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Evaluation Criteria Versus Firm Characteristics as Determinants of Public R&D Funding

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Abstract

This study provides new empirical evidence regarding the relevance of evaluation criteria and firm characteristics for public R&D funding decisions. The database used contains both accepted and rejected R&D project proposals, project evaluation scores and several firm characteristics. The probit estimations show that proposals with high scores on innovative content, spillover and knowledge gain are significantly more likely to be approved and that most firm-level characteristics are not significant, except for firm size. For example, good or very good assessments of innovative content raise the acceptance probability by between 18 and 37 percentage points, respectively. Small firms are more likely to receive a grant.

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1 Introduction

Governments regularly subsidize R&D activities in the business sector. The main reason for these subsidies is that R&D is expected to have higher social than private returns. As firms mainly consider private returns when deciding on R&D investments, the actual level of R&D investments will be below the socially optimal level in a free market (Arrow, 1962; Adams and Jaffe, 1996).[1] This market failure motivates governments to subsidize R&D investments in the business sector. These subsidies can be granted indirectly through tax incentives or directly through public R&D grants.

In the case of direct funding, firms must apply for grants. As a rule, the applications are reviewed and evaluated by an audit committee consisting of internal and external experts from industry and academia. Depending on how well the evaluation criteria are met, applications can be either accepted or rejected. Knowing which criteria are crucial for R&D funding is important for both R&D managers of firms and managers of the funding agency. In general, empirically little is known about how R&D subsidies are allocated among firms and projects.

Previous studies find that larger firms, high R&D intensity or R&D expenditures, capital intensity, previous successful R&D grant applications, and R&D projects with a high degree of novelty are more likely to receive a public R&D grant (Antonelli and Crespi, 2013; Aschhoff, 2010; Busom *et al.*, 2017; Cantner and Kösters, 2012; Duguet, 2004; Dumont, 2017; Feldman and Kelley, 2006; Gonzalez *et al.*, 2005; Heijs, 2005; Hussinger, 2008; Silva *et al.*, 2017; Takalo *et al.*, 2013). A drawback of these studies is that they mainly compare firms with public R&D funding to those without such funding. The latter group includes both firms that have applied for grants but been rejected and firms that have not applied at all. In fact, there are three selection steps. In the first, firms decide whether to apply for R&D grants. In the second, project proposals are evaluated and receive scores or evaluation ranks. In the third, grants are allocated based on the evaluation scores. Thus, previous studies lump together three selection stages. Nevertheless, these studies show the importance of firm characteristics for selection as an R&D grant winner. However, we do not know in which of the three steps are firm characteristics decisive for receiving a grant.

[1] Another reason to subsidize private R&D investments may be that a sector has a public-good character, such as the environment, water or defense sectors, where private markets do not exist. A last reason for the government to intervene is when the time horizon of R&D projects is extremely long.

The aim of this paper is to provide new empirical evidence on how firm characteristics and evaluation scores of quality indicators affect the allocation of R&D grants in the business sector. The main contribution is that we focus on the following third step: how evaluation scores affect the allocation of grants and whether these scores are dominated by firm characteristics.

To the best of our knowledge, this third step of the R&D-grant selection has not been empirically tested in the previous literature. A detailed database including both accepted and rejected project applications to the Austrian R&D funding agency (FFG) linked to firm-level administrative sources is employed for the analysis. This database encompasses detailed information regarding the evaluation scores of individual project applications and firm characteristics. Thus, the contribution of this study is the use of a detailed novel dataset that does not suffer from selection bias and allows the evaluation scores to be modeled along with the firm characteristics. Probit models with random firm effects are employed to estimate the relationships.

Project level databases with information regarding rejected R&D projects are rarely used to investigate the probability of funding. Exceptions include the studies conducted by Huergo and Trenado (2010) and Silva et al. (2017). For instance, by using data of applications for R&D funding at the project level in Spain, Huergo and Trenado (2010) find that the technical characteristics of the R&D project, such as technical capabilities, are the most relevant for an award of R&D funding. In the study by Silva et al. (2017), information regarding the evaluations of individual project applications could not be used due to the lack of data.

The main conclusions of our empirical estimations are that R&D projects that are considered innovative or associated with knowledge gains and spillovers in the project evaluation scores are significantly more likely to be approved. In contrast to previous studies, the importance of these factors remains significant when firm-level characteristics (size, R&D intensity, cash flow, industry affiliation) are considered. In fact, most firm characteristics are insignificant and could be more decisive for receiving R&D grants in the following first and second selection steps: whether to apply for a grant and how project proposals are evaluated. Another conclusion is that applicant firms should focus on radical, new and innovative ideas in their applications rather than on minor improvements.

The paper is structured as follows. Section 2 introduces the theoretical background and reviews the literature. Section 3 presents the database, descriptive statistics and the econometric model. Section 4 presents the empirical results, and section 5 concludes.

2 Theoretical background and previous literature

2.1 Picking the winner strategy

One of the most popular theories in the analysis of the allocation of public R&D grants in the business sector is the 'picking the winner' strategy. According to Stiglitz and Wallsten (2000), funding agencies tend to select projects with a high probability of success and low expected returns rather than risky projects with a lower probability of success but higher expected returns. There are several arguments for this behavior (Antonelli and Crespi, 2013; Cantner and Kösters, 2012). First, R&D projects are inherently risky and exhibit a high probability of failure. The theory of public choice suggests that a strong political commitment is needed to justify subsidizing many failed projects. Second, R&D subsidies distort competition. Subsidized firms gain an advantage at the expense of non-subsidized firms. By subsidizing good (efficient) rather than bad (inefficient) firms, the negative effects of crowding out non-subsidized competitors are minimized (Shane, 2009). Third, by selecting good-performing firms, authorities can finance future technologies directly, partly on the basis of public choice considerations. However, this strategy requires complete information.

The selection of winners can be measured in several ways, such as the applicant's past performance, capital endowment or funding experience. Further indicators are the degree of novelty of the planned R&D project and the subjective assessment of the evaluation committee in terms of degree of commercialization and expected returns. The cash-flow ratio measured in the year of the project application and the growth rates or turnover of employees can be used to measure firm performance.

2.2 Application experts

Firms experienced with government grants or applications in the past seem to have an advantage over inexperienced ones (Lerner, 2009) for three reasons. First, with each application submitted, firms gain knowledge of the grant application process. Such experienced firms should be more likely than others to receive grants. Second, previous grants − regardless of project outcome − help firms to legitimize themselves in a research area and recruit the necessary equipment and personnel. These resources can later be used for future research. Finally, there is also a risk that a certain funding agency will select firms that have received grants from other government resources in the hope of using their grant dollars. The result can be an influx of government subsidies to firms that are consistently underperforming. Therefore, Lerner (2009) emphasizes that government authorities should constantly assess both winning firms and entire programs to ensure that the objectives of the programs are achieved.

The “Matthew effect” is also helpful in motivating the high degree of persistence in the allocation of R&D subsidies (Antonelli and Crespi, 2013; Merton, 1968). According to the Matthew principle, outstanding scientists are disproportionately honored for their contributions to science, which means that firms that have successfully received public support for R&D activities in the past are more likely to receive R&D grants in the current application process.

2.3 Previous studies

Many studies have assessed the effectiveness of public R&D grant programs. The focus has been on whether R&D grants generate more R&D expenditures among recipients in the business sector (e.g., Almus and Czarnitzki, 2003; Duguet, 2004; Feldman and Kelley, 2006; Gonzalez *et al*., 2005; Takalo *et al.*, 2007). However, the process of selecting firms for grants is limited to a few studies and confirms that firm characteristics are highly relevant in obtaining R&D funding. In particular, a large firm size, high R&D intensity, previous successful applications for R&D grants and R&D projects with a high degree of novelty are likely to receive a public R&D grant (Antonelli and Crespi, 2013; Aschhoff, 2010, Blanes and Busom, 2004; Cantner and Kösters, 2012, Heijs, 2005; Silva *et al*., 2017). Related studies demonstrate that exporting, patent and R&D activities and skills are crucial for successfully receiving innovation funding (Czarnitzki and Delanote, 2015; Foreman-Peck, 2013; Heijs, 2005).

Using firm-level data, Blanes and Busom (2004) analyze which Spanish firms participate in R&D-grant funding programs. The authors find that large firms, firms that already conduct R&D activities and firms with previous funding from the program have a significant advantage in receiving R&D subsidies. Similarly, Aschhoff (2010) uses firm-level data to analyze German firms' participation in R&D funding programs. The author finds that there is a high degree of persistence among firms participating in public R&D programs. This makes it more likely that companies with previous funding will regain funding. In addition, firm size, R&D capability and the human resources of the applicant also increase the likelihood of funding. Cantner and Kösters (2012) investigate the allocation of R&D grants to German start-ups. The authors test the hypothesis that funding authorities follow a strategy of ‘picking the winner’. The authors find some support for this hypothesis. R&D grants are awarded to start-ups that 1) are spin-offs from science; 2) have innovative business ideas; and 3) have relatively high initial capital. However, the experience and ambitions of the founders so far have no influence on the probability of receiving R&D grants.

Antonelli and Crespi (2013) examine the determinants of firms' access to public R&D subsidies based on Italian firm-level data. Using probit models, the authors find that the probability of R&D subsidies in the current period is significantly positively related to obtaining R&D subsidies in the past. Furthermore, larger firms and firms with higher R&D capabilities are more likely to receive R&D subsidies. Using a dynamic random effects model, Busom *et al.* (2017) show that program participation in the past explains most of the likelihood of obtaining funding in the current period.

Morris and Herrmann (2013) note that larger firms and firms with higher capital intensities are more likely to receive R&D support. There is also a nonlinear dependence on the firm size; thus, the likelihood of receiving R&D support does not increase further with the firm size. Companies that export goods and those that are a part of a larger group are also more likely to receive R&D project funding. Foreign firms are less likely to receive project funding. Karhunen and Huovari (2015) show that the likelihood of R&D funding significantly depends on firm characteristics. Companies with a high proportion of employees with higher education are more likely to receive R&D funding. Productivity growth before the funding year is also higher among subsidized enterprises than non-subsidized enterprises. Previous R&D grants and other grants are also positively linked to new R&D grants. In addition, these authors find that firms engaging in export or import activity are more likely to receive a subsidy, while foreign ownership reduces this probability. Tingvall and Vidernord (2018) find that the probability of receiving publicly sponsored grants and their effectiveness varies across regions.

As mentioned in the introduction, these studies summarize three selection steps in the application for R&D grants. Therefore, we do not know at which step firm characteristics are relevant for receiving R&D grants. Furthermore, most previous studies do not provide information regarding the characteristics of the proposals at the project level, leading to omitted variable bias in the estimations.

Only a few studies explicitly model the factors influencing the likelihood of receiving R&D funding by using information regarding approved and rejected R&D proposals. Based on Spanish R&D project data, Huergo and Trenado (2010) find that the technical features of the R&D project, such as technical skills, increase the probability of receiving an award by 33 percentage points, followed by the introduction of new knowledge with 13 percentage points. Market and commercial perspectives are less important as the probability of funding increases by approximately 7 percentage points. Company characteristics also play a role. SMEs are 10 percentage points more likely to receive public support.

Barajas and Huergo (2010) analyze data of approved and rejected applications from Spanish companies to R&D consortia within the EU Framework Programme. The empirical results of the likelihood that the project will be approved or rejected show that project characteristics, such as leadership capacity, geographical distance between partners and previous experience in R&D cooperation, are significant determinants. Silva *et al.* (2017) investigate the likelihood of the funding of R&D projects based on both firm and project characteristics. The probit estimations show that the likelihood of funding depends on several firm characteristics (size and industry affiliation) and the amount of planned investment in the R&D project. However, information regarding the scores is not available.

In summary, there are comparatively many studies that examine the role of firm characteristics in the allocation of R&D subsidies. These characteristics include firm size, R&D capabilities, human resources, ownership, previous funding status and location factors. In contrast, there are too few studies that consider project level characteristics.

3 Database, descriptive statistics and empirical model

3.1 Database and descriptive statistics

The database used in the present study originates from the Austrian R&D funding agency (FFG).[2] FFG is the largest provider of public R&D grants to the business sector in Austria, with €300 million distributed in 2014. The database consists of two parts: a firm-level database with information on sales, employment and R&D activities of the applying firms and a project-level database consisting of the agency's ratings of the R&D project proposals. When submitting their applications for funding, firms must provide information on their basic characteristics for the past three years. The requested firm-level information is (i) total sales revenues (in thousand €), (ii) the share of exports in sales, (iii) the number of employees (full-time equivalents), (iv) the number of R&D employees (full-time equivalents), (v) expenses for R&D (in thousand €) and (vi) cash flow (in thousand €). In addition, there is information on industry affiliation and location (at the Federal state level).

The project-level database contains information on the planned duration of the project, planned project costs, the decision of the funding agency (approval or rejection), share of funding, type of funding (grant or loan), and expert ratings on approximately 16 evaluation criteria, grouped into 4 broader categories of criteria (relevance of the project in relation to the program line,

[2] Die Österreichische Forschungsförderungsgesellschaft (FFG).

quality of the project proposal, economic potential and utilization, and suitability of the applicants). These criteria are outlined below:

Relevance of the project in relation to the program

- Additionality effects on project R&D
- Additionality effects on firm R&D
- Additional funding opportunities through the R&D grants
- Knowledge gains through new technologies
- Risk of not achieving economic goals

Quality of the project proposal

- Innovative content
- Development risk
- Novelty of the technology or methodology
- Complexity of the task
- Scope of technology
- Future potential of the technology
- Environmental aspects

Economic potential and utilization

- Market prospects
- Exploitation potential

Suitability of the applicants

- Qualification and motivation of the staff
- Level of technical equipment

All firms with R&D activities can apply for R&D funding. Information regarding both R&D employees and R&D expenditures over the prior three years must be reported. The funding agency decides whether and how R&D funding is granted. No pre-selection is performed, but there are knock-out criteria for unacceptable projects. Each application for an R&D project is examined by experts, and the decision to award a grant for an R&D project and the amount of funding depend on certain selection criteria. According to FFG's guidelines, the fund aims to promote R&D in small firms and in start-up firms. Furthermore, there are special grant programs called "start-up" programs that favor technology-oriented firms established in the past 3 years and employing less than 50 employees.

The evaluation criteria are measured on an ordinal, five-level scale (++ for very good, + for good, - for poor, -- for very poor and KO for unacceptable projects). According to common scientific knowledge, ordinal variables produce biased estimates when used as regressors because the difference between category levels is not standardized.[3] Therefore, the ordinal regressor is divided into a series of dummy variables. Terza (1987) shows that applying the

[3] For example, the difference between "- -" and "-" does not need to be of the same magnitude as that between "-" and "+" or between "+" and "++".

conventional dummy variable approach to a small number of categories is not much worse than more advanced two-stage approaches. We split the ratings of the evaluation criteria into a set of dummy variables that equal one if the ratings are positive (+) and 0 otherwise and one if the rating is very positive (++) and 0 otherwise. The remaining ratings (KO, - or --) serve as the reference category for both dummy variables. We also experiment with the inclusion of more dummy variables, such as ratings ("-" and "- -"). However, the proportions of these categories are too low for some criteria. The project database is linked to firm-level characteristics dating back to one year before the start of the project.

Information is available for approximately 17 000 R&D projects during the period 2005−2012. The number of firms applying for funding is approximately 1 500, depending on the year, and the agency has many program lines. We select project applications in the largest program line, titled "Basic R&D grants". Projects applications that are follow-up projects of previously accepted project applications are excluded. So-called follow-up projects are not comprehensively evaluated and, therefore, are not comparable to initial applications.

The estimation sample consists of approximately 3 370 R&D project applications from 1 915 firms, of which 68 percent are approved. This figure corresponds exactly to the acceptance rate (68 percent) of "Basic R&D grant programs" for the year 2016 as calculated by the funding agency (FFG/OÖ, 2017). The relatively high acceptance rate likely reflects the fact that the basic R&D program is the largest funding line with the highest budget and that the Agency intends to expand the R&D base of the Austrian economy. After matching based on firm-level characteristics, information regarding 2 490 project applications from 1 355 firm remains. Of the project applications for funding, 72 percent received a grant. Since new criteria such as "innovative content of the project proposal" were introduced in 2008, two samples will be used: one for the total sample from 2005 to 2012 and another for 2008 to 2012. Note that a firm may submit several applications for funding within a given period. On average, each company submitted almost two applications for support (1.83).

[Table 1]

In Table 1, the proportions of rating scores vary depending on the criterion. For instance, regarding the criteria "additionality effects on firm R&D", 61 percent of the R&D project applications received a positive rating (either one plus (+) or two pluses (++)), while only a few applications received a positive rating on environmental aspects. Positive scores are most common on the following criteria with proportions of 60 percent or more of applications:

additionality effects at the firm level, additional funding opportunities, potential for exploitation, future potential of the technology, qualification of the staff, and additionality effects on project R&D and innovative content.

Table 2 shows that firm-level characteristics differ between successful and unsuccessful applications. The t-test for the same mean and median across funding decisions shows that the companies that received an R&D grant differ significantly in terms of age and export share. Based on the median test, which is less sensitive to influential observations and outliers, we find that company size is also relevant. Labor productivity, R&D intensity and cash flow ratio do not differ between companies that receive or do not receive an R&D grant.

[Table 2]

In Table 3, the acceptance ratio also differs across the evaluation criteria. As expected, highly scored research projects have significantly higher acceptance rates. These differences are significant for all 16 evaluation criteria based on Fisher's exact test with a significance level of 1 percent. In particular, the innovative content, additionality effects on firm R&D, development risk, future potential, and qualifications and motivation of the staff seem to be the most important factors for obtaining funding. The proportion of approved projects is between 34 and 50 percentage points higher for proposals with good (+) or very good ratings (++) compared to low-rated ones. In the case of market prospects, which are also among the most strongly weighted criteria according to FFG's selection rule, the proportion of approved projects is 30 percentage points higher for proposals with good or very good ratings. The other criteria (additional funding opportunities through R&D grants, additionality effects on project R&D, complexity of the task, exploitation potential, knowledge gains through new technologies, novelty of the technology or methodology, risk of not achieving economic goals, and technical equipment) are also relevant with differences in the acceptance rate ranging between 20 and 34 percentage points. Less relevant are environmental aspects, with a difference in the rate of approved projects of 11 percentage points.

[Table 3]

3.2 Empirical model

Given the theoretical considerations above, participation in R&D programs is not random and depends on company and project characteristics. The probit or logit model modelling the selection of individuals based on discrete sets of alternatives is typically motivated by the random utility model (Ben-Akiva and Lerman, 1985). The model assumes that each category represents a different utility level. The utility of an alternative depends on observable und unobservable attributes. Observed attributes are represented in the utility function by explanatory variables. The incentives for applying for grants or subsidies or the acceptance likelihood can also be motivated by a type of contest function in which the participants exert certain effort to obtain the grant (Tullock, 2001; Klette, Møen and Griliches, 2000; Gustafsson, Tingvall and Halvarsson, 2019 for a recent application). Here, it is assumed that the public funding agency managing the contest is passive because the grant is awarded randomly among the entrepreneurs participating in the contest. However, the Tullock model is a contest model in which entrepreneurs are faced with the decision to divide their efforts between grant seeking and market production. In equilibrium, high productivity firms abstain from seeking grants. Thus, some firms in this model do not seek grants. Therefore, the Tullock model is more applicable to testing the first step (whether to apply for grants) or all three steps (1. deciding to seek grants, 2. scoring of proposals; and 3. how scoring affects the grant decision, see the third paragraph in the introduction in our paper). However, the typical databases used in the literature are consistent with the Tullock model since they include both companies that have received grants and those that have not, and the latter group comprises both firms that applied but were rejected and firms that did not apply.

In the following discussion, it is assumed that applicants for an R&D grant face one of the following two possible outcomes: i) approval or ii) rejection. These two alternatives provide the firm with a given utility. For each application, *i*, we observe status *y* equal to 1 if the funding application is accepted and 0 if the application is rejected. The outcome is the funding agency's decision to select an R&D project, which is assumed to be an unobserved latent variable. The probit model links the observed funding to the unobserved funding probability with the underlying characteristics *X* via a standard normal cumulative distribution function (ϕ) (the individual index *i* is suppressed for convenience) as follows:

$$Pr(Y = 1 \mid X) = \phi(X' \beta). \tag{1}$$

where the funding likelihood, Y^*, is a function of the observable characteristics *X*:

$$Y^* = X' ß + \varepsilon . \tag{2}$$

The latent variable, Y^*, is observed as a binary variable *Y*, which is defined as follows:

$$Y = \begin{cases} 1 & \text{if} \quad Y^* > 0 \\ 0 & \text{if} \quad Y^* \leq 0 \end{cases} \quad (3)$$

X is a vector of covariates containing project- and firm-specific characteristics, and ß is the corresponding coefficient vector. Random factors and unobservable factors influencing the selection decision are captured by the error term, ε. The association can be estimated by the probit model using the maximum likelihood estimator. Alternatively, the logit model can be employed. Standard errors are clustered at the firm level because projects belonging to the same firm are not independent of each other.

Given the theoretical considerations and literature outlined above, the selection of an R&D grant application *Y* is specified as a function of several factors as follows:

$$Y_{ijt} = \beta_j + \sum_{C=1}^{Z} \beta_C CRITERIA_{ijtC} + \sum_{Y=1}^{Z} \beta_Y YEAR_{ijty} + \alpha_1 YOUNG_{ijt-1}$$

$$+ \sum_{S=1}^{4} \alpha_{2S} EMPCLASS_{ijtS} + \alpha_3 RDY_{ijt-1} + \alpha_4 EXY_{ijt-1} + \sum_{I=1}^{17} \alpha_{5I} SECTOR_{ijtI} +$$

$$\sum_{R=1}^{8} \alpha_{6R} REGION_{ijtR} + \varepsilon_{ijt} \quad (4)$$

where *i* denotes the planned R&D project for firm *j* at application year *t*. *CRITERIA* is a set of dummy variables consisting of expert ratings of several evaluation criteria (with a negative rating or knockout as the benchmark category). Yearly dummy variables, *YEAR*, are measured as the start of the planned project that control for aggregate time-varying factors such as the business cycle. *YOUNG* denotes a dummy variable for young firms (aged between zero and five years). *EMPCLASS* consists of a set of dummy variables measuring firm size based on the number of employees (1-9, 10-49, 50-249, 250+), with zero employees as the reference category. Other firm-specific variables include the ratio of R&D expenditures to turnover (*RDY*) and the ratio of exports to turnover (*EXY*). *SECTOR* is a set of dummy variables indicating the industry affiliation, *REGION* denotes the federal state of the applying firm, β_j denotes unobserved firm effects and ε_{ijt} is the error term.

The standard probit model with cluster-adjusted standard errors at the firm level is used to estimate the probability of obtaining an R&D grant. Notably, each company can submit more than one application. In our database, the average number of grant applications per company is 1.8. The acceptance probability of grant applications belonging to the same company is not independent of each other. Therefore, to account for unobserved firm effects, a two-level random-intercept model, which is analogous to a random effects probit model for panel data, is used (Skrondal and Rabe-Hesketh, 2004). In this model, the error term may vary across firms and, thus, accounts for unobserved time invariant firm factors, such as the specific location of the firm, management skills or ownership.

An alternative specification could also include the second step in the estimations, i.e., how firm characteristics affect the evaluation scores (*CRITERIA*) (see introduction). This estimation could be accomplished by an instrument variable technique in which *CRITERIA* is regressed on different firm characteristics. The estimated values of *CRITERIA* could then be inserted into equation (4). The problem with such a technique is that we have as many as 16 different project evaluation variables that need to be instrumented, and we do not have unique instruments for all variables. Therefore, we have to focus the empirical estimations on the following third step: how project evaluation scores and firm characteristics affect the probability of obtaining R&D financing.

We expect that the selection of the R&D grant application depends on the expert ratings of the funding criteria, with innovative content and complexity of the planned R&D project being the most important. Firm-specific factors might also be important. According to the picking-the-winner hypothesis, firms with a high cash flow are more likely to be awarded grants. Differences may also exist between large and small firms.

4 Empirical results

The probit estimations reveal that R&D projects judged to be innovative or novel are significantly more likely to be approved (Table 4). This finding holds in both the standard probit estimations and mixed-effects probit estimations. In contrast to previous studies, the importance of the quality of the grant applications is not dominated by firm-level characteristics (R&D intensity, cash flow, and industry affiliation). Table 4 shows the marginal effects of the determinants on the acceptance rate of R&D funding applications using both the standard probit and mixed-effects probit models.[4] Four different models are provided. In models 1a and 2a, we use the standard probit model, with Model 1a containing only the evaluation criteria and year dummies, while Model 2a adds firm characteristics as well as industry and regional dummies. Models 1b and 2b contain the same explanatory variables as Models 1a and 2a, but the mixed-effects probit model is used, and the constant can vary across firms.

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[4] Z-values of the marginal effects of the standard probit model are based on clustered adjusted standard errors at the firm level.

[Table 4]

The likelihood ratio (LR) test shows that the presence of random firm effects cannot be rejected at the 5 percent level. Therefore, the interpretation of the results focuses on the more general mixed-effects probit estimations (Models 1b and 2b). Interestingly, the standard probit estimations tend to overestimate the impact and significance of positive ratings (+). The differences in the marginal effects between Models 2a and 2b are approximately 2 percentage points on average.

The mixed-effects probit estimations reveal that the acceptance rate of R&D grant applications significantly depends on certain evaluation criteria. By contrast, firm-level characteristics do not have a significant impact on the acceptance rate. The only exception to this appears for firms with more than 250 employees, which have a significantly lower acceptance rate. Among the project evaluation criteria, the expected additionality effects on firm R&D, knowledge gains through new technologies, complexity of the task, future potential, qualifications and motivation of the staff and exploitation potential of the R&D project have the largest impact on the probability of being selected. The expected additionality effects on firm R&D have the highest impact, indicating spillovers onto other R&D projects within the firm. For instance, in Model 2b, the probability of receiving an R&D grant is 23 percentage points higher for firms with a very positive rating (++) than for firms with a negative rating (-. --, or KO).[5] For applications with good ratings (+), the marginal effect is 13 percentage points. For knowledge gains of the R&D project, the difference between good and very good ratings and the reference category is 13 and 14 percentage points, respectively. Similarly, a good rating for future potential is associated with 12- and 15- percentage-point-higher acceptance rates. Technical equipment and environmental aspects are less relevant, as indicated by the marginal effects.

Firm-level characteristics are generally not relevant for the acceptance of R&D grant applications in the estimations. The R&D intensity, labor productivity and export ratio are not significant at conventional significance levels (based on both the standard and mixed-effects probit models). This indicates that regardless of these characteristics, applicants have the same chances of receiving funding in the third step. Unreported results also show that the cash-flow ratio is not significant, indicating that R&D funding is neutral to internal financing possibilities.[6] Similarly, firm growth dynamics measured as a change in the log number of

[5] For almost all evaluation criteria dummies, the significance level is lower for the ++ dummies than for the + dummies, depending on whether a ++ score is less frequent than a + score (see Table 1).

[6] Cash flow is not included in the final specification because of the large number of missing values.

employees and log turnover are not significant at conventional levels (with z-values of 0.74 and 0.66, respectively; the results are available upon request). This finding indicates that fast-growing companies do not have a higher acceptance rate of R&D funding, which contrasts the "picking the winner" hypothesis. However, the results should be interpreted with caution as including the growth rate of the company reduces the sample by approximately 40 percent because the panel data set is highly unbalanced.

An exception is firm size, where the largest firms (> 250 employees) have an 18-percentage-point lower probability of receiving funding compared to firms without employees (model 2b). If random firm-level effects are not considered, then the firm-size effect is overestimated (+28 percentage points). The reason for the higher rejection rate might be that large firms submit multiple applications at the same time, which diminishes the probability of obtaining funding. The probability of receiving an R&D grant does not vary much across industries.[7]

In appendix Table A1, probit estimations including only firm-level characteristics are provided. The firm size, firm age, R&D intensity and labor productivity do not significantly differ from zero and, thus, do not appropriately explain the acceptance decision; only the export share is significant. This finding contradicts the previous literature, which reports that certain firm characteristics are significant. However, the insignificance of firm age is consistent with Silva et al. (2017). Since the previous literature has found that firm-level characteristics have an overall impact on the grant decision when lumping three selection steps together (see Introduction), our results indicate that such factors should be more important in the first and second steps. Indeed, the parameter estimates of the firm characteristics change from Model 3b (Table A1) to Model 2b (Table 4) when evaluation criteria are included. This might indicate that some of the evaluation scores are affected by the firm-level variables. Thus, firm-level characteristics should be more important in the second step.

Table 5 shows the probit estimates for the small sample for 2008–12, during which four more evaluation criteria became available. Again, the evaluation ratings for the different criteria are highly significant, while firm characteristics are not related to the acceptance rate. Innovative content stands out with very positive ratings, increasing the probability of acceptance by 37 percentage points. Expected additionality effects – either on firm-level R&D or project-level R&D – are also highly relevant. Assessment ratings related to scope of technology, risk of not

[7] Specifically, applicants from the pharmaceutical sector (NACE rev 21) and business services (NACE rev 2 63 to 96) have lower probabilities of receiving funding, whereas firms in the metal sector (NACE rev 2 24 to 25) and other manufacturing sectors have significantly higher probability (NACE rev 2 31 to 33).

achieving economic goals, development risk, additional funding opportunities through R&D grants, complexity of the task, market prospects, and qualifications and motivation of the staff are also significant, with marginal effects in the moderate range. Firm size is the only firm-level characteristic that is significantly related to the acceptance rate. For the small sample, we find that acceptance is monotonously negatively related to firm size. The largest firms (> 250 employees) have a 21-percentage-point-lower acceptance rate than firms with no employees.

[Table 5]

Several robustness checks are conducted. First, estimations conducted for firms with high and low R&D intensity are undertaken. The results show that the importance of the different criteria does not differ much between firms with low and high R&D intensity. Second, the results might also differ between SMEs and large firms. Unreported results show that firm size does not play a significant role in the sign and significance of the evaluation criteria.

Third, alternative size variables are included and measured as the logarithm of employees and its squared term. The unreported results show that the acceptance rate decreases with firm size. Fourth, several interaction terms are included to determine whether there is an additionality effect from different combinations of the criteria. For example, projects that have received an excellent rating in terms of both the scope of technology and the expected impact of additionality on the company's R&D could be more likely to be accepted than those with an excellent rating on the expected impact of additionality only. Here, the scope of technology measures the type of technology and, thus, the type of R&D activities. The underlying hypothesis is that a better rating will increase the impact of additionality on the acceptance rate. However, the marginal effects of the interaction terms (calculated by the delta method) are not or only weakly significant (at the ten percent level) (the results are available upon request). Similarly, mutually reinforcing effects can also be expected for the criterion “Risk of not achieving the economic goals” and a weak cash flow ratio. The unreported results show that the predicted probabilities of the cash flow ratio do not vary with the assessment of “Risk of not achieving the economic goals” and generally do not significantly differ from zero. The interaction terms between complexity of the task and expected additionality are also tested. Again, the interaction terms are not significant at the 10 percent level.

5 Conclusions

This study provides further empirical evidence regarding the evaluation criteria that are the most important for the probability of firms receiving public R&D funding. The empirical analysis is based on a novel database of accepted and rejected R&D grant applications that contains information regarding the evaluation scores. This database allows us to distinguish between the initial step in the funding application process (decision of firms to apply for grants) and the final stage focusing on applying firms only.

The mixed-effects probit estimates show that the likelihood of obtaining an R&D grant mainly depends on the degree of innovativeness, knowledge gains and expected spillovers within the firm as well as the future potential of the technology and the project. For example, good or very good assessments of innovative content raise the acceptance probability by between 18 and 37 percentage points, respectively. On the other hand, firm-level characteristics are mostly insignificant. Firm specific characteristics, such as having low R&D expenditures (as a ratio of turnover) or low levels of labor productivity, do not lead to a disadvantage in receiving R&D grants. Only the largest firms – those with more than 250 employees – have a significantly lower acceptance probability. Thus, small business firms are more likely than large firms to receive a grant.

Several conclusions can be drawn from our estimation results. First, R&D managers should focus on radical, new and innovative ideas with high knowledge gains and spillovers within the firm rather than minor improvements to successfully obtain application approval. Accordingly, R&D projects that involve minor technological changes to existing products or imitation of existing solutions, as well those that lack technological novelty, should not be submitted for funding. Given these results, R&D managers should not hesitate to apply for funding for very difficult projects. The evaluation characteristics of spillovers within the company are particularly important. Managers should ensure that the planned R&D project benefits other R&D projects within the company, and this information should be clearly stated in the application.

Second, young companies, low-productivity companies and companies in low-technology sectors are not disadvantaged in the likelihood of receiving R&D subsidies and should be encouraged to apply. These firm characteristics should be more crucial for receiving R&D grants in the following first and second selection steps: whether to apply for grants and how project proposals receive evaluation scores. Third, very small firms and loss-making firms or firms with low labor productivity should be encouraged to apply for R&D grants.

Despite providing the first empirical results regarding the determinants of the acceptance probability, some limitations of this study should be noted. Whether the results can be generalized to R&D funding programs in other countries is uncertain. More research is needed, especially on the basis of internationally comparable and harmonized data provided by funding organizations.

There are several directions for future research. One direction is to control the previous funding experience. However, this study would require new data and a larger sample. Another possibility is to consider additional firm level characteristics, which could require linking the data with firm level data from the national statistical office.

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Appendix

Table A1. Probability of obtaining an R&D grant (firm characteristics only)

	Standard probit estimations			Mixed-effects probit estimations		
	Model 3a			Model 3b		
Explanatory variables	dF/dx		z-stat	dF/dx		z-stat
Firm size 1-9 (ref 0)	0.003		0.05	-0.045		-0.70
Firm Size 10-49	0.059		0.98	0.010		0.15
Firm size 50-249	0.088		1.43	0.038		0.57
Firm size 250+	0.061		0.97	0.026		0.38
Young firm (0-5 years)	0.019		0.93	0.022		1.04
R&D to turnover t-1	0.028		1.43	0.032		1.47
ln Sales per employees t-1	0.005		0.51	0.004		0.39
Exports to turnover t-1	0.101	***	4.38	0.099	***	4.06
8 Regional dummies	Yes			Yes		
4 additive year dummies (reference 2005)	Yes			Yes		
15 additive sector dummies	Yes			Yes		
No. of observations	3 832			3 832		
No. of firms	1 856			1 856		
Pseudo R^2	0.036					
Correctly predicted obs. in per cent	89.3					
LR test vs. standard probit model (p-value)				0.00		

Notes: Asterisks ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. This table reports the marginal effects, dF/dx, and the corresponding z-values. Z-stat in the probit model is based on cluster-adjusted standard errors at the firm level. The mixed-effect probit model is estimated using the me-probit procedure of Stata 14.1

Table 1. Distribution of the rating scores for different criteria (shares).

Category	Criteria	Exclusion KO	Strong negative --	Negative -	Positive +	Very positive ++
Sample 2005−2012 (# obs. 3 217)						
Relevance	Additionality effects on firm R&D	0.005	0.030	0.353	0.568	0.046
	Knowledge gains through new technologies	0.001	0.071	0.403	0.460	0.066
	Add. funding opportunities through the R&D grants	0.007	0.040	0.210	0.435	0.308
	Risk of not achieving economic goals	0.000	0.122	0.501	0.326	0.048
Quality of the project	Scope of technology	0.000	0.060	0.526	0.380	0.034
	Complexity of the task	0.003	0.104	0.447	0.400	0.047
	Future potential of the technology	0.001	0.022	0.269	0.603	0.105
	Environmental aspects	0.000	0.004	0.764	0.219	0.013
Economic potential	Market prospects	0.005	0.032	0.404	0.553	0.006
	Exploitation potential	0.009	0.045	0.289	0.566	0.091
Suitability of applicant	Qualifications and motivation of the staff	0.003	0.026	0.165	0.649	0.157
	Technical equipment	0.002	0.032	0.278	0.571	0.118
Sample 2008−2012 (# obs. 1 553)						
Relevance	Additionality effects on project R&D	0.028	0.021	0.261	0.565	0.125
Quality of the project	Development risk	0.006	0.091	0.432	0.421	0.051
	Innovative content	0.011	0.032	0.349	0.563	0.046
	Novelty of the technology or methodology	0.001	0.156	0.490	0.306	0.048

Source: R&D funding agency, own calculations.

Table 2. Firm characteristics of funded and non-funded applications (mean and median).

	Non-funded Median	Funded Median	Test on equal mean (p-value)	Test on equal median (p-value)
R&D to sales ratio	0.067	0.070	0.055	0.664
No. of employees	55	89	0.315	0.055
Turnover per employee in Euro	160	165	0.992	0.486
Export share	0.560	0.700	0.000	0.003
Firm age in years	14	16	0.046	0.045
Cash-flow ratio	0.089	0.084	0.004	0.620

Note: Test on equal median is based on the least absolute deviation model with no control variables. Source: R&D funding agency, own calculations.

Table 3. Acceptance rate for different ratings across criteria (shares).

Category	Criteria	negative rating -, --, KO	positive rating ++, +	Fisher exact test (p-value)
	Sample 2005−2012 (# obs. 3 273)			
Relevance	Additionality effects on firm R&D	0.477	0.816	0.00
	Knowledge gains through new technologies	0.516	0.837	0.00
	Add. funding opportunities through the R&D grants	0.524	0.740	0.00
Quality of the project	Risk of not achieving economic goals	0.587	0.848	0.00
	Scope of technology	0.610	0.791	0.00
	Complexity of the task	0.560	0.840	0.00
	Future potential of the technology	0.422	0.793	0.00
	Environmental aspects	0.660	0.767	0.00
Economic potential	Market prospects	0.516	0.818	0.00
	Exploitation potential	0.500	0.781	0.00
Suitability of applicant	Qualification and motivation of the staff	0.376	0.759	0.00
	Technical equipment	0.527	0.756	0.00
	Sample 2008−2012 (# obs. 1 558)			
Relevance	Additionality effects on project R&D	0.483	0.798	0.00
Quality of the project	Development risk	0.541	0.879	0.00
	Innovative content	0.398	0.895	0.00
	Novelty of the technology or methodology	0.593	0.897	0.00

Source: R&D funding agency, own calculations.

Table 4. Probability of obtaining an R&D grant (total sample 2005−2012)

	Standard Probit estimations				Mixed-effect Probit estimations			
	Project characteristics		Project and firm characteristics		Project characteristics		Project and firm characteristics	
	Model 1a		Model 2a		Model 1b		Model 2b	
Explanatory variables	dF/dx	z-stat	dF/dx	z-stat	dF/dx	z-stat	dF/dx	z-stat
Additionality effects on firm R&D +	0.189***	9.98	0.189***	9.24	0.128***	10.15	0.134***	9.62
Additionality effects on firm R&D ++	0.210***	5.60	0.182***	5.73	0.224***	5.08	0.229***	4.98
Knowledge gains +	0.189***	10.42	0.172***	8.63	0.138***	10.40	0.133***	8.95
Knowledge gains ++	0.172***	4.10	0.140***	3.28	0.177***	5.00	0.144***	3.80
Additional funding opportunities +	0.105	4.74	0.082***	3.11	0.070***	4.28	0.064***	3.23
Additional funding opportunities ++	-0.030	-1.08	-0.007	-0.21	-0.026	-1.27	-0.004	-0.16
Risk of not achieving economic goals +	0.115***	5.57	0.127***	5.86	0.092***	5.82	0.104***	5.91
Risk of not achieving economic goals ++	-0.057	-1.08	-0.016	-0.31	-0.039	-1.11	-0.009	-0.23
Scope of technology +	0.080***	4.16	0.086***	4.23	0.057***	4.17	0.066***	4.29
Scope of technology ++	-0.021	-0.33	0.004	0.06	-0.021	-0.49	0.000	0.00
Complexity of the task +	0.136***	6.79	0.145***	6.66	0.100***	6.90	0.112***	6.95
Complexity of the task ++	0.113**	2.55	0.122***	2.81	0.105**	2.52	0.114**	2.48
Future potential of technology +	0.146***	7.53	0.169***	7.96	0.102***	7.42	0.118***	7.85
Future potential of technology ++	0.144***	4.18	0.150***	4.56	0.130***	4.44	0.149***	4.66
Environmental aspects +	0.077***	3.50	0.055**	2.25	0.050***	3.04	0.042**	2.23
Environmental aspects ++	0.065	0.73	0.091	0.94	0.057	0.85	0.088	1.10
Market prospects +	0.180***	9.49	0.156***	7.67	0.121***	9.40	0.109***	7.84
Market prospects ++	0.103	1.03	0.003	0.03	0.063	0.71	-0.008	-0.08
Exploitation potential +	0.193***	8.57	0.180***	7.46	0.134***	9.12	0.127***	7.53
Exploitation potential ++	0.161***	4.73	0.155***	4.71	0.145***	5.02	0.157***	5.06
Qualification of the staff +	0.220***	8.66	0.192***	6.28	0.145***	8.77	0.132***	6.93
Qualification of the staff ++	0.168***	5.92	0.140***	4.62	0.141***	5.54	0.127***	4.62
Technical equipment +	0.045**	2.06	0.060**	2.45	0.039**	2.50	0.040**	2.26
Technical equipment ++	-0.077**	-2.00	-0.011	-0.30	-0.020	-0.73	-0.002	-0.08
Firm size 1-9 (ref 0)			-0.070	-0.67			-0.057	-0.86
Firm size 10-49			-0.106	-1.02			-0.084	-1.27
Firm size 50-249			-0.143	-1.33			-0.109	-1.61
Firm size 250+			-0.262**	-2.30			-0.180***	-2.61
Young firm (0-5 years)			-0.041	-1.39			-0.029	-1.44
R&D to turnover t-1			-0.044	-1.45			-0.033	-1.61
ln Sales per employees t-1			-0.009	-0.64			-0.008	-0.75
Exports to turnover t-1			-0.055*	-1.80			-0.036	-1.57
8 additive regional dummies	No		Yes		No		Yes	
7 additive year dummies (ref. 2005)	Yes		Yes		Yes		Yes	
15 additive sector dummies	No		Yes		No		Yes	
Number of observations	3 271		2 487		3 271		2 487	
Pseudo R^2	0.35		0.404					
Correctly predicted obs. in per cent	82.6		84.4					
LR test vs. standard probit model (p-value)					0.000		0.030	

Notes: Asterisks ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. All evaluation criteria dummies are compared to the reference group of scores -, -- and KO. This table reports the marginal effects, dF/dx, and the corresponding z-values. Z-stat in the probit model is based on cluster-adjusted standard errors at the firm level. The mixed-effects probit model is estimated using the meprobit procedure of Stata 14.1 with random effects. The share of accepted applications is 68.5 per cent in Models 1a and 2a (excluding firm characteristics). The corresponding share is 71.3 percent in Models 1b and 2b (including firm characteristics). Additive dummies for years and sectors are not shown but are available from the authors on request.

Table 5. Probability of obtaining an R&D grant (sub sample 2008−2012)

	Standard probit estimations		Mixed effects probit estimations	
	Model 4a		Model 4b	
Explanatory variables	dF/dx	z-stat	dF/dx	z-stat
Additionality at project level +	0.222 ***	8.86	0.149 ***	8.89
Additionality at project level ++	0.118 ***	5.12	0.141 ***	4.98
Additionality effects on firm R&D +	0.142 ***	5.28	0.096 ***	5.84
Additionality effects on firm R&D ++	0.115 ***	3.81	0.178 ***	3.82
Knowledge gains through new technologies +	0.074 ***	3.12	0.056 ***	3.18
Knowledge gains through new technologies ++	0.017	0.33	0.016	0.36
Additional funding opportunities +	0.103 ***	3.44	0.078 ***	3.31
Additional funding opportunities ++	0.070 *	1.91	0.055 *	1.87
Risk of not achieving the economic goals +	0.119 ***	4.73	0.093 ***	4.83
Risk of not achieving the economic goals ++	-0.126	-1.58	-0.068 *	-1.68
Development risk +	0.107 ***	4.45	0.084 ***	4.32
Development risk ++	-0.058	-0.79	-0.037	-0.79
Innovative content +	0.285 ***	9.54	0.182 ***	10.01
Innovative content ++	0.135 ***	5.16	0.375 ***	3.90
Novelty of the technology or methodology +	-0.020	-0.60	-0.013	-0.54
Novelty of the technology or methodology ++	-0.284 **	-2.49	-0.130 ***	-2.57
Scope of technology +	0.061 ***	2.89	0.048 ***	2.82
Scope of technology ++	0.031	0.45	0.025	0.55
Complexity of the task +	0.099 ***	4.22	0.074 ***	4.09
Complexity of the task ++	0.089 *	1.79	0.101 *	1.90
Future potential of the technology +	0.031	1.32	0.020	1.06
Future potential of the technology ++	-0.010	-0.18	-0.007	-0.19
Environmental aspects +	0.060 **	2.55	0.049 **	2.42
Environmental aspects ++	-0.085	-0.65	-0.052	-0.77
Market prospects +	0.117 ***	4.56	0.076 ***	4.64
Market prospects ++	-0.355 *	-1.78	-0.161	-1.49
Exploitation potential +	0.244 ***	6.24	0.146 ***	6.66
Exploitation potential ++	0.139 ***	4.93	0.156 ***	4.74
Qualification and motivation of the staff +	0.109 ***	2.62	0.080 ***	3.50
Qualification and motivation of the staff ++	0.071 *	1.77	0.068 **	2.21
Technical equipment +	0.073 **	2.26	0.045 **	1.99
Technical equipment ++	-0.007	-0.18	-0.007	-0.21
Firm size 1-9 (ref 0)	-0.314 *	-1.97	-0.159 **	-2.14
Firm Size 10-49	-0.309 **	-2.23	-0.174 **	-2.36
Firm size 50-249	-0.375 ***	-2.60	-0.203 ***	-2.71
Firm size 250+	-0.374 ***	-2.67	-0.214 ***	-2.79
Young firm (0-5 years)	-0.011	-0.31	-0.009	-0.36
R&D to turnover t-1	-0.020	-0.64	-0.017	-0.67
ln Sales per employees t-1	0.004	0.22	0.000	-0.02
Exports to turnover t-1	-0.032	-0.87	-0.021	-0.82
8 Regional dummies	Yes		Yes	
4 additive year dummies (reference 2008)	Yes		Yes	
15 additive sector dummies	Yes		Yes	
No. of observations	1334		1334	
Pseudo R^2	0.59			
Correctly predicted obs. in per cent	89.3			
LR test vs. standard probit model (p-value)			0.05	

Notes: Asterisks ***, **, * denote significance at the 1%, 5% and 10% levels, respectively. All evaluation criteria dummies are compared to the reference group of scores -, -- and KO. This table reports the marginal effects, dF/dx, and the corresponding z-values. Z-stat in the probit model is based on cluster-adjusted standard errors at the firm level. The mixed effect probit model is estimated using the me-probit procedure of Stata 14.1 with random effects. The share of accepted applications is 68.5 per cent in Model I (excluding firm characteristics). The corresponding share is 71.3 percent in Models 2 and 3 (including firm characteristics). Additive dummies for years and sectors are not shown but are available from the authors on request.