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WHAT KINDS OF R&D CONSORTIA ENHANCE SMES PRODUCTIVITY? EVIDENCE FROM A SMALL-BUSINESS INNOVATION POLICY

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Abstract

We seek to contribute to the empirical literature on R&D collaboration by focusing on policy-elicited R&D consortia aimed at the upgrading of small and medium-sized enterprises (SMEs). We put forward a set of theoretically and empirically grounded hypotheses and we test them on a group of small-business innovation programs that have been implemented in Italy at the regional level. To this purpose, we design an ad hoc empirical strategy to measure the effects, in terms of labor productivity, arising for SMEs at the consortium level. This strategy enables us to account for SMEs participating in multiple consortia, also simultaneously. We find that consortia bring a higher contribution to SMEs performance when participating firms are linked by upstream and downstream relations, and when R&D consortia include intermediaries. The presence of large firms is beneficial only when participating SMEs have some absorptive capacity. This is not the case for universities, whose presence does not correlate with a higher contribution of the consortium to SMEs productivity.

Jelcodes:L53,O32

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Abstract

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Keywords: R&D consortia; innovation policy; small and medium-sized enterprises

JEL codes: L52, L53, O31, O32, O25

1. Introduction

Since the late '80s different strands of literature have approached the analysis of R&D collaborations highlighting that they can be an important tool to promote the production and internalization of knowledge spillovers. While theoretical contributions in the field of industrial organization have explored the private and social benefits of R&D joint ventures or consortia (Spence, 1984; Katz, 1986; d'Aspremont and Jacquemin, 1988), a great deal of theoretical and empirical works in the fields of evolutionary economics and innovation management have focused on the determinants and results achieved by a broad range of R&D partnerships (Kogut 1988; Hagedoorn 1993; Das and Teng 2000). In addition, scholars in economic geography have stressed the role that R&D networks or platforms can play for the innovation of firms and regions (Tödtling and Trippl, 2006; Asheim et al, 2011). Despite their many differences, all these strands of literature point to the importance of public intervention in favor of R&D collaborations.

A large number of countries and regions have developed their own R&D-collaboration policies. The EU, for example, has widely used this tool to support various forms of partnership both in large-scale programs such as FP7, and in smaller scale innovation programs. Individual EU regions have also launched small-scale programs to support upgrading and innovation in SMEs, via the promotion of resource pooling and/or the setup of linkages with larger firms or knowledge providers.

This latter context of policy-making is characterized by strong peculiarities, regarding both the goals pursued by the programs and the types of agents involved. However, these aspects have not been adequately investigated in the literature to date. On the one hand, most of the analyses on policy-elicited R&D collaborations have so far been concerned with the promotion of large-scale consortia: whether the conclusions reached by such literature are immediately applicable to the growing number of regional policies that intend to upgrade the knowledge and skills of small firms is a question open to debate. On the other hand, the relatively small number of contributions focusing on the analysis of policy-elicited R&D collaborations involving SMEs mostly has a qualitative nature, and do not adopt an evaluation perspective.

Focusing on one example of small-business R&D policy, our paper contributes to fill this gap by carrying out an analysis of relative effectiveness. In particular, we analyze what kinds of R&D consortia add more to the performance of SMEs, and which add less. In order to do so, we pay particular attention to the peculiarities of SMEs and of related policies, which result in a set of theoretically grounded hypotheses that guide our empirical analysis.

Our approach differs from previous studies on the performance of R&D consortia for a combination of the following reasons. First, approaches that – like ours – focus on the consortium level of analysis are still uncommon in the literature, despite the notable contribution in this direction by Branstetter and Sakakibara (2002), who, however, deal with consortia involving large firms. Second, the few existing contributions that refer to SMEs adopt a firm-level unit of analysis and do not usually refer to public programs (Okamuro 2007; Chun and Mun 2012). We instead use policy data: in so doing, we are likely to say less about firms' behavior in general, but we bring our contribution a little closer to the program evaluation literature, which is typically rich in policy insights and implications.

On the one hand, a limitation of our approach is that it remains largely descriptive, because we – like all previous studies on this topic – do not explicitly model the process of consortium formation, which may be the result of the agents' strategic behavior. This latter issue has been explored in theory (Jackson and Wolinsky 1996), but solutions for its empirical treatment are still in a pioneering phase (Toivonen et al. 2010; Christakis et al. 2010). Instead, we focus on the consortium after its inception, basically assuming exogenous consortia. Despite this, we believe that the proposed analysis is still interesting, since the decision on which types of consortia policies should promote can realistically be viewed as a choice between alternative static configurations.

On the other hand, we develop an original empirical approach to analyze the relative effectiveness of consortia, in terms of the performance achieved by the participating SMEs. This approach accounts for the fact that firms, at a given point in time, can participate in more than one consortium, which opens a problem of estimation of the benefits ascribable to each consortium. This problem cannot be addressed using standard statistical techniques and requires the design of an *ad hoc*, “homemade” solution.

In order to tackle this issue, we design an empirical approach in two stages. In the first stage, we measure overall consortium effects, not only net of all firms’ characteristics, but also in the presence of simultaneous participations. In the second stage, we examine the partial correlation between the consortium characteristics and its overall effects. The solution provided for this statistical problem presents some features that are novel in the methodological literature, which may be of particular interest in those cases where the fact that observations are not univocally nested into groups makes either the adoption of multi-level models, or the insertion of group-level characteristics in a single-equation model, unfeasible.

Some of our results are in line with those shown in previous studies focusing on large-scale policy-elicited consortia involving large firms. Other results relate instead to some peculiarities of SMEs. In line with the previous literature, our study shows that consortia involving similar (and, therefore, potentially competing) SMEs can be negatively affected by competition dynamics (Branstetter and Sakakibara, 2002), unless firms are part of a same production network, in which case the consortium is likely to work much better. Among the peculiar results we find that most performing consortia are those in which SMEs having a certain degree of absorptive capacity are combined with a large firm (and not necessarily with a university). Moreover, policy-elicited consortia for the upgrading of SMEs work better when they include one or more intermediaries. As shown by Howells (2006), this label can identify a wide variety of agents. However, their role in facilitating the working of the consortia is of particular importance in the presence of SMEs.

The paper proceeds as follows. Section two summarizes the main arguments and results of R&D collaboration literature, paying special attention to consortium-level analysis. Section three defines some theoretical and empirically-grounded hypotheses on the characteristics of well-performing consortia involving SMEs. Sections four and five are respectively devoted to the illustration of data and of the empirical strategy, while section six presents the main results of the analysis. Section seven concludes.

2. R&D partnerships and consortia: literature review

Theoretical industrial organization models have shown that cooperation may improve firm incentives to undertake highly inappropriable R&D activity, especially in contexts of high spillovers, when the participants are not direct competitors, and the product market is relatively not concentrated (Katz 1986; d'Aspremont and Jacquemin 1988). Under these circumstances, R&D collaborations allow firms to overcome the spillover problem, the presence of which would otherwise diminish the agents' incentives to undertake R&D. However a distinction has to be made between incoming and outgoing spillovers (Cassiman and Veugelers 2002). On the one side, high levels of incoming spillovers make the collaboration more attractive, as these imply that a large amount of information and knowledge will circulate within the group. Nevertheless, the ability to capture and take advantage of incoming spillovers is strongly influenced by the firm's absorptive capacity (Cohen and Levinthal 1989). On the other side, contexts characterized by a high level of outgoing spillovers can discourage collaboration, since firms' incentives to free-ride can be particularly high.

A number of firm-level empirical analyses – often drawn from large-scale surveys on firms' innovative behavior – have shown which kinds of collaborations are the best-performing. For instance, the literature has shown that the presence of high levels of incoming spillovers, and low levels of appropriability of the knowledge within the partnership, may make it difficult to collaborate with competitors, but not with universities or research centers. Moreover, the presence of incoming spillovers does not diminish the possibility of collaborating up- and downstream with providers and customers (Cassiman and Veugelers 2002; Belderbos et al. 2004a, 2004b; Aschoff and Schmidt 2008). For the specific case of SMEs, to which special attention will be paid in this paper, Chun and Mun (2012) find that small firms engage in R&D cooperation with universities in order to benefit from incoming spillovers. They also find that the higher the ability of firms to appropriate the results of R&D, the higher their propensity to collaborate with academic partners. However, the analysis of Okamuro (2007) shows that the presence of a university partner does not have a significant impact on SMEs' technological success. Instead, the cooperation with large firms or with firms belonging to different sectors (non-competitors) increases SMEs' success.

Contributions that shift the focus from the firm to the consortium or project level are usually part of the policy literature. The most significant findings of the literature assuming the consortium (or project) as its unit of analysis relate to three main aspects that might end up affecting firm performance: i) outgoing spillovers and competition-collaboration dynamics; ii) incoming spillovers and absorptive capacity; iii) organizational issues. Some of these aspects explicitly refer to pure group-level characteristics (e.g. the type of project governance or the size of collaborative project, which relates to the third category above), while others define group-level features starting from the individual characteristics of consortium members.

The first aspect refers to the fact that the presence of intense market competition among firms could erode the benefits arising from the presence of R&D spillovers, according to two main mechanisms. On the one hand, the existence of competition (even potential) may discourage the firms from entering the partnership for fear of leakage of relevant information, and this is most likely to happen when outgoing spillovers are high (Cassiman and Veugelers 2002). On the other hand, once the partnership has been established, the firm might try to limit its involvement and thereby reduce the amount of incoming spillovers internalized by the partnership. Consortium-level contributions that examine the role of competition include Branstetter and Sakakibara (2002), and Bizan (2003). In particular, in their analysis of the Japanese experience, Branstetter and Sakakibara (2002) find that the best-performing consortia are characterized by a low level of competition among partners, and by a focus on basic – rather than on applied – research. Besides the competition argument, Bizan (2003) finds evidence supporting the importance of partners' complementarity for the success of the collaboration.

The second aspect refers to the fact that the most successful collaborations are those that include a high level of incoming spillovers. Studies at project level that have provided empirical evidence in this direction include Branstetter and Sakakibara (2002; 2003). However, given that the mere presence of spillovers does not guarantee *per se* that information and knowledge are absorbed by the recipient firm, studies have also emphasized the presence of a diffused absorptive capacity as a determinant of good consortium performance. For instance, in their analysis of the Japanese experience, Branstetter and Sakakibara (2002) find that the best-performing R&D consortia are those that exhibit a high level of technological proximity among participants, as measured by the degree of similarity in the partners' patent portfolios. This latter feature, which is considered by the authors as a proxy for potential spillovers among partners, may also be considered as a proxy of the firms' capacity to absorb the knowledge produced by their partners. Other studies that focus on this aspect are those by Bougrain and Haudeville (2002) and Schwartz et al. (2010). In this latter case, the presence of large firms – usually characterized both by a high absorptive capacity and a high ability to contribute to the increase of incoming spillovers – has a positive effect on projects' relative performances.

The third aspect refers to all the organizational features that may enhance or diminish the performance of the consortium. From a transaction-cost perspective, collaborations work well when the related benefits are not overwhelmed by the coordination and, eventually, by the incentive cost (Oxley 1997). With respect to this issue, evidence is still controversial. For instance, the findings of Bizan (2003), and Schwarz et al. (2010) suggest that larger projects bring benefits that are greater than the transaction costs that may arise. On the contrary, Okamuro (2007), although starting from a firm perspective, finds evidence that firm performance may suffer from relevant transaction costs associated with the management of large-scale collaborative projects. Finally, the contribution of Duso et al. (2010) shows that small RJVs perform better than large ones because they offer a good environment for learning.

3. From the side of the SMEs: Are all partnerships good?

In this section, we will try to put forward a list of theoretical and empirically-grounded hypotheses about the characteristics of well-performing partnerships or consortia involving SMEs. As shown by Chun and Mun (2012), the determinants of R&D collaborations for small firms may be somewhat different from those of larger firms. Moreover, Nieto and Santamaria (2007) have also shown that the results of such collaborations may vary depending on the size of the firm.

Building on these contributions, as well as on a wider literature on the peculiarities of the SMEs in the innovation process, we will try to adapt some of the findings of the literature on R&D collaborations to the specific case of SMEs.

Outgoing spillovers and competition-collaboration dynamics. All firms, whatever their size, will be more willing to share knowledge in the partnership or consortium when the other members are not its direct competitors. However, in the case of SMEs, the fear of transmitting relevant information to a (potential) competitor can be aggravated by a peculiarity of the SMEs themselves. In fact, as shown by Kitching and Blackburn (1999) and MacDonald (2004), SMEs make limited use of formal mechanisms such as intellectual property rights to appropriate returns from their innovative effort. Instead, they rely more on informal mechanisms, which, however, are less-able than formal ones to protect an enterprise, especially one involved in R&D collaborations (Nieto and Santamaria 2010). The fear of transmitting relevant information, in fact, may drastically decrease the incentives to cooperate.

However, SMEs operating in a same market are often characterized by similar needs, interests, and knowledge, and this general similarity may provide a ground for mutual understanding and real involvement in the project. In fact, as suggested by many studies (Belderbos et al. 2004a, 2004b), R&D collaboration among members of a vertical partnership should be beneficial.

A specificity of smaller firms is that they are often part of local production networks composed of customers and suppliers along the stages of the supply chain (Piore and Sabel 1984). For this reason, we expect that the negative effects of competition between SMEs operating in the same sector can be positively counterbalanced when firms are part of the same production network. Therefore, we may formulate our first two hypotheses as follows:

H1: Competition or potential competition among SMEs has a negative effect on consortium performances.

H2: Consortia involving similar and potentially competing SMEs work better when firms are part of the same production network. Otherwise, competition prevails.

Incoming spillovers and absorptive capacity: Both the incoming spillover and the absorptive capacity arguments are crucial for smaller firms. On the one hand, as shown by Audretsch and Vivarelli (1996), knowledge spillovers are particularly important for small firms in order to foster innovation. In fact, small firms often need to complement their limited internal knowledge and competencies with the insertion of external resources (Acs et al. 1994). The collaboration with a knowledgeable partner, such as a large firm or a university (or research center), should provide small firms with access to the needed resources, and thus ease the inflow of knowledge spillovers (Rothwell and Dogdson 1991; Nooteboom 1999; Sadowski et al. 2003)[1]. On the other hand, the same limited presence of internal resources and competencies for innovation may limit the ability of small firms to absorb knowledge from outside their boundaries. This happens because SMEs tend to carry out mostly informal R&D activities, if any (Kleinknecht and Reijnen 1991), often relying on non-permanent departments, or entrusting this task to unspecialized personnel that is also allocated to other activities in the enterprise. In addition, smaller firms often lack the knowledge and expertise in areas that are complementary to R&D, such as, for example, management, marketing and others (Trajtenberg 2001).

For all these reasons, we may formulate our third hypothesis as follows

H3: Consortia that work better are those in which the presence of a knowledgeable partner such as a university or a large firm combines with a number of SMEs that have a certain degree of absorptive capacity.

Given their lack of skills in R&D-related activities, SMEs may not be able to manage innovative projects, or to search for and screen the right university partner to work with

[1] The recent work of Wang and Shapira (2012) provides a detailed description of the value of spillovers from university-industry interactions.

(Fontana et al. 2006). Although the literature describes some cases in which small firms and universities have a direct and fruitful relationship, many other studies show that this relationship may be difficult, particularly when firms do not carry out any formal R&D activity (Todtling and Kauffman 2001). In these cases, the presence of specialized intermediaries, such as innovation centers, technology centers or other forms of innovation service providers (Howells 2006) may provide a support to SMEs in building relations with universities or other knowledgeable partners (Izushi 2003)[2]. Therefore:

H4: Consortia that work better are those that include one or more intermediaries.

Organizational issues: R&D partnerships are beneficial provided that transaction costs are not too high, and do not outweigh the benefits of collaboration. This is why projects participated by a large number of agents may have a negative impact on consortium performance (Okamuro 2007). The scale of the project may depend not only on the number of participants, but also on the size of the individual investments. In the case of consortia composed of SMEs, which have limited management ability, an increase in the size of the individual investment might lead to high management costs. Therefore, we formulate the following hypothesis:

H5: Large-scale consortia perform relatively worse than small-scale consortia.

Another organizational issue considered here refers to the governance model of the consortium, which may be more or less decentralized. Horizontal models are likely to imply that the partners are all actively involved in the project. Instead, more hierarchical models imply the presence of one or a few partners acting as leaders. In the case of SME consortia,

[2] On the relationship between external business advice on SME growth see also Robson and Bennet (2004).

the presence of a leader could be on the one hand a positive element, as it might help reduce coordination costs borne by each partner, and might provide guidance to the innovative activity of the consortium. Of course, this happens only if those who exercise the role of leader are able to do so. On the other hand, if centralization is too high, peripheral partners could have low incentives to be fully involved in the project, as their interests might be insufficiently taken into account by the leaders. This latter situation could reduce peripheral partners' effort, and thus raise a moral hazard problem. In this case, it is difficult to formulate a univocal hypothesis.

4. Data from a regional policy in support of R&D consortia

The empirical analysis focuses on a set of policies supporting R&D consortia that have been implemented by the regional government of Tuscany (Italy). We have examined a set of four programmes implemented in different waves by the public agency in the time span from 2002 to 2008[3]. The programs were aimed at supporting innovative projects implemented by consortia of heterogeneous agents[4]. These interventions were intended to raise the innovative capacity of micro enterprises and SMEs, which constitute the large majority of enterprises in the region. In particular, the policy has encouraged the formation of R&D consortia (mostly) focused on process innovation. The outcomes of the projects were expected to be primarily adopted by the partner SMEs themselves.

[3] The empirical research was carried out over an extended time span, since the authors have participated in the monitoring of the programs. Monitoring reports are available, upon request to Tuscany's regional government, industry and innovation department.
[4] Here, consortium and (funded) innovative project are synonym. Agents (firms, universities and all the other types of agents that will be presented below) group together to elaborate an innovative project and to participate to a competitive bid. If the project is selected for funding, they form a consortium that will carry out the project. Therefore, the life of the consortium starts with the beginning of the project and ends with the end of the project..

The policy has been initially developed through two programs (lines 1.7.1 and 1.7.2 of the Regional Single Programming Document) - co-funded by the European regional development funds (ERDF) – encouraging the inception of relatively small R&D projects, and also the dissemination/diffusion of existing technologies. Another strand of the policy has consisted of two additional programs drawing upon the resources offered by the EU Regional Programme of Innovative Actions (RPIA). In all cases, great emphasis has been placed on process innovation. The whole set of programmes has been assigned almost 37 million euros, representing around 40% of the total funds spent on innovation policies by the regional government in that period. Half of these funds have been assigned to programs (or waves) in which projects were funded at 100%, while the rest has been administered in co-funding (with shares ranging from 75% to 85% of admittable costs). Through the four programs, the public agency has funded 168 projects.

The various programs have addressed a set of technological targets, such as ICT and multimedia, opto-electronics, mechanics, biotechnologies, and others. The identification of the sector(s) of application of R&D outcomes was left to the consortium members.

Both the size and the composition of individual consortia have only partly been influenced by the rules set by the public agency, and specified within each tender. Depending on the technology target, the consortia were required to include at least one university or one intermediary (innovation center, technology transfer center), or none at all. The same holds true for the number of participating SMEs. In some technology areas, the minimum was set at five, while in others there was no specific requirement. Some programs admitted multiple participations at the same time, and multiparticipation over time was always allowed. Projects could last no longer than 18 months. On average, they have lasted one year, with a very limited variability.

Once formal eligibility criteria were fulfilled, incentives were not granted automatically, but by means of a selection procedure based on the evaluation of submitted projects by a committee of experts. In case of a positive response, consortia were able to decide how to allocate the funds among their members. Large companies could be part of the consortium, but were not allowed to receive funds. Instead, universities and intermediaries were eligible for funding.

Our dataset is based primarily on the administrative records held by the governmental body that has implemented the program. It includes some data on the beneficiaries and also characteristics of the consortia and of the related projects. The public agency has also provided us with additional information and reports collected during process evaluation, allowing us to reconstruct some qualitative aspects of the projects that would not otherwise have been available on the basis of mere ex ante records concerning application and admission to the incentive. Finally, for each of the companies participating in funded consortia, we have collected balance sheet data from the AIDA-Bureau Van Dijk dataset. On the one hand, this has allowed us to control some of the information that the companies had provided to the public agency at the time of application. For example, if the firm had stated in the application that it had an internal R&D department, we checked for the presence of non-episodic R&D expenditures in the years immediately preceding the inception of the consortium. On the other hand, balance sheets have enabled us to enrich the dataset of administrative records with important information on the performance of firms one year before the consortium was started, and then during the project and after its completion. The use of balance sheet data poses some limitations in the Italian context, arising from the fact that not all companies are obliged by law to keep and publish their financial statements (such is the case of sole proprietorships and companies with unlimited liability). In addition, very small firms are permitted to draw up a balance statement in a simplified form. These two circumstances obviously raise a problem of missing data or, at best, the problem that only the data required in simplified statements are available for all firms. In order to minimize the impact and, where possible, overcome this problem, we have focused on a limited set of balance-sheet variables that were available for the vast majority of businesses. Where these were not available, we could directly (via phone) collect missing information from companies thanks to a formal request made by the public agency inviting them to provide – ex post – additional information.

Table 1 reports some key descriptive statistics on SMEs that have participated in the consortia funded by the programs. These statistics are limited to those cases – the vast majority – in which there is more than a single SME taking part in the project. It should also be noted that the table reports participations, and in our case, participations do not simply coincide with participants because of the possibility of each SME taking part in more than one consortium[5].

[5] Repeated participation has been a widely diffused practice. In fact, only 448 SMEs have joined only one consortium.

Table 1 – Some descriptive statistics on enterprises that have participated in the R&D consortia

variable	definition	Obs	Mean	Std. Dev.	Min	Max
Y= productivity of labor 1 year after the completion of the project (t+2)		765	75583.3	153889.9	-469102	2524318
$Produ_{t-1}$	productivity of labor 1 year prior to the start of the project (t-1)	765	52940	116030	-164821	2721000
$Empl_{t-1}$	n. of employees 1 year prior to the start of the project (t-1)	765	25.1	38.1	1	252
prev_part	Dummy that takes a value of 1 in case of participations that were started and completed in past yrs	765	0.197		0	1
multi_part	Dummy that takes a value of 1 if the firm is taking part in (same-time) overlapping projects, but these projects have started in different (adjoining) years	765	0.190		0	1
R&D_dept	Dummy that takes a value of 1 if the firm had a permanent R&D dept prior to the start of the project, and 0 otherwise	765	0.146		0	1
patents	n. of patent applications filed during 10 years prior to the start of the project up to (t-1)	765	1.531	3.297	0	9
grant	amount in Euros of the grant(s) obtained for participation to the project(s) in a given year	765	20384	104981	0	2813475
coop	legal form: cooperative	765	0.066			
limited	legal form: limited	765	0,608		0	1
unlimited	legal form: unlimited	765	0.013		0	1
other legal form	other legal form	765	0.046		0	1
year 2002	year of participation in the program: 2002	765	0,137			
year 2004	year of participation: 2004	765	0.067		0	1
year 2005	year of participation: 2005	765	0,235		0	1
year 2006	year of participation: 2006	765	0.075		0	1
year 2007	year of participation: 2007	765	0,101		0	1
year 2008	year of participation: 2008	765	0,122		0	1

Note to table 1: All monetary values have been deflated (base year = 2000).

The exclusion from our dataset of consortia including only one participating SME is a necessary prerequisite for the implementation of the empirical strategy presented in the next section. Moreover, it is evident that single-SME consortia are alien to the rationale underlying incentives to inter-firm R&D cooperation, and that they are more likely to fall under a general technology transfer policy rationale.

5. The empirical strategy

If we look more closely at the dataset described in the previous section, we may observe that data are laid in a hierarchical structure, with firms on the lower level, and projects/consortia on the upper level. It has been shown that ignoring this type of data structure, as it could happen by using a single equation model that combines individual and group-level regressors, implies an undesirable loss of relevant information and may bring to biased estimates (Skrondal and Rabe-Hesketh 2004). Hence, since our final goal is to examine which group characteristics are associated with better performances of the projects themselves, we might be tempted to adopt a multi-level random-effects approach (Skrondal and Rabe-Hesketh 2004). In fact, multilevel models allow for random components to be estimated at each level in the hierarchy, while allowing for the inclusion of covariates at all levels of the hierarchy. With respect to our case, the model would include random effects at the firm and consortium levels. Thus the variance would be partitioned into a between-project component and a within-project component (the variance of the firm-level residuals). In principle, this strategy would enable us to identify project effects (group-level residuals), representing unobserved project characteristics that affect firm outcomes. A multilevel model allows inserting also group-level variables in order to explain between-group variability. Upper-level explanatory variables usually include a set of group characteristics.

A special case of multilevel models, in which data are not purely hierarchical, arises in situations where lower-level units belong to two or more higher-level units. In our dataset, for example, enterprises may participate in different projects over time. This would impose the implementation of a multilevel multiple-membership model, in which every company receives a weighted combination of random effects from all the projects of which it was part. The problem with this approach is that, in our data, some firms take part in different projects at the same time (i.e. in the same year), and not only over time. This feature makes the design and application of a multilevel multiple-membership model very impractical, and no guidance is provided in the literature. This forces us to favor an alternative and more flexible fixed-effect strategy in two stages.

The goal of the first stage is to measure consortium fixed effects. These can be viewed as the "average shift" in the expected value of the outcome variable (which – as it will be discussed below - is firm-level labor productivity) associated to firm participation in one or more given consortia, after controlling for a set of firm characteristics. In the second stage, we specify a model where the outcome variable is represented by the consortium fixed effect that we have measured at the first stage, and regressors refer to a set of consortium characteristics defines in accordance to the suggestions coming from the relevant theoretical literature. It has to be stressed that the outcome variable used in the second stage is an "estimated" quantity. Under this circumstance it is unknown whether the asymptotic properties of the OLS estimator hold, therefore extreme caution has to be used with standard errors and significance levels. Given the descriptive approach taken in the paper, we will not emphasize them in the following analysis (they are reported in the appendix).

5.1. The first stage

We first collapse the time dimension of the data into a "pooled" cross-section, in which every firm is repeated as many times as the years in which its participations occur. In order to take into account multiple participations occurring in the same year (simultaneous participations), we use consortium/project dummies: for each firm-year observed, we have one or more dummies taking the value of one, depending on the number of consortia/projects into which the firm participates in that given year.

In the first stage we try to quantify the magnitude of project/consortium effects, net of firm characteristics. The outcome variable we use in this first model is labor productivity, and it is measured one year after the completion of the project ($t+2$). We are of course aware of the vast literature on the expected benefits of cooperation. Contributions have stressed both the importance of considering: i) the immediate effects of cooperation on innovation inputs, due to incoming spillovers, knowledge acquisition or research acceleration (Hagedoorn et al. 2000; Caloghirou et al. 2003) or to cost reduction (Beath et al. 1998); ii) the effects in terms of technological success (e.g. novelty of innovations, as in Amara and Landry 2005) or productivity of research (e.g. patent applications, Branstetter and Sakakibara 2002); iii) the effects in terms of economic success: innovative sales, productivity (Belderbos et al. 2004b) or other performance indicators. These latter approaches, similarly to the one we adopt in this study, investigate the benefits of R&D cooperation in an indirect fashion, i.e. without looking at (and modeling) how cooperation affects innovation inputs, and how these inputs later result into outputs. We will use here only labor productivity as outcome measure for the following reasons. Firstly, as stated in section 4, the programs analyzed here wanted to promote the upgrading of SMEs by means of process innovations that were expected to be primarily adopted by the partner SMEs themselves. As a consequence, most of the projects we observe have focused on process innovations, and this makes any measure related to product innovation (such as the sales of innovative products) rather inconsistent with what was actually promoted by the policy. Secondly, we have verified that some of the alternative measures used in the literature, such as patent applications, relate to events that are very rare for SMEs in our case of small-scale projects, both prior to and after the consortium inception. This is not surprising given that propensity to patent varies a lot across sectors and technological fields, and our consortia are very diverse with respect to this point. In addition, it is well known that SMEs usually have a relatively low propensity to patent (Acs and Audretsch 1988).

We calculate the OLS coefficients for our full population of SMEs the following labor productivity equation:

$$produ3_i = \alpha + \beta_1 produ1_i + \beta_2 \Delta produ_i + \beta_3 empl1_i + \beta_4 \Delta empl_i + \beta_5 prev\_part_i + \beta_6 multi\_part_i + \beta_7 rd\_dept_i + \beta_8 patents_i + \beta_9 grant_i + \boldsymbol{\beta_j X_i} + \boldsymbol{\beta_k P_i} + \varepsilon_i \quad (1)$$

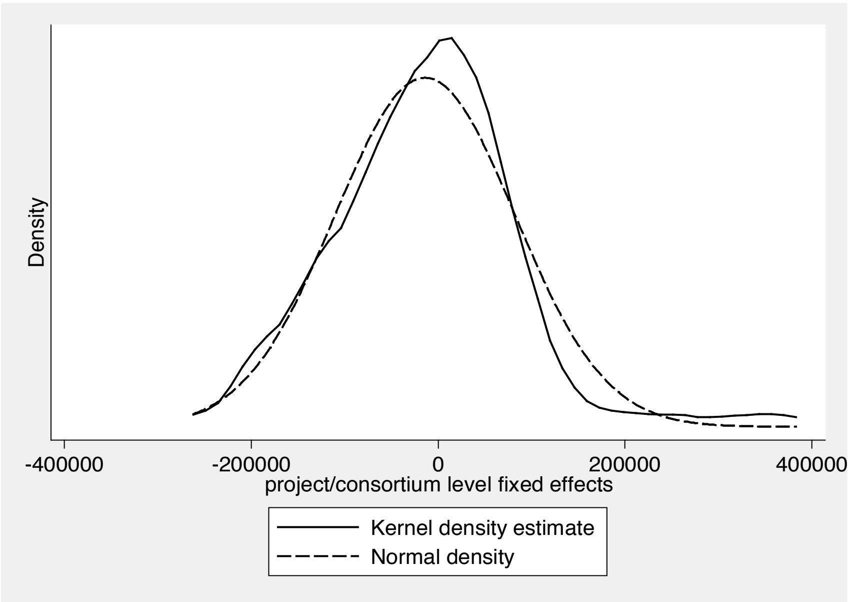
The outcome variable (labor productivity of firm *i*) is measured one year after the completion of the project (*t+2*) and all right-hand-side variables are measured one year before the project inception (*t-1*). The definition of most variables is provided in table 1. In addition, **X** is the matrix of the *J* control variables (NACE two-digit sectors, legal forms, year of the call for tender, and also province of localization). **P** is the matrix of the dummies for the K consortia/projects: the associated coefficients $\boldsymbol{\beta_k}$ are the estimand of our interest, i.e. the consortium fixed effects. These effects can be interpreted as the contribution of each consortium to the productivity of participating SMEs.

It should be noted that, among the explanatory variables, we include the lagged level of labor productivity measured one year before the inception of the project (*t-1*), as well as the percent variation of labor productivity observed from (*t-1*) to *t*; this variation is represented by the term Δ in equation 1. In a similar fashion, we insert in the model both the lagged level of employees and their variation. In so doing, we try to control for firm attributes that remain unobserved, which could endogenously determine labor productivity both before and after the firm takes part in the consortium.

Previous participations in projects that have been completed before year *t*, as well as a company's multiple participations in projects that are initiated in different years but whose durations partially overlap in *t*, are taken into account by means of respective dummy variables.

The roughly-normal distribution of the measured consortium fixed effects is shown in figure 1. The fixed effects can be seen as deviations from the outcome predicted by firm regressors. As it is shown by the figure 1, deviations can be either positive or negative.

Figure 1. The distribution of the consortium fixed effects measured at the first stage



5.2. The second stage

Once we have measured project/consortium fixed effects controlling for all SMEs' characteristics, we specify a second OLS model in which the consortia fixed effects are regressed on a set of project characteristics, according to the following equation:

$$project\_effect_k = \alpha + \varsigma_1 competition_k + \varsigma_2 input\_output_k + \varsigma_3 rd\_share_k + \varsigma_4 potential\_interfirm\_absorption_k + \varsigma_5 potential\_research\_absorption_k + \varsigma_6 intermediaries_k + \varsigma_7 budget\_dispersion_k + \varsigma_8 avg\_budg\_ph_k + \boldsymbol{\varsigma_j X_k} + \varepsilon_k \quad (2)$$

All explanatory consortium-level variables are presented in table 2, including the matrix of J control variables.

The variables have been grouped into the three broad categories discussed in sections 2 and 3: level of competition, absorptive capacity, and organizational issues.

As a proxy for competition among consortium members, we use the Gini index of concentration calculated on SMEs' NACE three-digit sectors (variable: *competition*). In order to account for the possible mitigation effect brought about by the presence of production linkages among SMEs operating in the same sector, we construct a variable (*input_output*), which results from the interaction among the previously mentioned Gini index and a dummy variable that takes the value of 1 if the majority of firms had previous input-ouput relations, and 0 otherwise. This latter dummy variable (*up_downstream linkages*) has been constructed drawing from intermediate evaluation reports provided by the public agency.

As for the absorptive capacity, we have considered the following. A first variable counts in each consortium the number of SMEs that had a permanent R&D department prior to the consortium inception, out of the total number of participating SMEs (*rd_share*). In order to explore hypothesis 3, we construct two distinct interactions. The first one (*potential_interfirm_absorption*) multiplies *rd_share* to a dummy that takes the value of 1 if at least one large company is part of the project, and 0 otherwise (*large_ent*). Similarly, the second interaction (*potential_research_absorption*) multiplies *rd_share* to a dummy that takes the value of 1 if at least one university (or research center) is part of the project, and 0 otherwise (*universities*). The presence of intermediaries in the consortium is captured by a homonymous dummy variable (*intermediaries*).

The organizational features of the consortia are proxied by two variables. The first one provides a measure of consortium size, by averaging the total consortium budget over the number of all participants, not only SMEs (*avg_budg_ph*). The second one (*budget_dispersion*) is defined as the reciprocal of the Gini index calculated on the budget shares of all participants, and indicates how horizontal the governance model is.

Table 2 - Some descriptive statistics on consortium-level explanatory variables

Variable	*definition*	*expected sign*	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Y=project_effect			146	-13970.8	96401.5	-231720.8	353058.4
COMPETITION							
competition	Gini index estimated on SMEs at three-digit sectors within the project	-	146	0.499	0.271	0	0.91
up_downstream linkages	Dummy that takes a value of 1 if the majority of firms had previous input-output relations, and 0 otherwise	N.I.	146	0.445		0	1
input_output	Interaction btw competition and up_downstream linkages	+	146	0.196	0.289	0	0.91
ABSORPTIVE CAPACITY							
rd_share	N. of SMEs in the project that had a permanent R&D dept prior to consortium inception, pct share.	+	146	0.133	0.157	0	0.75
large_ent	Dummy that takes the value of 1 if at least one large company is part of the project, and 0 otherwise.	N.I.	146	0.110		0	1
potential_interfirm_absorption	Interaction btw rd_share and large_ent.	+	146	0.020	0.086	0	0.75
universities	Dummy that takes the value of 1 if at least one university is part of the project, and 0 otherwise	N.I.	146	0.151		0	0.75
potential_research_absorption	Interaction btw rd_share and universities.	+	146	0.113	0.153	0	0.75
intermediaries	Dummy that takes a value of 1 if at least one intermediary is part of the project, and 0 otherwise.	+	146	0.555		0	1
ORGANIZATIONAL ISSUES							
avg_budg_ph	Avg budget per participant, estimated on all partners.	-	146	29189.7	47420.1	2306.719	545612
budget_dispersion	Reciprocal of the Gini index estimated on the budget shares of all partners.	+/-	146	0.343	0.145	0	0.81
OTHER VARIABLES							
mean_p	Avg group productivity, estimated on SMEs, one year prior to the start of the project	c	146	50412.5	56888.5	-3166.4	690968.3

vc_p	Group-level variation coefficient of productivity, estimated on SMEs, one year prior to the start of the project	c	146	0.812	2.126	0.000	25.329
near_to_appl	Dummy that takes a value of 1 if project focuses on near-to-application R&D, and 0 otherwise	c	146	0.589		0	1
program 1.7.1	Identifies a specific program	c	146	0.781			
program 1.7.2	Identifies a specific program	c	146	0.048		0	1
program prai/itt (888)	Identifies a specific program	c	146	0.096		0	1
program prai/vinci (999)	Identifies a specific program	c	146	0.075		0	1
technology 1	The project focuses on: other technologies	c	146	0.116			
technology 2	Biotechnologies	c	146	0.041		0	1
technology 3	Organic chemistry	c	146	0.096		0	1
technology 4	Renewable sources of energy	c	146	0.041		0	1
technology 5	ICT/multimedia	c	146	0.479		0	1
technology 6	Mechanics	c	146	0.068		0	1
technology 7	Multiple technologies	c	146	0.007		0	1
technology 8	Nanotechnologies	c	146	0.014		0	1
technology 9	New materials	c	146	0.041		0	1
technology 10	Optoelectronics	c	146	0.096		0	1
target industry 1	R&D outcomes are intended to be applied in: agroindustry	c	146	0.048			
target industry 2	Other industries	c	146	0.027		0	1
target industry 3	Preservation of cultural heritage	c	146	0.041		0	1
target industry 4	Energy & environment	c	146	0.199		0	1
target industry 5	Logistics & transportation	c	146	0.068		0	1
target industry 6	Textiles, clothing, jewellery & furniture	c	146	0.260		0	1
target industry 7	Mechanics	c	146	0.055		0	1
target industry 8	Biomedical	c	146	0.075		0	1
target industry 9	More than one specific industry	c	146	0.171		0	1
target industry 10	Shipbuilding	c	146	0.055		0	1

Note to table 2: "+", "–" or "+/-" in the third column signify that the expected signs of the coefficients of the variables are, respectively, positive, negative or ambiguous; c stands for control variable, and N.I. identifies a variable that has not been inserted in the model.

Before proceeding to discuss the results, we wish to emphasize that we have also inserted among control variables a measure of the average pre-consortium labor productivity estimated, for each consortium, for all participating SMEs (*mean_p*). We also insert the variation coefficient observed for the same productivity measure (*vc_p*). In so doing, we try to account for inter-consortia differences, and to capture information about within-group heterogeneity. Although we have already dealt with these aspects in equation 1, we believe that the insertion of these consortium-level variables may further control the second model for the potential effect due to unobserved self-selection mechanisms, which are likely to lead each of the companies to join one consortium instead of another.

In addition, control variables include a dummy that distinguishes consortia that focus on projects that are relatively close to the engineering and testing stages from consortia whose activity is in the initial R&D stages (*near_to_appl*)[6]. In fact, the former are more likely to bring measurable results one year after the completion of the project.

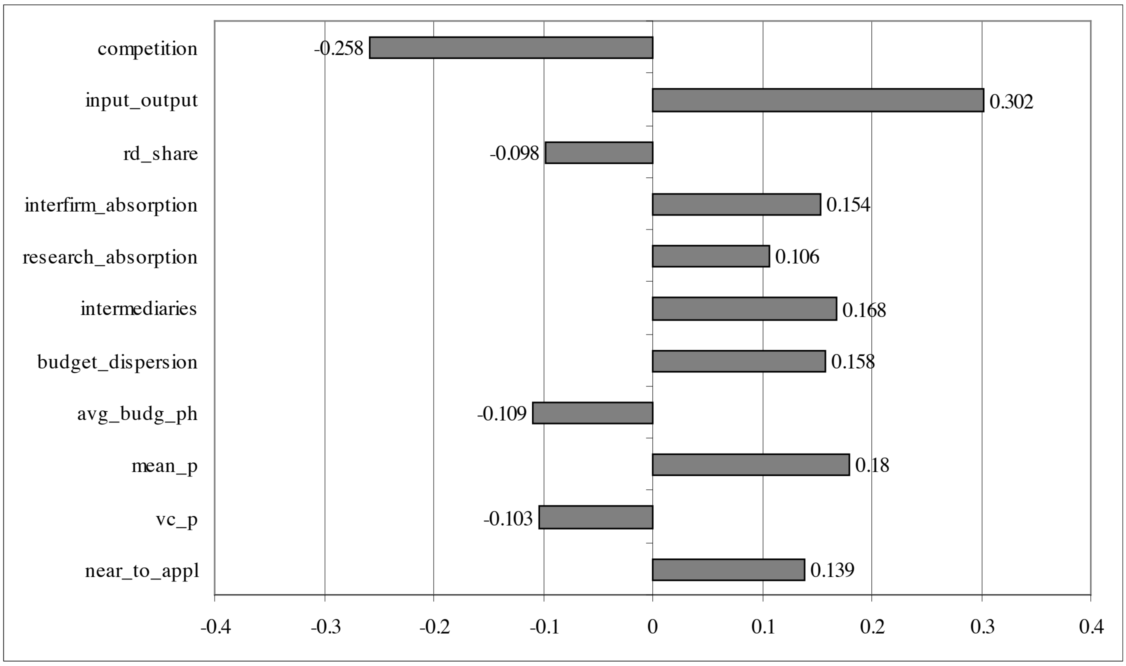
Indicators of the program that has funded the consortium and for the technological area of each project, as well as for its target sector of application, are also included as explanatory variables.

6. Results

Let us now present the main results of the application. Since the first model is instrumental merely to the measurement of consortium-level fixed effects, we focus attention on the second model, which examines the correlation between the magnitude of the effects and characteristics of the consortia. Results are summarized in figure 2 that shows the standardized (beta) coefficients, which are in our case very interesting as they allow to compare the relative weight of each regressor, i.e. they measure the partial correlations occurring in the population under study. In the light of the previous discussion in section 5, we do not report here neither standard errors nor significance levels. They are, however, reported in Table A in the Appendix.

[6] We define this variable on the basis of the intermediate monitoring reports, in which consortium members were asked to discuss project advancements.

Figure 2 – Assessing the influence of consortium characteristics by means of standardized coefficients



Note to figure 2: All control variables inserted (including program, technology, and target industry), as in table 2. Number of observations: 146; R-squared = 0.5361; Adjusted R-squared = 0.4048; Root Mean Square Error = 74375

First of all, our findings confirm theoretical predictions (H1), as competition is negatively (and significantly) associated with the extent of the consortium outcomes in terms of productivity of labor. Notwithstanding, negative effects of competition seem to be counterbalanced when firms are part of the same production network. In this case, as stated by our second hypothesis (H2), potential competition among firms belonging to the same industry is mitigated by the presence of upstream and downstream linkages. Moreover, as shown in figure 2, these two variables appear to have the larger weight of all the other we have considered. This might happen for two main reasons. First, as stated by some contributions, firms should be willing to take part in a consortium if they can find a pool of knowledge and competencies which complement their internal resources (Sakakibara 1997), and the presence of this kind of complementarity can boost the activity of the consortium (Kogut 1988). Second, according to a transaction costs perspective, the presence of productive linkages developed prior to the consortium is likely to keep transaction costs down.

The extent of SMEs in the consortium having absorptive capacity is positive only when it combines with the presence of large firms or universities; otherwise it is negative. The combination of the number of SMEs with absorptive capacity and the presence of one or more large companies is positively associated with higher project outcomes. A positive, but smaller correlation is found for the case of interactions with universities. Therefore, with respect to H3, consortia that work better are those in which the presence of a large firm combines with a number of SMEs that have a certain degree of absorptive capacity. The negative result we have found with respect to the presence of absorptive capacity alone might be due to the fact that, in the absence of a knowledgeable partner (non-SME) from which to absorb relevant spillovers, firms can have lower incentives to put their effort in the consortium because they expect to get less benefits.

The relation with academia seems to provide a little contribution to the productivity of the SMEs. There may be several explanations for this result, which is in line with other contributions (Bougrain and Haudeville, 2002; Okamuro, 2007), which are based on the lack of incentives from the side of the university, or on the presence of relevant set-up costs of the relations. First, given the small scale of our projects, monetary incentives provided to universities have been relatively modest. In addition, the university is rather more interested in working on large projects involving basic research, where the constraints of time, budget and application sectors are not particularly narrow (Hall et al. 2000). This is not the kind of environment offered by the projects and consortia analyzed here, which focused on narrow, applied research objectives to be achieved in a relatively short time. Second, previous process evaluation has shown that especially in the first phase of implementation of programs, some of the SMEs – especially those operating in lower-tech sectors – experienced their very first approach to universities. Many of the consortia have thus been offered the opportunity to open channels of cooperation, rather than to exploit them effectively (see also Izushi 2003). For these reasons, not all projects involving universities have immediately resulted in a tangible benefit for small firms. On the contrary, if the consortium involved a large company, small businesses could benefit from a partner who was able to direct the research activities in a way that was in line with the time-to-market and business needs.

To summarize, these results provide only a partial confirmation of our third hypothesis (H3), suggesting that in the particular case of SMEs, inter-firm R&D cooperation might be easier (and more effective) than university-SMEs cooperation[7].

As stated in section 3, the literature claims that intermediaries may play a useful connecting role between SMEs and other agents, such as universities. This prediction (H4) is confirmed by our findings.

As for the organizational features of the consortia, we find that the governance model of the consortium does play a significant role. In particular, horizontal forms of governance are positively associated with performance. This might derive from the fact than a horizontal model encourages an active and diffused involvement of SMEs, thereby limiting possible moral hazard problems. Finally, the size of the project is negatively associated with project outcomes. This result could be interpreted as follows. First, in line with the analysis of Okamuro (2007) on SMEs, we can interpret this negative sign by recalling that in the specific case of SMEs, involvement in large projects may cause an increase of management costs and therefore be too demanding. According to a transaction cost perspective, this might result in a reduction of the overall benefits of the project. Second, in the cases we observe, the average budget size of the projects is relatively small, and projects could last as little as one year.

[7] It should be noted that universities take part in a large part of the consortia analyzed here (110 out of 144). In 94 out of 110 cases in which universities are included in the consortia, large firms are excluded. Moreover, in some of the projects in which large firms are present, universities are absent. In general, interviews with participants have shown that large firms do not behave as intermediaries in the partnership with universities. Instead, they act as independent sources of knowledge and often behave as project leaders.

Larger and more complex projects requiring larger budgets are likely to last longer before obtaining remarkable results.

It is worth dwelling a bit longer on some of the control variables. In fact, in our view, it has to be emphasized that the contribution to SMEs' labor productivity provided by the consortium is significantly higher when participating SMEs were already more productive prior to the consortium's inception. Our findings seem also to suggest that better consortia consist of homogeneous firms in terms of ex-ante productivity. In fact, as shown in figure 2, the variable *vc_p* has a negative sign. Finally, consortia that carry out projects that are relatively closer to the engineering and testing stages do have better results. This is not surprising, since these are the kinds of projects that are more likely to bring results in the short run.

7. Concluding remarks

In this paper, we have analyzed policy-elicited consortia involving SMEs. Taking a consortium-level approach, we have tried to identify which kind of consortia contribute more to the enhancement of the productivity of SMEs. In line with a wider number of contributions on R&D collaborations, the results of our analysis show that consortia work better when consortium firms are not potential or effective competitors (i.e. when they work in different sectors). But in the presence of pre-existing up- and downstream business linkages among the consortium firms, the negative effects of competition among same-sector SMEs are offset, and the consortium is likely to make a positive contribution.

SMEs' productivity is also enhanced when the consortium includes a large firm, and at the same time SMEs are provided with some absorptive capacity. On the contrary, the presence of a university does not lead to significant improvement of firms' performance due to consortium activity. This last result, which might seem quite surprising, is in line with that obtained by some previous contributions. This may cast some doubts on the usefulness of policies that encourage SMEs to collaborate with universities. However, in our opinion the question should be put in a different way. Obviously, small firms are not all equal and, in fact, the literature reports cases of fruitful relations between SMEs and academia which involve highly innovative firms. More problems arise in the presence of non-innovative small firms, with little capacity to absorb new external knowledge. In these cases, policies that support the formation of university-industry relationships may not result in a significant increase in the performance of firms. Perhaps possible positive effects should be sought with respect to the learning and behavioral dimensions of SMEs, without assuming that these dimensions are necessarily able to raise productivity or performance in the short run.

Another interesting result of our analysis is that intermediaries do play a significant role. In fact, their presence within the consortia brings positive results to the performances of the single firms.

A last concluding element refers to the historical picking-the-winner *vs* aiding-the-poor trade-off in industrial policy. Although our approach has not directly analyzed the self-selection process that accompanies the formation of consortia, we know the result of this same process ex-post (at the inception of the consortium). Our findings show that consortia that contribute more to the enhancement of SMEs' productivity are those in which firms were already more productive (prior to the consortium). This suggests that 'better' agents tend to group into an environment which offers opportunities for both technological and productivity spillovers, which in turn boost the consortium's contribution to firm performance. On the contrary, less-productive SMEs benefit less from participation in R&D consortia. Therefore, inclusive policies that set the same general rules for all kinds of participants, and then leave the agents free to choose their best match, may bring ambiguous results. Our future research will try to address these issues explicitly.

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Appendix

Table A. Regression results

Y: project_effect	Coef.	Std.Err.	t	P>t	[95% Conf. interval]		Beta coef.
competition (H1)	-91768.99	28466.07	-3.22	0.002	-148165.40	-35372.58	-0.258
input_output (H2)	100828.60	26778.62	0.18	0.000	47775.32	153881.90	0,302
rd_share	-60129.76	90266.63	-0.67	0.352	-238964.20	118704.70	-0.098
potential_interfirm_Absorption (H3)	172523.60	86796.18	0.11	0.049	564.74	344482.50	0.154
potential_research_Absorption (H3)	66421.70	101797.10	0.05	0.358	-135256.80	268100.20	0.106
Intermediaries (H4)	32519.97	16538.42	0.11	0.052	-245.62	65285.55	0.168
budget_dispersion	104981.70	51857.42	2.02	0.045	2242.84	207720.60	0.158
avg_budg_ph (H5)	-0.22	0.15	-1.46	0.103	-0.52	0.08	-0.109
mean_p	0.31	0.13	2.32	0.022	0.04	0.57	0.180
vc_p	-4664.61	3357.44.00	-1.39	0.116	-11316.29	1987.08.00	-0.103
near_to_appl	27094.60	14601.58	0.10	0.066	-1833.77	56022.97	0.139

All control variables inserted (including program, technology, and target industry), as in table 2. Number of observations: 146; R-squared = 0.5361; Adjusted R-squared = 0.4048; Root Mean Square Error = 74375