D expenditure (Vagnozzi et al., 2006; Esposti et al., 2010), and it has been one of the first Italian regional authorities to adopt a new regulation (Regional Law 28/98) to re-organize the selection process of research funding towards more competitive principles.

Regional Law 28/98 represents an exemplary case of the competitive funding mechanism depicted in Figure 1 as it implies a selection among submitted projects (1221 over the period under consideration) performed by panels of (at least three) external and independent experts that assign an evaluation score to any project. The panelists are nominated by the regional authority and selected from a list of high-level experts (mostly from academic or research institutions) whose experience is recognized in specific fields. After this independent assessment of the scientific value of the proposals (1st stage), the funding institution (Regione Emilia-Romagna) assigns the approved projects to groups of three internal expert officers whose task is to attribute any project a further score expressing its suitability with respect to predetermined priorities of the regional agricultural context and to take the final admittance or rejection decision on any proposal that passed the first stage. Eventually, on the basis of this information, the Region decides the cofinancing rate to be granted to any selected project. [6]

The regional law 28/98 also fixes formal eligibility criteria for candidate projects and submitters. In particular, it states that R&D projects have to be carried out on the regional territory and be proposed by local actors. The type of possible applicants is also established by the regulation. In particular, projects can be submitted either by research institutions (e.g., universities) or by private enterprises (SMEs, cooperatives and firms' associations included), but also by organizations that act as intermediaries (or *innovation brokers*, IB) between researchers or research institutions and innovation users (farmers, agri-food companies etc.). These latter submitters are expected to propose projects that more closely reflect the research needs of the regional territories, sectors and actors. Within the database under consideration, these innovation brokers submitted 32% of the projects, of which 48% have been selected and funded. The remaining 68% of proposals (though only 52% of funded projects) were submitted by about 60 different subjects, 52% of which are private enterprises.

[6] The researcher can reject the cofinancing rate offered by the Region and, thus, skip the contract. This funding mechanism, however, does not impose any constrain on other possible research activities the researcher can carry out in parallel.

Over the period under consideration here (2001-2006), 589 projects have been selected and funded. Their total cost approximately amounts to €75 million, of which €59 were provided by the Region through cofinancing (thus, overall, a 79% cofinancing rate).

Despite the obvious specificities in the implementation of this kind of functioning mechanism of the Regione Emilia-Romagna, this case still remains representative both for the relevance and size of this institution and its R&D funding, and for its exemplary and paradigmatic traits and this contributes to the generalization of the empirical results of the present study. In fact, very similar competitive grant fund allocation procedures, with the consequent choice of the cofinancing rate, can be found in other regional public authorities in Europe (Bornmann and Daniel, 2006; Eickelpasch and Fritsch, 2005; Garcia and Menéndez, 2004, Henningsen, et al., 2012). Also outside Europe, previous studies already depicted and investigated analogous funding mechanism (see, for instance, Jayasinghe et al. (2001).

3. The econometric model

3.1. Functional specification

To empirically assess the relationship between r_i and the set of observable variables $\mathbf{X}_i$, a functional specification of $r_i = f(\mathbf{X}_i)$ must be adopted. This specification has to be empirically tractable and a good approximation of the real linkages between r_i and the covariates $\mathbf{X}_i$. These linkages are not only unknown but, as discussed, their sign and magnitude may be not univocal and vary across heterogeneous groups of projects. Therefore, for the empirical investigation we need a specification of $r_i = f(\mathbf{X}_i)$ that is general (or flexible) enough to let the data eventually identify, with the minimum *ex-ante* restrictions, the direction (i.e., sign) of these linkages best fitting the observed data.

This generality (flexibility) can be obtained by approximating $r_i = f(\mathbf{X}_i)$ with a second-order Taylor polynomial and, in particular, with a generalized quadratic function. Within this family of flexible functions (Chambers, 1988), the most widely used specification is the translogarithmic (or translog) function. The unknown function $r_i = f(\mathbf{X}_i)$ can be thus approximated, at the approximation point $S = SU = D = H1 = H2 = B = 1$, by the following empirical specification:[7]

[7] $\alpha_{jl} = \alpha_{lj}$ due to symmetry.

$$\ln r_i = \ln[f(\mathbf{X}_i)] \approx \alpha_0 + \sum_j \alpha_j \ln X_{ji} + 1/2\, \alpha_{j2} (\ln X_{ji})^2 + 1/2 \sum_j \sum_l \alpha_{jl} \ln X_{ji} \ln X_{li} + \alpha_T T_i + \alpha_F F_i, \quad \forall i = 1,\dots,N; \; X_j, X_l \in \mathbf{X} \text{ where } \mathbf{X} = (S, SU, D, H1, H2, B) \tag{1}$$

where T_i and F_i are qualitative dummies expressing the type of proponent and the research field (see below), respectively. At the approximation point, the value, the first and the second-order derivatives of this function correspond to the unknown function $r_i = f(\mathbf{X}_i)$.

There are two additional reasons to adopt a specification in the logarithms. First of all, such specification allows interpreting the unknown parameters of (1) directly as elasticities. Secondly, it is worth noticing that, by definition, the cofinancing rate r_i varies within the interval [0,1], therefore within a linear regression model it behaves as a left and right-censored variable. After the logarithmic transformation, the dependent variable in (1) ($\ln r_i$) remains censored but only on one tail of its statistical distribution. While the maximum value of $\ln r_i$ is 0 and, therefore, the respective statistical distribution is right-censored at 0, the logarithmic transformation eliminates the lower bound and amplifies the range of variation of the dependent variable: $\ln r_i$ is not left-censored and varies over the interval (-∞,0]. Therefore, the logarithmic transformation mitigates censoring occurring in the model's dependent variable and, therefore, also mitigates the complications in estimating a linear regression model like (1) under censoring. Nonetheless, estimation of (1) still has to appropriately take into account the censored distribution of the dependent variable (see next section).

3.2. Data and model variables

As anticipated, model specification (1) is here applied to the agro-food R&D activity promoted and funded by Regional Law 28/98 in Italian region Emilia-Romagna over years 2001-2006 (see section 2.4). The dataset contains the N=589 observations (R&D projects) on which the following variables are directly observed: the rate of cofinancing granted by the Region (r_i); the score assigned by the external and independent peer-reviewers (S_i); the project's duration (D_i); the project's cost (total budgeted expenditure) (C_i); the year of funding (t) and the total budget for that year (B_t) leading to the variable $B_i = C_i / B_t$;[8] the typology of the proponent (T_i); the project typology in terms of sector or field of application (F_i).

The other model variables combines several types of information the financier gets from the first stage of the process and by other sources it has the access to. SU_i is the score attributed by officers of the Regione Emilia-Romagna to any approved project according to its closeness to financier's own priorities.[9] $H1_i$ is the percentage of successful proposals submitted by the same proponent to the financier in previous funding rounds or periods; $H2_i$ is the ratio between the total cost of the current proposal and the total cost of the previous successful proposals plus the current one.

Some clarifications are needed for dummies T_i and F_i. T_i enters the model as a simple dummy distinguishing between proponents and it takes value 1 for projects presented by an IB and 0 otherwise. F_i is the variable taking into account the heterogeneity among agricultural R&D activities, as already discussed in section 2.4, and expresses the research field or field of application of the project. More specifically, here F_i is a combination of three dummies. According to what established in Law 28/98,[10] projects are classified in three typology groups: crop productions (*VEG*); animal productions (*ZOO*); farm and rural development, environment and marketing (*ALT*). Therefore, within the adopted empirical model, F_i is a vector of dummies: $\mathbf{F}_i = (VEG_i, ZOO_i, ALT_i)$, where each dummy takes value 1 for the *i*-th project belonging to that group and 0 otherwise.

Table 2 reports some descriptive statistics on these model variables within the sample.

3.3. Estimation issues and strategy

Given the available data and the dummy variables adopted, the estimated model is eventually the following:

(2)

$$\ln r_i = (\alpha_0 + \alpha_V VEG_i + \alpha_Z ZOO_i + \alpha_T T_i) + \sum_j \alpha_j \ln X_{ji} + 1/2\,\alpha_{j2} (\ln X_{ji})^2 + 1/2 \sum_j \sum_l \alpha_{jl} \ln X_{ji} \ln X_{li} + \sum_j \alpha_{jV} VEG_i \ln X_{ji} + \sum_j \alpha_{jZ} ZOO_i \ln X_{ji},\ i = 0,...,589;\ X_j, X_l \in \mathbf{X} \text{ where } \mathbf{X} = (S, SU, D, H1, H2, B)$$

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[8] It is worth noticing (see also Table 2) that the available budget *B* under Law 28/98 remained quite constant from years 2000 to 2004, while it clearly decreased in 2005 and 2006. Consequently, B_i becomes a variable not only expressing specific features of the i-th project (its cost, in particular) it is also the only time-specific variable entering model (1).

[9] See Materia et al. (2014) for more details on the reconstruction of these variables.

[10] These fields are defined *ex-ante* and the assignment of any research project to one of these fields is fully observed by the financier already at the first stage of the process.

where ε_i is the conventional i.i.d. disturbance term: $\varepsilon_i \sim N(0,\sigma^2)$. Due to the interaction terms $VEG_i \ln X_{ji}$ and $ZOO_i \ln X_{ji}$, dummies $\mathbf{F}_i$ not only behave as shifters but they also make the coefficients associated to $\mathbf{X}_i$ vary across the research fields.

From the estimation of (2) it is possible to analyse the response of the financier's cofinancing rate (r_i) to the project's and proponent's characteristics ($\mathbf{X}_i$). In particular, the elasticity of r_i with respect to the continuous variables S_i, SU_i, D_i, $H1_i, H2_i$ and B_i can be easily computed as follows:

(3) $\partial \ln r_i / \partial \ln X_{ji} = \left(\alpha_j + \alpha_{jV} VEG_i + \alpha_{jZ} ZOO_i\right) + \alpha_{j2} \ln X_{ji} + \sum_{l \neq j} \alpha_{jl} \ln X_{li}$

To achieve a proper estimation of (2) and, thus, of (3), however, two further empirical issues must be adequately considered. First of all, since the translog specification is here adopted as a local approximation of *f(***X***)* at $\mathbf{X} = 1$ ($\ln \mathbf{X} = 0$), it is helpful, before estimation, to normalize all model variables (excluding the dummies) with respect to the sample mean (by subtracting the mean) such that the approximation is exact in the sample mean point. As a consequence, for any *j-th* variable in $\mathbf{X}=(S, SU, D, H1, H2, B)$, in the sample mean point the elasticity in (3) becomes $\partial \ln r_i / \partial \ln X_{ji} = \left(\alpha_j + \alpha_{jV} VEG_i + \alpha_{jZ} ZOO_i\right)$. It is also straightforward to compute the respective second order derivates, that is: $\partial^2 r_i / \partial X_{ji}{}^2 = \alpha_{j2} - \left(\alpha_j + \alpha_{jV} VEG_i + \alpha_{jZ} ZOO_i\right)$. The second order derivative provides a further useful information about the response of r_i to $\mathbf{X}_i$. In particular, it allows testing whether this response is concave, where by *concave (convex) response* we mean here that the variation of r_i induced by a positive variation of $\mathbf{X}_i$, though monotone, decreases in magnitude (i.e., in absolute terms) as $\mathbf{X}_i$ increases. Evidently, in any other sample point or sub-sample mean such elasticities and derivatives may assume different values and signs according to the respective values of S_i, SU_i, D_i, $H1_i, H2_i$ and B_i.

The second, and more important, empirical issue concerns r_i, and $\ln r_i$, as a censored variable. As well known (Cameron and Trivedi, 2005), though (2) apparently is a classical linear regression model, the OLS estimation of its parameters under censoring of the dependent variable is biased and inconsistent. Looking at the observed data (i.e., observed r_i) we might argue that the censoring of the dependent variable $\ln r_i$ actually occurs on both tails of the statistical distribution. In practice, the application of Law 28/98 has acknowledged a minimum cofinancing rate of 45%. One possible explanation could be that the funding institution (Regione Emilia-Romagna) has refrained from lower cofinancing rates (though admitted) because a too low rate would discourage even capable researchers to submit projects thus inducing adverse auto-selection (Materia and Esposti, 2009a). Therefore, it is always $r_i \geq 0{,}45$ and we might also conclude that the distribution of $\ln r_i$ is itself left-censored at -0.80 and ranges within the [-0.8, 0] interval.

It should be clarified that the censoring on $\ln r_i$ is of different nature compared to r_i.[11] In fact, r_i is by construction censored on both tails of the statistical distribution. $\ln r_i$, on the contrary, while definitely right-censored, may still take any value on the left tail of the distribution. The lowest value (-0.8) could just be the lowest sample draw from a left-uncensored distribution. Therefore, $\ln r_i$ actually has a left-censored distribution only under the assumption that the funding institution deliberately, though unofficially, decide to not go below this cofinancing rate. For $\ln r_i$, therefore, left-censoring is just an hypothesis whose implication on estimation results can be evaluated only estimating the model with and without it.

Following this argument, three alternative estimates are performed. Firstly, equation (2) is estimated as a classical linear regression model using an OLS estimator. Under censoring these estimates are biased but the size of the bias depends on how relevant censoring is, that is, how many observations concentrates on the limit values of the censored distribution (Cameron and Trivedi, 2005). Then, the two distribution limits are introduced in sequence. Firstly, a right-censored (at $\ln r_i = 0$) normal distribution and then a left ($\ln r_i = -0{,}8$) and right-censored normal distribution are assumed. Equation (2) becomes a *censored-normal regression* and can be properly estimated through a Maximum Likelihood (ML) estimator.[12] Unlike OLS estimates, these latter parameter estimates are consistent under a censored distribution, provided that $\varepsilon_i \sim N\left(0, \sigma^2\right)$ (Cameron and Trivedi, 2005; McDonald, 2009).[13]

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[11] This difference justifies the advantage of working with the logarithmic transformation.

[12] What we call here *censored-normal regression* is more often known as *Tobit model*, or *type-I Tobit model* (Wooldridge, 2002). As clarified by Wooldridge (2002, 517-520), the present application should be not even considered a case of censoring as it is rather a "corner solution model". From the econometric point of view, however, it raises exactly the same issues and can be thus legitimately considered a two-limit Tobit model. More details on this, as well as on the comparison between OLS and Tobit estimates, can be found in McDonald (2009).

[13] It can be shown (Wooldridge, 2002) that the OLS bias under censoring increases as the fraction of sample that is censored increases.

4. Results

4.1. Model estimates: general evidence

Table 3 reports the model parameter estimates under the three abovementioned estimators and the various specifications. In particular, the model is estimated on sub-samples *VEG*, *ZOO*, *ALT* and on the whole sample, with and without the *T* dummy. The first general evidence, as discussed, concerns the hypothesis that r_i really represents a response of the funding institution to the observed features of selected projects and beneficiaries. The statistical significance of at least some of the parameters associated to $\mathbf{X}_i$ demonstrates that this hypothesis is accepted in the present case. This general result seems quite robust across the alternative specifications and sub-samples.

It may be firstly noticed that, compared to OLS, ML estimation provides slightly more statistically significant parameters under both right censoring and left and right censoring, particularly for parameters associated to ln*S* and ln*D*. As a matter of fact, though censoring, concerns many observations (172 projects, overall), OLS and ML estimates do not differ much and ML estimates with only right-censoring and with censoring on both tails are quite similar (as confirmed by χ^2 tests). To avoid repetitions, and because of their consistency, only left and right-censored ML estimates are here commented and discussed further.

In particular, the parameters associated to *SU* and *D* turn out to be always statistical significant and maintain the same sign across estimates. At the same time, other results vary across sub-samples, that is, across research fields *VEG*, *ZOO*, *ALT*. In this respect, the most relevant evidence emerging concerns the different behaviour of ln*S*, ln*H1* and ln*B* in the sample mean point, namely the different sign and statistical significance of parameters α_S, α_{H1} and α_B.[14] For *VEG* (and ALT) projects, presumably an highly heterogeneous group, α_S and α_B estimates are statistically different from 0 and negative, while they are not significant in the case of the *ZOO* group. On the contrary, α_{H1} estimate is not significant for *VEG* and *ALT*, while it is significantly negative for *ZOO*. The interpretation of these differential results may be that, in establishing the proper cofinancing rate, the financier acknowledges that the *ZOO* group probably is more homogeneous and with proponents with well established reputation so that the specific content of the proposals, both in

[14] It must be reminded that censoring makes the relation between variables non-linear at the extreme points of the distribution. Due to this intrinsic non-linearity, the marginal effects differ between censored and uncensored observations. They still correspond, however, to parameter estimates for the (uncensored) latent variable, that is, the unobserved dependent variable for which the linear relation with the independent variables always holds true. Only in this sense, estimated parameters can be interpreted as marginal effects (Wooldridge, 2002; Cameron and Trivedi, 2005).

terms of scientific merit (*S*) and cost (*B*), becomes less relevant than the past history of the proponent (*H1*).

Despite these specific results concerning the *ZOO* group, however, estimates do not indicate major differences across fields as the parameters associated to the respective dummies in the full sample estimates are not statistically significant (parameters α_{xV} and α_{xZ}, with the only exclusion of α_{H2Z} and α_{BZ} as expected). It is also worth reminding that model estimation on sub-samples does not fully exploit the available statistical information. On the contrary, the full sample estimates with sectoral dummies use all observations but still allows for different model parameters (α_V, α_Z, α_{jV} and α_{jZ}) across sectors. Therefore, in these latter estimates, the between-sector heterogeneity is admitted and it follows that this specification represents the best compromise between the maximum exploitation of the degrees of freedom granted by the full sample estimation without sectoral dummies and the appropriate consideration of the possible heterogeneity across sectoral typologies as emerged from sub-samples estimation.

A final general result concerns the role of the typology of the proponent. There is only a weak evidence about a differential behaviour of the financier with respect to projects proposed by intermediaries (IB) rather than research institutions. The respective dummy (i.e., parameter α_T) suggests that only for the group of *ZOO* projects this parameter is statistically significant and negative, thus confirming that the *ZOO* group represents somehow a peculiar case where, when an IB is the proponent, the financier tends to reduce, *ceteris paribus*, the cofinancing rate. This parameter is also significant and negative in the full-sample estimation when the sectoral dummies are excluded, but becomes insignificant again when these latter are admitted thus confirming that being a IB as proponent turns out to be a (negative) factor only for specific fields of research proposals (*ZOO*).

4.2. What drives the agricultural public R&D cofinancing rate?

Having discussed the general evidence on whether the cofinancing rate responds to observed features of projects and proponents, a second, and more important, order of evidence concerns how the funding institution responds to these variables and, consequently, what information we can derive about the rationale underlying financier's choices. To perform this analysis, beside individual parameter estimates, we can look at elasticity estimates reported in Table 4. These estimates allows to directly go back to Table 1a and test the hypotheses about the expected relationship between variables in $\mathbf{X}_i$ and r_i.

As here, in particular, we look for the response of *r* to scientific merit (*S*), relevance (*SU*), complexity (*D*), reputation (*H1* and *H2*) and budget constraint (*B*), Table 1b compares the estimated elasticities with the signs expected *ex ante* and summarizes the evidence about concavity of the response.

Starting with *S*, it is worth reminding that the hypotheses put forward in section 2 about the response of *r* to an higher scientific evaluation score may be inconclusive, i.e. do not indicate univocal effect on *r*. As mentioned, this effect can vary across different projects and proponents typologies according to which of the following two tendencies eventually prevails. On the one hand, the financier may want to reward with a higher *r* projects of higher scientific quality. On the other hand, however, the financier might also acknowledge risk to high score projects and, then, decide to attribute to the proponent itself more responsibility through a lower cofinancing rate. Apparently, empirical results suggest that, at least in the sample mean point (i.e, on average), the second tendency eventually dominates.

This interpretation can be reinforced by looking at other variables here associated to the perceived level of risk and, in particular, those expressing the reputation, i.e., *H1* and *H2*. Actually, for *H2* a not significant elasticity is observed thus suggesting that the total amount of resources granted in the current and previous funding periods is not relevant for the cofinancing rate decision. Alternatively, we might argue that *H2* is highly redundant (thus, collinear) with *H1* in showing that, at least in the present case, a higher reputation actually implies a lower *r*. According to the interpretation above, rather than rewarding reputation, the financier responds to it by leaving the beneficiary more responsibility, and burden, in carrying out the funded R&D activity.

The response of the financier (thus, *r*) to the perceived risk associated to a given R&D project can be evoked also for the interpretation of the estimated elasticity of variable *D*, here considered as a proxy of the underlying attribute of complexity. A higher *D* is expected to be interpreted as higher complexity and results seem concordant with what emerges for *H1*. Here, the financier responds to more risk/complexity by increasing its participation (cofinancing rate) evidently to augment its capacity to control and condition the proponents' behaviour and the projects' results. These results concerning the behaviour of *r* in response to variables and attributes signalling risk of failure represent one of the most interesting evidence of the present exercise but clearly deserve further investigation in the future.

Of easier interpretation are the estimated elasticities of *r* with respect to both *SU* and *B* as they both follow the theoretical expectations. The financier positively responds to an increase of project's relevance as indicated by *SU*, while it responds negatively whenever the budget constraint becomes more binding (i.e., B_i increases).

Another worth noticing result emerging from Table 4 concerns the different behaviour of *VEG*, *ZOO* and *ALT* sub-samples.[15] Estimates indicate that, despite the observed heterogeneity in single parameters' estimation, the elasticity maintains the same sign across all groups, though not always statistically significant, the only exception being *H2* for which ALT sub-sample shows a different sign. This result further confirms the indeterminacy of estimates associated to this variable.

A final comment on the estimation results concerns the second order derivatives. While the elasticity (and the first order derivative) expresses the sign, i.e. the direction of the response of *r* to **X**, the second order derivative indicates whether this response, assumed it is monotone,[16] linkage is concave or convex or, in other words, whether the response to the variables in **X** declines or increases in magnitude (i.e., in absolute terms) as they increase. In general terms, a concave response is intuitively expected simply because the range of variation of the responding variable (*r*) is bounded. In practice, if we limit the attention to the full sample estimations, we observe a significant second order derivative only for two variables. The first concerns *H1* and confirms the concave response: *r* declines when *H1* increases, as discussed, but the magnitude of this response becomes lower as *H1* increases. On the contrary, the response of *r* to an increase of *B* is not only negative but it is also reinforced, in magnitude, as *B* increases. Even this latter result, however, is somehow reasonable since whenever the budget constraint becomes more binding, also the response, in terms of lower *r*, tends to become stronger.

5. Concluding remarks

This paper focuses on the public support to R&D activities when funds are granted to research projects selected with a competitive procedure then followed by a cofinancing agreement. The literature debate on this funding mechanism has discussed its main motivations but substantially neglected to investigate how these public funding institutions eventually establish the cofinancing rate and what drives their decision in this respect.

[15] It is worth reminding that in subsample mean points elasticities and derivatives do not simply correspond to estimated parameters as these estimates have been obtained on the whole sample.

[16] Or, alternatively, in a point close enough to the sample mean.

The paper aims at providing empirical evidence supporting the idea that, in fact, the financier chooses the cofinancing rate on the basis of some observable features of the selected projects and proponents. For this purpose, an econometric model is specified and estimated to assess whether the hypotheses coming from the theoretical analysis are supported by the real data. Prior to the empirical assessment, therefore, some theoretical conjectures are proposed about the possible determinants of this choice and about their underlying rationale. According to these theoretical arguments, the cofinancing rate choice can be intended as the best response of the financier to observed features of funded projects and proponents.

The empirical application concerns the research program funded with Law 28/98 by one of the largest Italian regional institution (Regione Emilia-Romagna) over years 2001-2006. Estimation results firstly suggest that the basic hypothesis underlying the present analysis, i.e., the selected cofinancing rate responds to some observable characteristics of projects and proponents, finds a robust statistical support. Secondly, the estimated magnitude and direction of this response are mostly consistent with the hypotheses derived from theoretical arguments and conjectures. For some of these observable features, these hypotheses do not actually provide an univocal indication about the direction of the response as the financier might actually look for a compromise between contrasting needs. Results suggest that the eventual response of the financier to the risk of failure of funded projects tends to leave more responsibility (i.e., lower cofinancing rate) to high-reputation proponents while taking more control (higher cofinancing rate) when complexity increases.

Despite this robust evidence, estimates also show that a different behaviour may be observed across heterogeneous research fields and, in particular, between crop production research and animal production research. Neglecting such heterogeneity inevitably prevents from correctly identifying the response of the cofinancing rate to the project/proponents characteristics and, at the same time, finding common patterns (i.e., common parameters in sign and magnitude) across these heterogeneous groups seems particularly challenging.

Beside the present focus on the econometric results, however, it remains true that the empirical exercise here proposed leaves several open questions to future research. First of all, though some conjectures are put forward, a consistent theoretical model describing how the financier chooses the cofinancing rate in response to the observed variables is still lacking. Nonetheless, the present empirical results may suggest some possible directions where this modelling effort can be oriented. Secondly, and more from the empirical perspective, further effort is needed to assess if and how heterogeneous fields of R&D may actually bring about differentiated responses and behaviour and, thus, different policy implications.

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Tables and Figures

Figure 1 – The two-stage logic of the competitive grant funding mechanism: selection among competing research projects (1st stage) and cofinancing agreement (2nd stage)

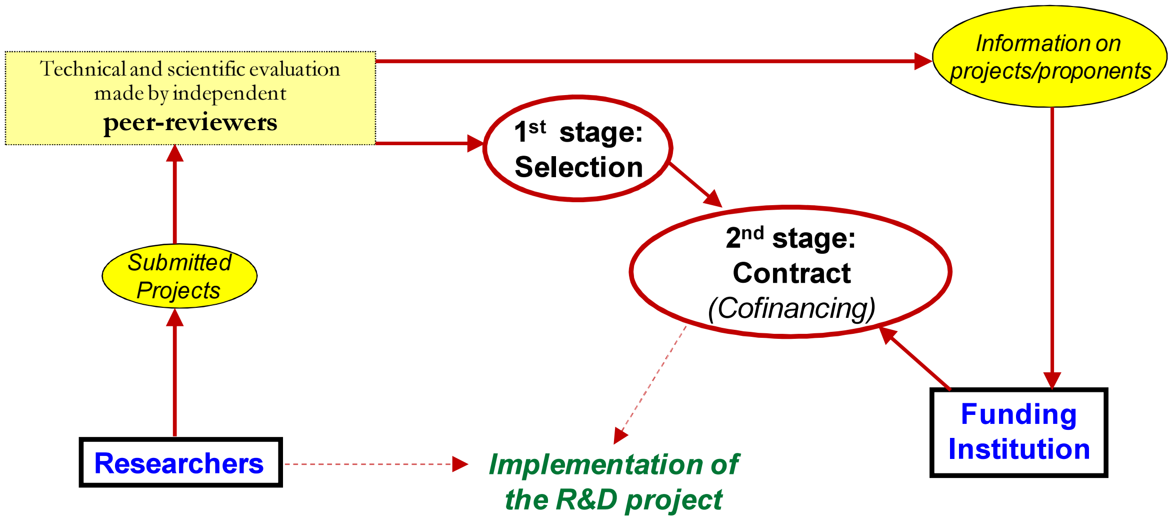

Table 1a – Linkages between unobservable attributes, the observable characteristics ($\mathbf{X}_i$) of projects/proponents and the granted cofinancing rate (r_i)

Attributes		*Expected response of r_i*	$\mathbf{X}_i$ *(observable variables)*	*Testable hypotheses (relationship between $\mathbf{X}_i$ and r_i)*
Scientific Merit		+/-	S_i	$\partial r_i / \partial S_i > 0$ or < 0
Relevance		+	SU_i	$\partial r_i / \partial SU_i > 0$
Risk	Complexity	+/-	D_i	$\partial r_i / \partial D_i > 0$ or < 0
	Reputation	+/-	$H1_i\ H2_i$	$\partial r_i / \partial H1_i, \partial H2_i > 0$ or < 0
Budget Constraint		-	B_i	$\partial r_i / \partial B_i < 0$

Table 1b – Comparison between expected response of the granted cofinancing rate (r_i) to the observable characteristics ($\mathbf{X}_i$) and the respective estimated elasticities and second order derivatives

Attributes		$\mathbf{X}_i$ *(observable variables)*	*Expected response*	*Estimated elasticity*	*Estimated second order derivative*
Scientific Merit		S_i	$\partial r_i / \partial S_i$ >0 or <0	-	Not significant
Relevance		SU_i	$\partial r_i / \partial SU_i > 0$	-	Not significant
Risk	Complexity	D_i	$\partial r_i / \partial D_i > 0$ or < 0	+	Not significant
	Reputation	$H1_i$	$\partial r_i / \partial H1_i, \partial H2_i$ >0 or <0	-	Concave response
		$H2_i$		Not significant	Not significant
Budget Constraint		B_i	$\partial r_i / \partial B_i < 0$	-	Convex response

Table 2 – Descriptive statistics of model variables

Variable (unit of measure)	**Mean**	**Minimum**	**Maximum**	**Coefficient of Variation**
r (%)	82	45	100	0.19
S (score 0-500)	199	56	380	0.42
SU (index 0-1)	0.62	0.43	0.92	0.23
D (months)	20.5	3	48	0.55
C (million €)	0.16	0.07	1.62	1.16
H1(index 0-1)	0.63	0.000	1	0.25
H2(index 0-1)	0.38	0.000	1	1.12
B (index 0-1)	0.017	0.001	0.18	1.22

Number of granted projects by sector/field (*F*), proponent (*T*) and year (*t*)

F:		*t:*	
VEG	356	*2001*	142
ZOO	140	*2002*	114
ALT	93	*2003*	101
T:		*2004*	96
IB	203	*2005*	66
non-IB	386	*2006*	70
		Total	589

Table 3 – Parameter estimates of model (2) (standard error in parentheses) according to different samples and estimators

Sample:	*VEG*			*ZOO*			*ALT*			*WHOLE SAMPLE (without F_i dummies)*			*WHOLE SAMPLE (with F_i dummies)*		
Estimator: Parameter:	**OLS**	**ML** (right censored)	**ML** (left and right censored)	**OLS**	**ML** (right censored)	**ML** (left and right censored)	**OLS**	**ML** (right censored)	**ML** (left and right censored)	**OLS**	**ML** (right censored)	**ML** (left and right censored)	**OLS**	**ML** (right censored)	**ML** (left and right censored)
α_0	0,090**	0.120**	0.161**	0.054	0.056	0.070	-0.009	-0.029	-0.019	0.082**	0.109**	0.120**	0.051	0.085*	0.089*
	(0,044)	(0.050)	(0.061)	(0.044)	(0.053)	(0.059)	(0.137)	(0.143)	(0.208)	(0.031)	(0.036)	(0.042)	(0.043)	(0.046)	(0.051)
α_T	-0,016	-0.013	-0.020	-0.113**	-0.104**	-0.120**	0.066	0.114	0.152	-0.043**	-0.038*	-0.047*	-0.037*	-0.031	-0.036
	(0,024)	(0.029)	(0.034)	(0.040)	(0.034)	(0.037)	(0.063)	(0.073)	(0.109)	(0.020)	(0.023)	(0.027)	(0.020)	(0.023)	(0.027)
α_S	-0.081*	-0.174**	-0.211**	-0.059	-0.096	-0.090	-0.187*	-0.319**	-0.430**	-0.084**	-0.167**	-0.188**	-0.090	-0.194**	-0.211**
	(0.046)	(0.052)	(0.062)	(0.062)	(0.061)	(0.066)	(0.110)	(0.143)	(0.207)	(0.035)	(0.035)	(0.042)	(0.069)	(0.076)	(0.091)
α_{SU}	0.137*	0.182**	0.220**	0.143	0.233*	0.242**	0.496**	0.538**	0.728**	0.205**	0.258**	0.294**	0.331**	0.376**	0.469**
	(0.073)	(0.084)	(0.099)	(0.114)	(0.110)	(0.120)	(0.181)	(0.199)	(0.285)	(0.050)	(0.059)	(0.070)	(0.122)	(0.137)	(0.164)
α_D	0.111**	0.134**	0.212**	0.085*	0.092**	0.103**	0.150	0.223	0.374*	0.111**	0.141**	0.173**	0.109*	0.173**	0.206**
	(0.027)	(0.030)	(0.046)	(0.048)	(0.042)	(0.045)	(0.120)	(0.139)	(0.217)	(0.018)	(0.021)	(0.026)	(0.058)	(0.065)	(0.077)
α_{H1}	0.011	0.018	0.084	-0.368**	-0.402**	-0.535**	0.037	0.114	0.195	-0.135	-0.130	-0.176	-0.113	-0.086	-0.131
	(0.219)	(0.224)	(0.266)	(0.113)	(0.132)	(0.175)	(0.200)	(0.203)	(0.323)	(0.098)	(0.088)	(0.108)	(0.106)	(0.100)	(0.123)
α_{H2}	0.005	0.007	0.009	-0.003	-0.002	-0.003	0.002	0.003	0.007	0.000	0.001	0.002	-0.003	-0.002	-0.003
	(0.005)	(0.006)	(0.008)	(0.004)	(0.005)	(0.005)	(0.007)	(0.008)	(0.012)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
α_B	- 0.060**	-0.068**	-0.083**	-0.021**	-0.036	-0.039	-0.084**	-0.104**	-0.144**	-0.040**	-0.050**	-0.060**	-0.065**	-0.080**	-0.097**
	(0.015)	(0.016)	(0.019)	(0.023)	(0.024)	(0.026)	(0.033)	(0.037)	(0.055)	(0.010)	(0.011)	(0.013)	(0.028)	(0.028)	(0.034)
α_{S2}	-0.233	-0.218	-0.249	0.230*	0.266	0.293	-0.766**	-0.715	-1.352*	-0.118	-0.077	-0.077	-0.119	-0.092	-0.103
	(0.193)	(0.214)	(0.253)	(0.178)	(0.191)	(0.206)	(0.350)	(0.434)	(0.697)	(0.129)	(0.145)	(0.174)	(0.128)	(0.145)	(0.174)
α_{SU2}	-0.175	-0.099	-0.153	0.861	1.441*	1.620*	3.556**	6.211**	8.483**	0.292	0.735	0.887	0.276	0.679	0.793
	(0.717)	(0.825)	(0.969)	(0.807)	(0.847)	(0.921)	(1.469)	(2.461)	(3.561)	(0.529)	(0.612)	(0.727)	(0.533)	(0.614)	(0.729)
α_{D2}	-0.057	-0.057	-0.321**	0.032	0.034	0.033	-0.035	0.286	0.366	0.003	0.015	0.005	-0.009	-0.001	-0.019
	(0.064)	(0.071)	(0.149)	(0.026)	(0.027)	(0.029)	(0.592)	(0.462)	(0.672)	(0.016)	(0.027)	(0.032)	(0.020)	(0.032)	(0.039)
α_{H12}	0.022	0.027	0.051	-0.221	-0.234**	-0.302**	-0.035	-0.016	0.028	-0.065	-0.065*	-0.087**	-0.056	-0.056	-0.076*
	(0.103)	(0.117)	(0.139)	(0.063)	(0.070)	(0.093)	(0.095)	(0.092)	(0.149)	(0.043)	(0.036)	(0.044)	(0.047)	(0.036)	(0.045)
α_{H22}	0.000	0.001	0.001	0.002	0.002*	0.002**	0.003	0.003	0.005	0.001	0.001	0.001	0.001*	0.002*	0.002*
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
α_{B2}	- 0.066**	-0.076**	-0.099**	0.038	0.050*	0.054	-0.107	-0.138**	-0.192**	-0.047**	-0.058**	-0.074**	-0.053**	-0.065**	-0.083**
	(0.019)	(0.019)	(0.023)	(0.024)	(0.030)	(0.033)	(0.066)	(0.060)	(0.088)	(0.017)	(0.016)	(0.019)	(0.017)	(0.016)	(0.019)
α_{SSU}	-0.111	-0.247	-0.294	-0.771**	-0.927**	-1.001**	-0.375	-0.788	-1.283	-0.356**	-0.620**	-0.753**	-0.362**	-0.616**	-0.737**
	(0.214)	(0.257)	(0.304)	(0.232)	(0.206)	(0.224)	(0.427)	(0.615)	(0.913)	(0.124)	(0.169)	(0.203)	(0.126)	(0.169)	(0.201)
α_{SD}	-0.103	-0.127	-0.165	0.009	-0.014	-0.039	-0.394**	-0.536*	-0.800*	-0.180**	-0.233**	-0.327**	-0.193**	-0.245**	-0.338**
	(0.113)	(0.097)	(0.115)	(0.076)	(0.084)	(0.092)	(0.159)	(0.295)	(0.420)	(0.051)	(0.062)	(0.078)	(0.053)	(0.063)	(0.078)
α_{SH1}	-0.215	-0.237	-0.221	0.221*	0.238	0.255	-0.020	-0.013	0.029	0.013	-0.036	-0.038	-0.001	-0.040	-0.042
	(0.211)	(0.205)	(0.245)	(0.133)	(0.171)	(0.185)	(0.188)	(0.220)	(0.351)	(0.036)	(0.073)	(0.085)	(0.063)	(0.081)	(0.096)

α_{SH2}	-0.003	-0.002	-0.003	-0.003	-0.007	-0.007	0.026**	0.038**	0.059**	-0.001	-0.003	-0.003	-0.001	-0.003	-0.003
	(0.006)	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)	(0.010)	(0.018)	(0.026)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)
α_{SB}	-0.069*	-0.075*	-0.088*	-0.085**	-0.070*	-0.081*	0.090	0.182	0.232	-0.045	-0.031	-0.033	-0.044	-0.034	-0.038
	(0.041)	(0.039)	(0.047)	(0.036)	(0.042)	(0.045)	(0.142)	(0.161)	(0.234)	(0.027)	(0.029)	(0.036)	(0.027)	(0.030)	(0.036)
α_{DSU}	-0.165	-0.248	-0.272	-0.193	-0.223	-0.226	-0.346	-1.007	-1.269	-0.050	-0.090	-0.049	-0.010	-0.042	-0.002
	(0.200)	(0.184)	(0.217)	(0.175)	(0.159)	(0.172)	(0.321)	(0.614)	(0.870)	(0.098)	(0.119)	(0.146)	(0.102)	(0.121)	(0.147)
α_{DH1}	0.008	0.007	-0.097	0.088	0.131	0.139	0.046	0.065	-0.089	0.003	0.037	0.037	0.058	0.117*	0.120
	(0.201)	(0.192)	(0.237)	(0.155)	(0.156)	(0.169)	(0.207)	(0.206)	(0.385)	(0.012)	(0.038)	(0.044)	(0.047)	(0.065)	(0.078)
α_{DH2}	0.010**	0.011**	0.015**	-0.001	0.000	0.000	-0.015	-0.026*	-0.035*	0.006**	0.008**	0.009**	0.006**	0.008**	0.010**
	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.010)	(0.015)	(0.021)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)
α_{DB}	-0.014	-0.017	-0.010	-0.036	-0.037	-0.044	0.009	-0.036	-0.015	-0.015	-0.027	-0.034	-0.011	-0.019	-0.026
	(0.028)	(0.028)	(0.034)	(0.025)	(0.025)	(0.028)	(0.100)	(0.141)	(0.201)	(0.016)	(0.019)	(0.023)	(0.017)	(0.019)	(0.024)
α_{H1SU}	0.367	0.505**	0.530*	0.039	-0.133	-0.140	0.533	0.603	0.719	0.008	0.089	0.096	-0.009	0.067	0.075
	(0.241)	(0.248)	(0.292)	(0.257)	(0.370)	(0.401)	(0.412)	(0.480)	(0.698)	(0.049)	(0.113)	(0.131)	(0.049)	(0.118)	(0.137)
α_{H1H2}	-0.022	-0.028	-0.043	0.078**	0.081**	0.102**	0.005	0.000	-0.014	0.019	0.019*	0.026**	0.016	0.017	0.022*
	(0.037)	(0.041)	(0.048)	(0.017)	(0.020)	(0.028)	(0.025)	(0.023)	(0.037)	(0.013)	(0.010)	(0.013)	(0.015)	(0.010)	(0.013)
α_{H1B}	0.090	0.130**	0.141**	0.012	0.051	0.053	-0.009	0.010	0.014	0.017**	0.041*	0.042	0.010	0.033	0.035
	(0.058)	(0.058)	(0.068)	(0.068)	(0.086)	(0.093)	(0.032)	(0.046)	(0.070)	(0.005)	(0.023)	(0.026)	(0.013)	(0.026)	(0.030)
α_{H2SU}	-0.010	-0.013	-0.013	0.013	0.022**	0.023**	-0.030	-0.032	-0.046	-0.003	0.000	0.000	-0.004	-0.002	-0.002
	(0.010)	(0.010)	(0.012)	(0.009)	(0.010)	(0.011)	(0.020)	(0.028)	(0.041)	(0.007)	(0.008)	(0.009)	(0.007)	(0.008)	(0.009)
α_{H2B}	-0.001	-0.001	-0.002	-0.006**	-0.007**	-0.007**	0.009*	0.013**	0.018**	-0.002	-0.001	-0.002	-0.002	-0.002	-0.003
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.005)	(0.005)	(0.008)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
α_{SUB}	0.254**	0.313**	0.373**	0.090	0.051	0.063	0.004	-0.058	-0.099	0.177**	0.206**	0.249**	0.169**	0.197**	0.246**
	(0.084)	(0.075)	(0.090)	(0.077)	(0.085)	(0.093)	(0.178)	(0.191)	(0.272)	(0.055)	(0.054)	(0.065)	(0.056)	(0.054)	(0.065)
α_{V}	-	-	-	-	-	-	-	-	-				0.034	0.031	0.038
													(0.029)	(0.031)	(0.037)
α_{Z}	-	-	-	-	-	-	-	-	-				0.020	0.007	0.020
													(0.030)	(0.033)	(0.039)
α_{SV}	-	-	-	-	-	-	-	-	-	-	-	-	0.003	0.023	0.012
													(0.074)	(0.084)	(0.101)
α_{SUV}	-	-	-	-	-	-	-	-	-	-	-	-	-0.165	-0.168	-0.229
													(0.138)	(0.153)	(0.182)
α_{DV}	-	-	-	-	-	-	-	-	-	-	-	-	0.004	-0.042	-0.038
													(0.060)	(0.069)	(0.083)
α_{H1V}	-	-	-	-	-	-	-	-	-	-	-	-	-0.062	-0.111	-0.113
													(0.079)	(0.080)	(0.096)
α_{H2V}	-	-	-	-	-	-	-	-	-	-	-	-	0.005	0.005	0.007
													(0.004)	(0.004)	(0.005)
α_{BV}	-	-	-	-	-	-	-	-	-	-	-	-	0.016	0.024	0.027
													(0.031)	(0.031)	(0.037)
α_{SZ}	-	-	-	-	-	-	-	-	-	-	-	-	0.009	0.044	0.049
													(0.076)	(0.093)	(0.112)
α_{SUZ}	-	-	-	-	-	-	-	-	-	-	-	-	-0.118	-0.093	-0.173
													(0.142)	(0.171)	(0.204)
α_{DZ}	-	-	-	-	-	-	-	-	-	-	-	-	-0.041	-0.085	-0.099
													(0.065)	(0.078)	(0.093)

α_{H1Z}	-	-	-	-	-	-	-	-	-	-	-	-	0.030 (0.063)	0.018 (0.056)	0.021 (0.068)
α_{H2Z}	-	-	-	-	-	-	-	-	-	-	-	-	0.006 (0.004)	0.007* (0.004)	0.010** (0.005)
α_{BZ}	-	-	-	-	-	-	-	-	-	-	-	-	0.058* (0.033)	0.060* (0.036)	0.080* (0.043)
Observations:	356	306 *uncensored* 50 *right-censored*	48 *left-censored* 259 *uncensored* 50 *right-censored*	140	121 *uncensored* 18 *right-censored*	10 *left-censored* 112 *uncensored* 18 *right-censored*	93	67 *uncensored* 26 *right-censored*	21 *left-censored* 46 *uncensored* 26 *right-censored*	589	495 *uncensored* 94 *right-censored*	78 *left-censored* 417 *uncensored* 94 *right-censored*	589	495 *uncensored* 94 *right-censored*	78 *left-censored* 417 *uncensored* 94 *right-censored*
R^2:	0.241			0.545			0.533			0.239			0.257		
LR χ^2 :		107.91**	115.08**		111.12**	114.26**		72.81**	74.12**		182.57**	184.82**		194.28**	199.02**

**,*: statistically significant at 5% and 10% confidence level, respectively

Table 4 – Estimated elasticities and second order derivatives of r_i with respect to C_i and S_i in the sample mean by groups of research projects (estimation performed on the whole sample with time and sectoral dummies; left and right censored ML estimate)

Sample	$\partial \ln r_i / \partial \ln S_i$	$\partial^2 r_i / \partial S_i^{\ 2}$	$\partial \ln r_i / \partial \ln SU_i$	$\partial^2 r_i / \partial SU_i^{\ 2}$	$\partial \ln r_i / \partial \ln D_i$	$\partial^2 r_i / \partial D_i^{\ 2}$
TOTAL	-0.192** (0.042)	0.088 (0.163)	0.290** (0.071)	0.503 (0.730)	0.159** (0.027)	-0.129 (0.094)
VEG	-0.256** (0.056)	-0.153 (0.181)	0.304** (0.095)	1.038 (0.736)	0.136** (0.032)	-0.010 (0.083)
ZOO	-0.219** (0.077)	-0.148 (0.233)	0.360** (0.129)	1.087 (0.791)	0.076 (0.050)	0.128 (0.100)
ALT	-0.082 (0.087)	0.035 (0.215)	0.413** (0.167)	0.881 (0.829)	0.240** (0.081)	0.019 (0.054)
	$\partial \ln r_i / \partial \ln H1_i$	$\partial^2 r_i / \partial H1_i^{\ 2}$	$\partial \ln r_i / \partial \ln H2_i$	$\partial^2 r_i / \partial H2_i^{\ 2}$	$\partial \ln r_i / \partial \ln B_i$	$\partial^2 r_i / \partial B_i^{\ 2}$
TOTAL	-0.194** (0.090)	0.119** (0.058)	0.004 (0.003)	-0.002 (0.003)	-0.062** (0.014)	-0.081** (0.024)
VEG	-0.236* (0.124)	0.042 (0.109)	0.004 (0.004)	-0.010 (0.009)	-0.110** (0.018)	-0.073** (0.035)
ZOO	-0.103 (0.130)	-0.084 (0.069)	0.007 (0.004)	-0.004 (0.003)	-0.056** (0.027)	-0.134** (0.053)
ALT	-0.115 (0.100)	-0.101** (0.049)	0.240** (0.081)	0.019 (0.054)	-0.069* (0.036)	-0.177** (0.064)

**,*: statistically significant at 5% and 10% confidence level, respectively