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How do Public Programmes Shape Strategic R&D Collaborations? Project-Level Evidence from the 5th and 6th EU Framework Programmes

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Abstract:

We analyze the micro rationale of EU-sponsored collaborations compared to non-sponsored, spontaneous collaborations. We compare the incentives and coordination mechanisms of each type of collaboration, and derive propositions that we test empirically. Our econometric analysis uses recent data on (sponsored and non-sponsored) projects conducted by participants in the 5th and 6th European R&D Framework Programmes. Our empirical findings support our main propositions. Compared to spontaneous collaborations, EU-sponsored collaborations clearly have different characteristics and follow a different rationale. However, there is no major difference between the different types of EU-sponsored collaborations.

Keywords: Strategic R&D Collaborations; European Framework Programmes; Research Joint Ventures.

JEL Codes: L21, L24, O31, O32

The question of whether companies distinguish, from a strategic point of view, between publicly and privately funded R&D collaborations remains largely unanswered. It may have, nevertheless, important policy implications. Indeed, there exists, both in the USA and in the European Union, a variety of programs designed to increase R&D partnerships through public funding. In this paper, we focus on the European case, and contrast R&D collaborations sponsored by European Framework Programmes (hereafter FP) with spontaneous, privately funded R&D collaborations. The latter are defined as formal partnerships between independent organizations that do not benefit from any kind of public support.

Relying on a survey of the literature, we analyse R&D collaborations as organisational forms, putting the emphasis on their incentive and coordination functions, and taking into account the pervasive role of learning. We then argue that FP-sponsored collaborations and spontaneous ones should exhibit contrasted motivation and coordination patterns, because of two institutional characteristics of European FP: mandatory information disclosure and tight monitoring procedures. These contrasting patterns are summarized in five propositions. Compared to spontaneous ones, EU-sponsored collaborations should: (i) concern more peripheral activities; (ii) be more exploration-oriented; (iii) involve less conflicts but more rigidities; (iv) entail a higher administrative burden and (v) imply less intense interactions between partners.

The empirical relevance of these propositions is examined using data from the 2007 Innovimpact survey, in which companies were asked to characterize their cooperative R&D projects. The survey distinguished between three types of collaborative projects: two types of EU-sponsored projects, and spontaneous collaborations. We use this data to build a database of 2983 collaborative projects, and estimate a multinomial Logit model to characterize the first two types with respect to the third one. Overall, the empirical findings comfort our propositions.

The paper is organized as follows. A brief overview of the literature on inter-firm collaborations helps us develop, in Section 1, an original conceptual framework stressing the specificity of EU-sponsored collaborations. Section 2 presents the data. Section 3 is devoted to the econometric analysis and to the presentation of the empirical results. Section 4 derives important policy implications from these results, and a final section concludes.

1. Conceptual framework

This paper examines whether EU-sponsored collaborations differ from spontaneous inter-firm R&D collaborations, and how. This is an important question which has so far been largely overlooked in the literature. In the market-failure approach[1], these two forms of cooperation are generally considered as substitutes: public programmes should be implemented if (1) R&D collaborations improve social welfare and (2) there is a lack of spontaneous, privately-funded R&D collaborations. Other strands of literature examine either type of collaborations, but do not generally compare them. For instance, the strategic management literature about inter-firm technological alliances implicitly concentrates on spontaneous collaborations.

An interesting exception is Hagedoorn and Schakenraad (1993), who compare private and subsidised R&D collaborations in the IT industry. They do not find strong differences in terms of number and/or intensity of inter-firm linkages. However, we contend that sharp differences may appear when opening the 'organizational black box' of inter-firm relationships.

In this contribution, we consider R&D collaborations as particular organisational forms, which rely on the sharing of resources between independent firms with the explicit aim of creating new valuable knowledge. Organisations are generally defined as systems that coordinate the actions of agents endowed with different preferences, information, knowledge and interests (March and Simon, 1993). Like any organizational structures, inter-firm R&D collaborations have to fulfil three functions: incentive, learning, and coordination.

In the remainder of this section, we analyse R&D collaborations along these three fundamental organisational dimensions. We put the emphasis on the incentive and coordination functions, taking into account the pervasive role of learning in each case. We explain how characteristics of public R&D programmes may impact on incentive and coordination mechanisms. This leads to the emergence of two well-distinct patterns of R&D collaborations: publicly sponsored collaborations on the one hand, and private spontaneous collaborations on the other.

1.1. Incentives to collaborate in R&D

In this section we present some important issues concerning the motivation of firms to form R&D collaborations. We first underline the main results from the literature. This conceptual framework helps us characterize firms' incentives to participate in EU-sponsored R&D collaborations.

1 In the line of D'Aspremont and Jacquemin (1988) and Katz and Ordover (1990).

1.1.1. The incentive issue in the literature

The literature suggests that technological innovation is at the centre of most inter-firm cooperation strategies. These cooperation strategies generally involve high-tech companies facing a turbulent environment. They need to find quick access to external competencies and/or resources, a rather broad motivation[2] that can be split into - at least - two categories.

The first is reaching a critical mass via the pooling of similar resources. This includes the motivations that are central in the traditional economic analysis of cooperative R&D (e.g., Katz and Ordover, 1990; De Bondt, 1997; Salant and Schaffer, 1998; Amir, 2000): sharing R&D costs and risks, achieving economies of scale in R&D, agreeing on common technical standards.

The second category of motivations is to combine complementary, dissimilar resources in order to create value (Richardson 1972; Teece, 1986). In line with Richardson (1972)'s vision, the "competence-based view of the firm" regards it as a portfolio of strategic, distinctive core competencies (Prahalad and Hamel 1990; Teece 1992). Core competences are built through a time-consuming cumulative process. They constrain the scope of the future activities of the firm. The *distance from the core* determines the type of external growth to be chosen: a core competence is highly strategic and has to be internalized, whereas a peripheral competence can be outsourced. R&D collaborations lie in an intermediary area between core competencies and peripheral knowledge, "where the firm holds significant pieces of knowledge but needs access to complementary forms of knowledge held by other firms to be able to develop and use the knowledge efficiently" (Amesse and Cohendet, 2001, p.1470).

However, R&D collaborations may be used not only for exploiting existing complementary pieces of knowledge, but also for *exploring new technological options*. Maintaining an appropriate balance between exploitation and exploration is a critical activity for an organization in a turbulent environment (March, 1991). Both activities are essential but compete for scarce resources. The refinement of existing technological trajectories is often favoured, because of the temporal and spatial proximity of exploitation learning. R&D collaborations represent a way to compensate for excessive exploitation. Some authors (e.g., Ciborra, 1991) claim that technological collaborations trigger specific learning processes: *radical, exploratory learning*. Collaborative learning may be more radical because it entails the confrontation of the distinct and heterogeneous knowledge bases of the participants.

[2] We recognize the existence of other motivations such as: (1) the search for power and/or hidden domination of a rival (a somewhat extreme case of "opportunism with guile"), and (2) the acquisition of reputation and other "network" assets. However, both can be considered as second-order motives.

These two categories of incentives (reaching a critical mass and combining complementary resources) are not mutually exclusive. Both may influence the decision to participate in a collaborative R&D project. Nevertheless, the constraints imposed by EU Framework Programmes may induce specific motivational characteristics, which we will now examine.

1.1.2. Incentives in EU-sponsored collaborations

Firms participating in FP projects receive subsidies, but have to disclose information. These two features of public programmes might generate a specific behaviour which would not be observed in spontaneous collaborations.

As far as confidentiality is concerned, it is relevant to take into account the strategic importance of the project, i.e. its *distance from the core competencies* of the firm. Participating in a public programme implies that information on the project becomes public. In the case of European programs, the EU Cordis database provides free access to the list of funded projects, including a summary of the research objectives and the different partners. For a given company, it may be assumed that the firm does not mind disclosing this kind of information because: (1) the project concerns generic, non confidential knowledge, pertaining to long term research[3]; (2) the project is not a critical one, in the sense that it belongs to the intermediary area close to peripheral competences of the company; (3) revealing this information is a deliberate signalling strategy (e.g. to display a technical competence or its willingness to cooperate).

By contrast, spontaneous R&D collaborations enable the firm to access external complementary knowledge without having to make the collaboration public. If the R&D project is closely connected to the core activity of the firm, it may decide to keep the cooperation secret. Spontaneous collaborations are thus more compatible with the preservation of secrecy, often required for highly strategic activities. This does not mean that EU-sponsored project never concern strategic, core competences, but simply that, *compared to spontaneous collaborations*, they are more likely to concern peripheral activities. The previous discussion is synthesized in Proposition 1.

Proposition 1: *The disclosure of information imposed by EU programmes induces that, compared to spontaneous privately funded collaborations:*
(i) FP projects should be characterized by a longer term R&D horizon
(ii) FP projects should concern more the peripheral activities (and less the core competences) of the participating firm.

[3] For a similar argument on the effects of the lack of confidentiality of EU sponsored projects, see Luukkonen (2002).

Let us consider now issues connected to the presence of a subsidy. Government-sponsored collaborations benefit from public funds, which, from a social point of view, should not represent a substitute for private ones, but a complement (David et al., 2000; Bozeman and Dietz, 2001). We should bear in mind that firms, at least large ones, generally do not pursue a single research project but manage a portfolio. The opportunity to benefit from subsidies may influence the type of projects which are undertaken.

More precisely, the decision to finance research collaborations with public instead of internal funds is closely related to the exploration/exploitation dilemma. Returns to exploitation are usually better known, more certain and less remote in time, because of their proximity to the current knowledge base of the firm. Thus exploitation activities attract more easily the company's resources than exploration activities. Exploration typically requires some kind of organizational slack (in the sense of Cyert & March, 1963) or additional resources. In line with these ideas, we suggest that the more the collaboration is oriented toward exploitation, the more the company will be prompted to invest on its own. By contrast, EU funding provides additional resources for exploring and opening up *new technological options*. The company is able to carry out R&D it would not have undertaken (or not to that extent) otherwise.

We do not mean that spontaneous R&D collaborations are confined to pure exploitation. They entail exploration but they are more likely to concern investigations about *previously selected options*, closer to current activities of the company. To some extent, FP collaborations are more exploration oriented and spontaneous private funded collaborations are more exploitation oriented, hence Proposition 2.

Proposition 2: *Since subsidies provide additional resources to open up new technological options, EU-sponsored collaborations should be more exploration-oriented. By contrast, since companies are more prompt to invest internal funds in exploitation activities, spontaneous collaborations should be more exploitation-oriented.*

1.2. Coordination issues in R&D collaborations

We now turn to the rules guiding the division of labour between the partners. A short review of the literature leads us first to distinguish between formal and informal rules, i.e. contractual terms versus coordination routines. We then identify the specific coordination mechanisms of EU-sponsored collaborations.

1.2.1. Coordination of R&D collaborations in the literature

Transaction cost economics is probably the most widely-used approach to explain the comparative advantages of inter-firm collaborations as modes of governance (Williamson, 1979). This literature highlights a dilemma caused by the necessity to cope simultaneously with opportunism and uncertainty. Writing down contractual terms can reduce opportunism, but diminishes flexibility. On the contrary, relying on informal mechanisms preserves flexibility but opens the door to opportunistic behaviour.

This dilemma can be applied to the internal coordination of R&D collaborations as follows: On the one hand, the coordination and division of labour can be obtained through formal, detailed contractual terms and safeguards, specified through a costly negotiation process. But this formal specification of the allocation of the tasks, obligations, and outcomes for each party can be very rigid and thus inefficient in a quickly changing context. In particular, a too-detailed description of the division of labour between partners can impede learning processes. On the other hand, agreements based on routines, trust and informal coordination processes make the filling of the contractual gaps less necessary. They are more likely to preserve the flexibility of the tasks at hand, but they need time and a favourable climate to emerge, since they are built on past behaviour.

As a consequence, a first step of reciprocal commitment, formal contractual safeguards and/or exchange of hostages (Williamson 1985) can be necessary in order to provide a stable window for the future (Bureth *et al.*, 1997). This first step may prevent the occurrence of destructive conflicts arising from opportunistic behaviour. Reference to the formal document will be less and less necessary as the collaboration evolves and grows through time. Informal rules and relational capital (Palay, 1984; Kale *et al.*, 2000) progressively substitute for formal explicit contractual terms (Ring & Van de Ven, 1994). The emergence of relational capital and tacit collective routines requires intense, frequent and face-to-face interactions between the participants (such as those occurring through the creation of a joint facility). Note that this effective communication is also a prerequisite for the activation of radical learning processes.

1.2.2. Coordination issues in EU-sponsored collaborations

FP collaborative projects show strong peculiarities in terms of coordination mechanisms, most of which are imposed by the design of the European program itself. First, EU framework programmes often impose minimum rules to be abided by the partners. For instance, research contracts must specify the allocation and coordination of tasks: definition of work packages, allocation of funds, duration and milestones of the collaborative agreement, etc. Moreover the partners should agree on the results and/or property rights. This pre-defined framework makes coordination easier and contributes to build communication channels. It helps to set up the initial conditions of the collaboration and constitutes an important factor diminishing misunderstandings and destructive conflicts.

In most spontaneous R&D collaborations, partners first have to elaborate and agree upon the kind of rules to be used. This confers the partners a higher degree of freedom and flexibility. Ability to reorient the project content can be better preserved, allowing partners to cope with unanticipated events or to seize new opportunities. But flexibility and informal coordination have a counterpart. This additional degree of freedom may cause hazards and misunderstandings. This may explain the high, well-documented failure rate of inter-firm collaborations (i.e. premature termination of cooperation).

The second feature of EU framework programmes is the existence of an arbitrator, i.e. a public supervisor in charge of the management and control of the programme. The presence of this agent favours the *ex ante* reduction of opportunism and the stability of the project[4]. For instance, in case of non-enforcement of the agreed rules by one of the parties, the arbitrator can solve the problem by using some credible threat (e.g., no more subsidies, exclusion from the project). In spontaneous collaborations, there is generally no official arbitrator and the partners are left to their own devices to solve the conflict. Asking a third party (very often lawyers and courts) to intervene is usually an expensive solution that does not preserve the continuity of the relationship. The joint influence of pre-defined rules and of the arbitrator is summarized in Proposition 3.

<u>Proposition 3:</u> *Due to the existence of pre-defined rules and of an arbitrator, FP collaborative projects should be:*
(i) less likely to experience destructive conflicts, compared to spontaneous collaborations, but also
(ii) less likely to preserve flexibility, i.e. the ability to reconfigure quickly the project content.

The supervision structure of EU programmes together with the *ex ante* specification of rules entail additional rigidities (besides the previously mentioned lack of flexibility): they are associated with high bureaucratic costs. Compliance to tight monitoring procedures (recurrent reporting, financial and other types of justifications, red tape, etc.) is a time-consuming activity, especially for SMEs. This leads to Proposition 4.

<u>Proposition 4:</u> *Compared to spontaneous R&D collaborations, FP projects should suffer from higher administrative burden.*

Finally, it is worth mentioning another consequence of the existence of the aforementioned pre-defined rules. Part of these rules concern inter-partner coordination: the division of labour has to be specified e*x ante* through the definition of work packages, the partners have to organize a limited number of formal meetings, etc. These rules are only minimal requirements but may exert a strong influence on the effective organization of FP projects. Projects strictly complying with such coordination rules would probably adopt a kind of modular organization, each company being in charge of a rather autonomous work package and having only few interactions with the other modules. We do not contend that all FP projects conform to this extreme case. We simply suggest that these predefined coordination rules do not favour rich and intense interactions, as stated in Proposition 5.

Proposition 5: *Compared to spontaneous R&D collaborations, FP projects should be coordinated through weaker interaction modalities (e.g., meetings rather than joint research facility).*

The literature reviewed in 1.2.1. suggests that, because of this feature, FP projects may be a poor framework for stimulating effective radical learning. More intensive exchanges, like personnel mobility or the creation of a common research facility, might be a better stimulant for the collective creation of new knowledge.

To sum up this first section, we expect EU-sponsored collaborations to have the following characteristics. Compared to spontaneous R&D collaborations, they should: (1) be more likely to concern peripheral activities; (2) be oriented towards exploration rather than exploitation; (3) entail less conflicts and also less flexibility; (4) suffer from a higher administrative burden; (5) be coordinated through weaker interaction modalities. In the remainder of this paper, we examine whether this picture finds some empirical support in the case of the 5th and 6th EU Framework Programmes.

2. Data

The data comes from the 2007 Innovimpact survey[5], conducted within the scope of the EC "Innovation Impact project" (funded by the DG Enterprise). An interesting feature of the Innovimpact survey is that, in a specific part of the questionnaire, firms were asked to characterize the cooperative projects in which they engaged. The questionnaire distinguished between three types of cooperative projects. **Type 1** consists in Network of Excellence (hereafter, NoE) and Integrated Projects (hereafter, IP). These very large research-oriented projects involving a multiplicity of partners are rather peculiar EU instruments and have to be analysed separately from other EU-sponsored collaborations. **Type 2** regroups the other

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[4] For a more general discussion about the role of government agency in discouraging opportunistic behaviour in collaborative R&D, see Tripsas *et al.* (1995).

5 This paper is based on work (questionnaire building and preliminary data exploitation) conducted for the Innovation impact project, funded by the European Commission (DG Enterprise).

projects falling within the scope of the 5th and 6th Framework Programmes (FP5 and FP6, respectively). **Type 3** gathers together the cooperative projects exclusively funded from internal R&D budget i.e. the spontaneous, privately funded collaborations.

Firms were asked to characterize any project type in which they participated along the following incentive and coordination features: project cost (low/high), degree of scientific or technical risk (low/high), degree of commercial risk (low/high), scientific and technical complexity (low/high), R&D horizon (short/long term), distance from the core technological area (core/peripheral), type of technological strategy (exploration/exploitation), conflicts preventing project from going ahead (few/many), administrative burden (low/high), flexibility and ability to re-orient project (low/high), and intensity of interactions.

The Innovimpact survey sampled the population of European organizations which participated in at least one FP-funded cooperative project between 1998 and 2006. This period covers both FP5 (1998-2002) and FP6 (2002-2006). A representative sample of 54492 organizations (70% of which participated in FP5, and 30% in FP6) was invited to answer an online survey about the impacts of EU projects. 7098 questionnaires were returned (13.0% response rate). Out of these 7098 *organizations* participating in a European Programme, we identified 3379 *firms*. For the purpose of this study, we had to keep only firms that answered the questions relative to projects characteristics. By doing so, and after eliminating observations with missing, incomplete, or otherwise incoherent information, we obtained a final sample of 1405 firms (hereafter referred to as "firm sample").

Although this sample may seem very small indeed, our concern is elsewhere. We want to exploit the unique opportunity offered by this survey, in order to verify whether a particular project type is related to specific project characteristics (in accordance to our conceptual framework). To do so, we use this small firm sample to build a more substantial project sample, on which we conduct our econometric analysis. We are nevertheless concerned by how representative the firm sample is, and tried to make sure that it is not *too* biased.

We first examined some key variables: firm age / date of creation, firm turnover, number of employees, and R&D expenditures. A quick glance at Table 1 reveals that the mean and standard deviation of these variables are quite close in the original database and in the selected sample. We can therefore consider the firm sample to be fairly representative of the original set of 3379 firms in terms of age, turnover, number of employees, and R&D.

TABLE 1 ABOUT HERE

We also examined the distribution of firms across industries (defined using our most reliable indicator, which is a very aggregated, 4-category variable). After cleaning, we find that the respective proportions of firms operating in the research and services sectors are roughly the same in the original dataset and in the firm sample (see Table 2). The proportion of manufacturing firms, however, is slightly more important in the sample than in the original dataset, whereas the proportion of "other" firms is less important.

TABLE 2 ABOUT HERE

Based on these statistics, we can reasonably consider that the firm sample is representative enough (of firms participating in European FP) for the purpose of our study. The reader should keep in mind that our main objective is not to conduct a firm-level analysis, but to compare different types of projects using unique project-level information. The empirical literature on FP generally relies on firm-level information to explain the propensity to collaborate in R&D (e.g., Hernan, Marin and Siotis, 2003; Marin and Siotis, 2008). Exceptions include Guy *et al.* (2005) and Polt and Streicher (2005), who provide descriptive statistics on the characteristics of FP projects. None of these strands of literature compare EU-sponsored R&D collaborations with spontaneous ones. Matt and Wolff (2004) sketch a comparison government-sponsored and spontaneous R&D collaborations, but provide only anecdotal evidence based on case studies.

Starting from the firm sample, we built a database on 2983 typical projects (hereafter referred to as the "project sample"), each project being of a single type: Type 1 (NoE and IP), Type 2 (Other FP5 and FP6 R&D projects) or Type 3 (cooperative projects funded exclusively on internal R&D budget). The proportion of each project type in the sample is given in Table 3: each project type represents roughly 1/3 of our sample of projects, with Type 2 projects being slightly more represented.

TABLE 3 ABOUT HERE

3. Econometric Analysis

3.1. Modelling and estimation strategy

We conduct our econometric analysis on the dataset of 2983 typical projects described in the previous section. The dataset has a hierarchical structure: our unit of analysis is the typical project, and projects are nested within firms. For each typical project, we have information on project characteristics (including its type), and on the characteristics of the firm where the project took place. Let $Pr(y_{ijk} = 1)$ denote the probability that a typical project i, conducted in firm j, be of type k (with $k = 0, \dots, M$). We specify the link between this probability and its determinants as a multinomial Logit model:

$$(1) \qquad Pr(\, y_{ijk} = 1\,) = \frac{exp(\beta_k x_{ijk})}{\sum_{\ell=1}^{M} [1 + exp(\beta_\ell x_{ij\ell})]}, \quad k = 1, ..., M,$$

where x_{ijk} is a vector of explanatory variables and β_k its associated vector of parameters. In our application, k = 0, 1, 2 and category 0 ("Project *i* is a Type 3 project") is the reference category. We set k = 1 for Type 1 projects (NoE and IP) and k = 2 for Type 2 projects (other FP5 and FP6 projects). Note that Model (1) allows the probability $Pr(y_{ijk} = 1)$ to depend on both project-specific characteristics and firm-level factors.

In our empirical specifications, the main explanatory variables are the project characteristics described in the previous section. We estimated two different specifications of the model: We first estimated a model in which we control for firm-level factors using (observed) firm-specific variables. Firm-level characteristics included in x_{ijk} are: size (number of employees), age, previous experience with European Framework Programmes, a 4-category indicator of industry, and indicators of innovation protection[6]. Summary statistics for both project-related and firm-related variables can be found in Table 4.

TABLE 4 ABOUT HERE

Alternatively, we estimated a multinomial Logit in which firm-specific variables were replaced by a firm-specific random-effect:

$$(2) \qquad Pr(\, y_{ijk} = 1\,) = \frac{exp(\beta_k x_{ijk} + \zeta_{jk})}{\sum_{\ell=1}^{M} [1 + exp(\beta_\ell x_{ij\ell} + \zeta_{j\ell})]}, \qquad k = 1, ..., M,$$

where ζ_{jk} denotes the firm-specific random effect for category k. The motivation for estimating this model is that the progress of a project may be affected by unobserved as well as observed firm characteristics. Using a firm-specific random effect in our multinomial logit model allows us to control for both observable and unobservable firm characteristics.

Both models were estimated by Maximum Likelihood. However, while the likelihood of Model (1) can easily be maximized, this is not the case with the likelihood of Model (2). Because this model includes a random effect, the likelihood must be evaluated using some approximation method. Here, we use a quadrature approach: the approximation of the likelihood is conducted by assuming a discrete distribution for the random effect (see Rabe-Hesketh and Skrondal, 2008, pp. 258-261, for more details about this approach). In other

[6] We also implemented a model in which the indicators of innovation protection were replaced by indicators of innovation activity. This alternative model yielded essentially the same results and will not be mentioned later on; full tables of results for the alternative model remain available upon request from the authors.

words, the random effect can have *R* possible values (called "quadrature points" or "points of support"), with *R* associated probabilities of occurrence. The approximation gets more precise as *R* increases. Empirically, we estimated Model (2) using the GLLAMM program developed by Rabe-Hesketh *et al.* (2004).

3.2. Results of the analysis

The results of the estimations for both multinomial Logit models are given in Table 5. Model (1) was estimated using conventional Maximum Likelihood, which allowed us to implement Hausman and Small-Hsiao tests of the IIA assumption; the IIA hypothesis was never rejected at any of the conventional levels of significance (the p-values of both tests are reported right after Table 5).

Model (2) was estimated using the quadrature approximation technique described in Section 3.1. We first estimated Model (2) using 4 points of support for the distribution of the random effect. This first estimation converged, yielding parameter estimates that we used as starting values for a second estimation using 8 points of support. This second estimation also converged, and we used the estimates as starting values for a final estimation using 12 points of support. We stopped at 12 points of support because the change in the estimates was remarkably small, which suggests a good quality of the quadrature approximation.

Since the likelihood of Model (2) is approximated, we did not perform tests of the IIA assumption for this model. However, the results obtained with Model (2) are so close to those obtained with Model (1) that we can be fairly confident as far as the validity of the IIA assumption is concerned. Indeed, both models yield estimates that are very similar in terms of both significance and magnitude. In particular, we find strong correlations between the type of a project and its characteristics. We focus the discussion below on these results.

TABLE 5 ABOUT HERE

EU-funded projects (be they of Type 1 or Type 2) have characteristics that are clearly different from spontaneous collaborations (i.e. Type 3 projects, our category of reference). First of all, the probabilities that a project be of Type 1 or of Type 2 (rather than Type 3) are both associated with a lower commercial risk; in other words, both types of EU-funded projects involve a lower commercial risk than spontaneous collaborations.

The parameter estimates for the "Short-term R&D" and "Close to the core technological area" variables are both significantly negative for Type 1 and for Type 2 projects. These results mean that both types of EU-funded projects (1) involve long-term rather than short-term R&D, and (2) concern peripheral technological activities (rather than activities that are close to the core technological area of the firm). Both results support our Proposition 1, stated in Section 1.1.2.

Both Type 1 and Type 2 projects are also associated with the exploration of new technological options rather than with the exploitation of existing technological strategies. This result supports our Proposition 2, stated in Section 1.1.2. The parameter estimates for the "Low flexibility" variable are significantly positive for both Type 1 and Type 2 projects. EU-funded project are therefore less flexible, on average, than spontaneous collaborations. Moreover, the probability that a project be of Type 2 is negatively associated with the "Many or frequent conflicts" variable: FP projects (outside of NoE and IP) therefore entail less frequent conflicts than spontaneous collaborations. Taken together, these results support (partially, at least) our Proposition 3, stated in Section 1.2.2.

The parameter estimates for the "Low bureaucratic burden" variable are significantly negative for both Type 1 and Type 2 projects: both types of EU-funded projects therefore involve a higher bureaucratic burden and more red tape than spontaneous collaborations. This result supports our Proposition 4, stated in Section 1.2.2. Finally, a look at the "Intensity of interactions" variable shows that personnel mobility and the creation of joint team are less likely to occur than frequent meetings. In other words, the main mode of interaction in EU-funded projects is through frequent meetings: stronger and more binding modes of interaction (such as the creation of joint teams) are uncommon. These results bring some support to our Proposition 5, stated in Section 1.2.2.

In a nutshell, both Type 1 and Type 2 projects share similar characteristics, which correspond to those we expected from our thorough reading of the theoretical literature. Type 1 projects (NoE and IP) have an additional distinguishing feature: they also involve less technological risk. Overall, firm-level factors have little influence on the probability that a project be of a given type. Model (1) suggests, though, that Type 2 projects are more likely to occur in firms with low use of patents, whereas Type 1 projects are more likely to take place in firms relying on other means to protect their intellectual property. In Model (2), the predicted values of firm random effects ζ_{j1} and ζ_{j2} in Model (2) are not significantly different from zero. Again, this suggests that project characteristics prevail over firm-level factors: in other words, a given project type is more associated to specific project characteristics than to firm characteristics.

3.3. Robustness checks

The sampling rules for the Innovimpact survey implied to select firms that participated in at least one EU-funded project, under either FP5 or FP6. This means that some of the sampled firms conducted only EU-funded projects, whereas other conducted both EU-funded projects and spontaneous collaborations. This entails that spontaneous collaborations may be underrepresented in our project sample. In order to check whether this affects our results, we restrict our sample of 1450 firms to a sample of 930 firms doing both EU-funded projects *and* spontaneous collaborations (i.e., we drop firms that did not report any spontaneous collaboration). From this restricted sample of 930 firms, we built a (restricted) sample of 2410 projects. By doing so, we make sure that all of these projects took place in firms involved in both EU-supported projects and spontaneous collaborations.

We re-estimated Model (1) and Model (2) on this restricted project sample, again contrasting Type 1 and Type 2 projects with spontaneous collaborations (Type 3 projects, our category of reference). The results of these estimations are presented in Appendix 1. They are very similar to those reported and discussed in the previous sub-section. In particular, our key explanatory variables have the same estimated effects in terms of significance, sign, and magnitude: We find the same empirical evidence as before, supporting the five propositions stated in Section 1.

4. Policy implications

If the government-sponsored collaborations obey specific motivation and coordination features then it becomes necessary to revisit the rationales behind European Framework Programs. This is the objective of the present section.

4.1 Incentive issue

The market failure approach typically assumes that: 1) firms are symmetrical in terms of skill and knowledge, 2) sponsored firms share similar resources and cost-sharing is the main motive; 3) government-sponsored collaborations are equivalent to spontaneous ones. Public programmes are justified in areas where R&D collaboration improves welfare and firms do not cooperate spontaneously. The present research has led us to question these simplifying assumptions. For the sake of policy discussion, it is important to bear in mind that, beyond mere cost-sharing, there exists at least a second important driver of R&D cooperation: the need to access complementary knowledge. In that broader perspective, firms manage a portfolio of collaborative R&D projects, in which sponsored collaborations and spontaneous ones are clearly distinct in strategic terms.

The decision to enter into a certain type of R&D collaboration in a given technological area depends on the distance of the latter from the core competencies of the firm. Our econometric results show that an activity closer to the core has a higher probability to be managed with internal funds, whereas activities closer to the periphery can be managed by applying to FPs. Let us assume that firms are able to rank their projects in terms of strategic priority. Subject to monetary constraints, firms know which projects to carry out with certainty and with internal funds and which ones may need public subsidy. The former are close to the core, whereas the latter are close to the periphery: they are currently less strategic, though of importance for the future (i.e. they may open new valuable options).

This consideration has an important implication for the debate in terms of input additionality *versus* substitution. Input additionality exists when the State sponsors actions to which agents would not have dedicated resources on their own, provided these actions are welfare improving. By contrast, substitution corresponds to a situation of "waste" where public funds are used to support actions that would have been carried out spontaneously. If sponsored collaborations differ from spontaneous ones in strategic terms, then E.U programs should be explicitly dedicated to sustain peripheral valuable activities. They cannot claim to support highly strategic projects, since firms with a portfolio of projects will not ask the EU to fund their "close to the core" strategic projects. Strategic spontaneous projects tend to be privately funded – at least by large companies. Hence, substitution between strategic spontaneous projects and publicly-funded projects should not be a major issue. If substitution exists, it concerns basically peripheral activities. Waste and free riding occur when firms deliberately go to public programs to carry out unimportant, minor projects and have a "wait and see" strategy or a pure networking strategy. In other words, the policy maker's problem of substitution *versus* additionality should be turned into "opening new valuable options" *versus* "sustaining minor activities". Of course, this supposes that firms have a clear vision about the right options to open and are able to differentiate between (1) peripheral activities that might be considered as important for the future and (2) minor activities that will never become of importance. It also supposes that the State is able to select the technological options with a high "public" value (of social interest).

4.2. Coordination issue

Our econometric results show that the existence of pre-defined rules (1) diminishes the ability to reorient projects, (2) increases administrative burden and (3) induce weaker interactions between the partners. All these rigidities might heavily influence the direction of learning, and even impede learning and/or innovation.

For instance the rules related to the research agenda of the project (working packages, milestones, contribution of each partner, theoretical background, technological options,...) impose the determination of a precise division of labour and a minimum number of meetings. The project design thus implicitly supposes that each participant will work on its contribution in-house and will learn about the results of partners during the meetings. This resembles a modular organization, which presupposes by definition a well-suited, efficient predefined architecture. Only with this architecture is it possible to build each module (working package) independently from the others.

We may however question the relevance of an *a priori* rigid architecture and rules in the case of highly explorative projects, such as those undertaken within EU programmes. In such an uncertain context, more integrative work is necessary in order to generate interactive learning and, hence, valuable technological knowledge. The number of rules should be kept to a minimum in order to stabilize the initial conditions without constraining learning.

4.3. Redundant policy instruments

The results of the multinomial Logit model clearly shows that Type 1 (IP and NoE) and Type 2 (other FP5 and FP6) projects share similar characteristics, with only slight differences (Type2 projects exhibit less conflicts and Type1 lower technological risk). This similarity of both types of EU instruments (from the company point of view) was already documented by simple descriptive statistics (available upon request from the authors): indeed, the characteristics of the projects remain the same across firms of different type and size. They also remain quite similar between FPs, even though some instruments have changed from FP5 to FP6. The econometric analysis has essentially confirmed what the descriptive statistics only hinted at.

In terms of policy, the stability of this result suggests that there is no need to build complex instruments nor to introduce new ones at each new FP. On the contrary, keeping funding instruments simple and stable over different FPs would probably help to save part of the high costs of Programme administration, *via* learning effects and simplicity.

5. Conclusion

In this paper, we characterized theoretically the specific incentive and coordination properties of EU-sponsored R&D collaborations, as compared to spontaneous R&D collaborations. These properties were summarized in five propositions, stating that the former should: (i) focus on peripheral activities; (ii) be more exploration-oriented; (iii) reduce conflicts and opportunistic behaviour, but be prone to rigidities; (iv) entail a higher administrative burden and (v) use weaker modes of interaction. These propositions find strong empirical support in our econometric analysis, conducted on a sample of 2983 collaborative projects (including EU-sponsored collaborations as well as spontaneous ones).

Having identified distinctive features of EU-sponsored collaborations, we use them to derive important policy considerations concerning the additionality debate, the organizational design of EU-sponsored projects, and the variety of R&D policy instruments used. Regarding the latter, we argue that the variety of policy instruments may be too high, which may result in learning impediments. A further step in the research would be to identify more precisely the type of learning that can be activated through EU-sponsored collaborations, as well as the resulting patterns of evolution of these collaborations.

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Table 1: summary statistics in original firm dataset and cleaned firm sample

Variables	**Original dataset (3379 firms)**		**Cleaned firm sample (1490 firms)**	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev.*
Age	21.1	20.32	25.45	19.00
Date of creation	1986	20	1982	19.00
Turnover	2346.61	49244.64	1858.98	41678.13
# employees	2.91	1.54	2.78	1.53
RD expenditures	27.73	259.97	25.08	275.21

Table 2: breakdown of original firm dataset and firm sample by industry

Industry (2-digit NACE code)	**Original dataset (3379 firms)**		**Cleaned firm sample (1490 firms)**	
	Frequency	*%*	*Frequency*	*%*
Manufacturing	1894	56.05	926	62.15
Research	79	2.34	21	1.41
Services	717	21.22	346	23.22
Other	689	20.39	197	13.22
TOTAL	3379	100	1490	100

Table 3: breakdown of the project sample by type of project

Project type	**Frequency**	**%**
Type 1 (NoE and IP)	854	29.15
Type 2 (Other FP5 and FP6)	1129	38.53
Type 3 (privately funded only)	947	32.32
Total	2930	100.00

Table 4: summary statistics (project sample)

Variable	Mean	Std. Dev	Variable	Mean	Std. Dev
Project characteristics			**Firm characteristics**		
Type 1 project (y/n)	0.29	0.45	Size: < 10 employees	0.22	0.41
Type 2 project (y/n)	0.39	0.49	[10 - 50[	0.30	0.46
Type 3 project (y/n)	0.32	0.47	[50 – 100[	0.11	0.31
Project cost: Low	0.27	0.44	[100 – 250[	0.11	0.32
High	0.66	0.47	[250 – 500[	0.27	0.44
NA	0.07	0.26	Firm age	26.07	19.21
Technological risk: Low	0.24	0.43	Experience of FP	0.53	0.50
High	0.69	0.46	No experience of FP	0.39	0.49
NA	0.07	0.26	No answer	0.09	0.28
Commercial risk: Low	0.30	0.46	Use of patents: Low	0.37	0.48
High	0.60	0.49	High	0.51	0.50
NA	0.10	0.30	NA	0.12	0.32
Complexity: Low	0.11	0.32	Use of other IPR: Low	0.28	0.45
High	0.82	0.38	High	0.64	0.48
NA	0.07	0.25	NA	0.09	0.28
Short-term R&D	0.18	0.39	Use of secrecy: Low	0.14	0.34
Long-term R&D	0.74	0.44	High	0.80	0.40
No answer	0.07	0.26	NA	0.06	0.24
Close to core technological area	0.42	0.49	Use of lead time: Low	0.11	0.31
Peripheral	0.48	0.50	High	0.83	0.37
No answer	0.10	0.30	NA	0.06	0.24
Technological strategy: Exploration	0.34	0.47	Use of services: Low	0.11	0.31
Exploitation	0.57	0.50	High	0.82	0.39
No answer	0.09	0.28	NA	0.07	0.26
Conflicts during project: Few	0.48	0.50	Pace of renewal: Low	0.09	0.29
Many	0.37	0.48	High	0.81	0.39
No answer	0.15	0.36	NA	0.09	0.29
Administrative burden: Low	0.28	0.45	Retention of HR: Low	0.05	0.22
High	0.62	0.49	High	0.90	0.31
No answer	0.10	0.29	NA	0.05	0.22
Ability to reorient project: Low	0.27	0.44	Complexity: Low	0.11	0.31
High	0.64	0.48	High	0.83	0.38
NA or missing	0.09	0.28	NA	0.07	0.25
Intensity of interactions: None	0.03	0.16	Manufacturing	0.62	0.48
Only few	0.22	0.42	Research	0.02	0.12
Frequent	0.54	0.50	Services	0.22	0.42
Personnel mobility	0.05	0.23	Other	0.14	0.35
Joint team	0.12	0.32			
NA or missing	0.04	0.19			

Table 5: multinomial Logit model estimates

	Model (1) (includes firm-specific variables)				Model (2) (includes firm-specific RE)			
	Project type 1		Project type 2		Project type 1		Project type 2	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Constant term	0.55	(0.20)***	1.11	(0.19)***	0.48	(0.14)***	1.01	(0.13)***
Project Characteristics								
Project cost is:								
High (reference)								
Low	0.00	(0.14)	-0.12	(0.13)	0.00	(0.13)	-0.10	(0.13)
Information missing	-0.29	(0.36)	-0.26	(0.34)	-0.47	(0.33)	-0.46	(0.31)
Technological risk is:								
High (reference)								
Low	0.34	(0.16)**	0.14	(0.16)	0.32	(0.15)**	0.15	(0.15)
Information missing	0.03	(0.46)	-0.39	(0.44)	0.24	(0.42)	0.08	(0.40)
Commercial risk is:								
High (reference)								
Low	0.47	(0.14)***	0.40	(0.14)***	0.46	(0.14)***	0.39	(0.13)***
Information missing	0.29	(0.33)	0.18	(0.31)	0.21	(0.29)	0.23	(0.28)
Project complexity is:								
High (reference)								
Low	0.04	(0.19)	0.19	(0.18)	0.08	(0.19)	0.22	(0.18)
Information missing	0.09	(0.52)	0.24	(0.49)	-0.13	(0.47)	-0.07	(0.44)
Project involves:								
Long-term R&D (ref.)								
Short-term R&D	-0.94	(0.15)***	-0.71	(0.14)***	-0.92	(0.15)***	-0.62	(0.14)***
Information missing	-0.51	(0.42)	0.19	(0.38)	-0.24	(0.38)	0.22	(0.36)
Technological area:								
Peripheral (reference)								
Close to the core	-0.33	(0.12)***	-0.42	(0.11)***	-0.30	(0.11)***	-0.40	(0.11)***
Information missing	0.11	(0.30)	0.14	(0.28)	0.01	(0.28)	0.13	(0.26)
Technological strategy:								
Exploitation (reference)								
Exploration	0.41	(0.12)***	0.44	(0.11)***	0.41	(0.12)***	0.41	(0.11)***
Information missing	-0.12	(0.33)	-0.18	(0.32)	-0.09	(0.31)	-0.07	(0.30)
Conflicts:								
Few or rare (reference)								
Many or frequent	-0.11	(0.12)	-0.29	(0.12)**	-0.09	(0.12)	-0.32	(0.12)***
Information missing	-0.12	(0.21)	-0.29	(0.20)	-0.13	(0.20)	-0.27	(0.19)
Bureaucratic burden:								
High (reference)								
Low	-1.39	(0.12)***	-1.54	(0.12)***	-1.36	(0.12)***	-1.52	(0.11)***
Information missing	0.16	(0.28)	-0.29	(0.28)	0.15	(0.27)	-0.23	(0.27)
Project flexibility:								
High (reference)								
Low	0.89	(0.13)***	1.04	(0.13)***	0.84	(0.13)***	0.96	(0.12)***
Information missing	-0.35	(0.31)	-0.29	(0.30)	-0.26	(0.30)	-0.36	(0.29)
Intensity of interactions:								
Frequent meetings (reference)								
No meeting	-0.37	(0.24)	-0.96	(0.25)***	-0.35	(0.23)	-1.02	(0.25)***
Only few meetings	0.06	(0.14)	-0.14	(0.13)	0.08	(0.13)	-0.15	(0.13)
Personnel mobility	-0.50	(0.23)**	-0.77	(0.22)***	-0.58	(0.22)***	-0.78	(0.21)***
Joint team	-1.09	(0.17)***	-1.21	(0.16)***	-1.10	(0.17)***	-1.18	(0.16)***
Information missing	-0.38	(0.33)	-0.35	(0.31)	-0.30	(0.30)	-0.39	(0.28)

(Table 5 continued)	**Project type 1**		**Project type 2**		**Project type 1**		**Project type 2**	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Firm characteristics								
Size *(ref: [1 - 10[)*								
[10 - 50[	-0.21	(0.15)	-0.29	(0.14)**				
[50 – 100[	-0.15	(0.21)	-0.18	(0.20)				
[100 – 250[	-0.11	(0.20)	-0.23	(0.19)				
[250 – 500[	-0.20	(0.18)	-0.27	(0.17)				
Age	0.00	(0.00)	0.00	(0.00)				
Previous experience of FP:								
No (*reference*)								
Yes	0.12	(0.11)	-0.02	(0.11)				
Information missing	0.15	(0.21)	0.14	(0.20)				
Protection of innovation								
Use of patents:								
High (reference)								
Low	0.15	(0.13)	0.28	(0.13)**				
Information missing	0.17	(0.26)	0.51	(0.24)**				
Use of other IPR:								
High (reference)								
Low	-0.26	(0.14)*	-0.17	(0.13)				
Information missing	0.07	(0.28)	0.15	(0.26)				
Use of secrecy:								
High (reference)								
Low	-0.03	(0.18)	0.05	(0.17)				
Information missing	0.06	(0.32)	0.18	(0.29)				
Use of lead time:								
High (reference)								
Low	0.13	(0.20)	0.08	(0.19)				
Information missing	0.40	(0.29)	0.21	(0.28)				
Use of services:								
High (reference)								
Low	-0.06	(0.19)	-0.03	(0.18)				
Information missing	-0.12	(0.24)	0.02	(0.23)				
Pace of renewal:								
High (reference)								
Low	-0.01	(0.21)	-0.01	(0.20)				
Information missing	-0.03	(0.22)	-0.01	(0.21)				
Retention of qualified personnel:								
High (reference)								
Low	-0.05	(0.28)	0.10	(0.26)				
NA or missing	0.05	(0.30)	-0.11	(0.28)				
Complexity:								
High (reference)								
Low	0.19	(0.20)	0.13	(0.19)				
Information missing	-0.20	(0.30)	0.28	(0.27)				
Industry *(ref: manufacturing)*								
Research	0.10	(0.42)	0.16	(0.40)				
Services	0.04	(0.14)	0.14	(0.13)				
Other	-0.35	(0.19)*	-0.31	(0.18)*				
Log-likelihood	-2828.36				-2950.59			
LR test (102 d.f.) of global fit	656.29***				610.41***			
Pseudo R² (Mc Fadden R²)	0.10				0.09			

*** 1% level significance ** 5% level significance * 10% level significance

Test of I.I.A for Model (1):

The IIA assumption is not rejected by the Hausman test:

The p-value of the test of H_0: "$\beta_{1u} = \beta_{1c}$ if 2 excluded" is 0.779

The p-value of the test of H_0: "$\beta_{2u} = \beta_{2c}$ if 1 excluded" is 0.988

The IIA assumption is not rejected by the Small-Hsiao test:

The p-value of the test of H_0: "$\beta_{1u} = \beta_{1c}$ if 2 excluded" is 0.295

The p-value of the test of H_0: "$\beta_{2u} = \beta_{2c}$ if 1 excluded" is 0.263

Additional statistics for the firm-level RE in Model (2):

- Predicted mean of the random effects:

ζ_{j1} = -1.06×10^{-23} ζ_{j2} = -1.36×10^{-23}

- Covariance matrix:

$$\begin{pmatrix} \operatorname{cov}(\zeta_{j1}, \zeta_{j2}) & \sigma_{\zeta_{j1}} \\ \sigma_{\zeta_{j2}} & \end{pmatrix} = \begin{pmatrix} 2.34\times10^{-22} & 2.24\times10^{-22} \\ 2.87\times10^{-22} & \end{pmatrix}$$

where ζ_{jk} denotes the firm-specific random effect for multinomial logit alternative k.

- Correlation coefficient:

$\rho_{12} = \operatorname{corr}(\zeta_{j1}, \zeta_{j2}) = 0.93$

Appendix 1: robustness check - multinomial Logit model estimates on restricted sample

	Model (1) (includes firm-specific variables)				Model (2) (includes firm-specific RE)			
	Project type 1		Project type 2		Project type 1		Project type 2	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Constant term	0.23	(0.22)	0.64	(0.21)***	0.13	(0.15)	0.58	(0.14)***
Project Characteristics								
Project cost is:								
High (reference)								
Low	-0.02	(0.15)	-0.09	(0.14)	-0.03	(0.14)	-0.10	(0.14)
Information missing	0.13	(0.41)	0.07	(0.39)	-0.07	(0.37)	-0.06	(0.35)
Technological risk is:								
High (reference)								
Low	0.24	(0.18)	0.06	(0.17)	0.19	(0.17)	0.04	(0.17)
Information missing	-0.09	(0.56)	-0.40	(0.54)	-0.01	(0.51)	-0.04	(0.49)
Commercial risk is:								
High (reference)								
Low	0.48	(0.16)***	0.43	(0.15)***	0.46	(0.15)***	0.41	(0.15)***
Information missing	0.52	(0.36)	0.50	(0.35)	0.35	(0.32)	0.39	(0.31)
Project complexity is:								
High (reference)								
Low	0.19	(0.21)	0.20	(0.21)	0.15	(0.21)	0.22	(0.20)
Information missing	-0.28	(0.69)	0.04	(0.65)	-0.33	(0.61)	-0.14	(0.58)
Project involves:								
Long-term R&D (ref.)								
Short-term R&D	-0.87	(0.17)***	-0.73	(0.16)***	-0.85	(0.17)***	-0.69	(0.16)***
Information missing	-0.66	(0.51)	-0.29	(0.47)	-0.37	(0.45)	-0.22	(0.43)
Technological area:								
Peripheral (reference)								
Close to the core	-0.36	(0.13)***	-0.44	(0.12)***	-0.33	(0.13)***	-0.45	(0.12)***
Information missing	0.08	(0.34)	-0.06	(0.33)	0.04	(0.31)	-0.11	(0.31)
Technological strategy:								
Exploitation (reference)								
Exploration	0.50	(0.13)***	0.52	(0.12)***	0.49	(0.13)***	0.50	(0.12)***
Information missing	-0.17	(0.39)	0.08	(0.37)	-0.23	(0.37)	0.09	(0.35)
Conflicts:								
Few or rare (reference)								
Many or frequent	-0.01	(0.13)	-0.15	(0.13)	-0.01	(0.13)	-0.19	(0.13)
Information missing	0.09	(0.22)	-0.16	(0.22)	0.06	(0.21)	-0.15	(0.21)
Bureaucratic burden:								
High (reference)								
Low	-1.49	(0.14)***	-1.50	(0.13)***	-1.45	(0.14)***	-1.48	(0.13)***
Information missing	0.12	(0.31)	-0.05	(0.31)	0.07	(0.30)	-0.05	(0.30)
Project flexibility:								
High (reference)								
Low	0.85	(0.14)***	1.09	(0.14)***	0.80	(0.14)***	1.04	(0.13)***
Information missing	-0.25	(0.34)	-0.52	(0.34)	-0.11	(0.33)	-0.51	(0.34)
Intensity of interactions:								
Frequent (reference)								
None	-0.17	(0.26)	-0.83	(0.28)***	-0.17	(0.25)	-0.88	(0.27)***
Only few	0.17	(0.15)	-0.15	(0.14)	0.15	(0.14)	-0.17	(0.14)
Personnel mobility	-0.52	(0.25)**	-0.76	(0.24)***	-0.60	(0.24)**	-0.73	(0.23)***
Joint team	-1.08	(0.20)***	-1.38	(0.19)***	-1.08	(0.19)***	-1.37	(0.19)***
Information missing	-0.43	(0.38)	-0.33	(0.35)	-0.34	(0.34)	-0.34	(0.32)

	Project type 1		Project type 2		Project type 1		Project type 2	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Firm characteristics								
Size *(ref: [1 - 10[)*								
[10 - 50[	-0.09	(0.17)	-0.05	(0.16)				
[50 – 100[	-0.01	(0.23)	0.03	(0.22)				
[100 – 250[	0.05	(0.22)	-0.02	(0.22)				
[250 – 500[	-0.03	(0.20)	0.02	(0.19)				
Age	0.00	(0.00)	0.00	(0.00)				
Previous experience of FP:								
No (*reference*)								
Yes	-0.09	(0.13)	-0.13	(0.12)				
Information missing	0.07	(0.24)	0.06	(0.23)				
Protection of innovation								
Use of patents:								
High (reference)								
Low	0.08	(0.14)	0.10	(0.14)				
Information missing	0.15	(0.30)	0.17	(0.28)				
Use of other IPR:								
High (reference)								
Low	-0.17	(0.15)	-0.10	(0.14)				
Information missing	-0.08	(0.33)	0.15	(0.31)				
Use of secrecy:								
High (reference)								
Low	-0.19	(0.20)	0.10	(0.19)				
Information missing	0.11	(0.38)	0.18	(0.35)				
Use of lead time:								
High (reference)								
Low	0.15	(0.22)	0.06	(0.22)				
Information missing	0.10	(0.34)	-0.11	(0.33)				
Use of services:								
High (reference)								
Low	-0.03	(0.21)	-0.11	(0.20)				
Information missing	-0.20	(0.27)	-0.11	(0.26)				
Pace of renewal:								
High (reference)								
Low	-0.13	(0.23)	-0.12	(0.22)				
Information missing	-0.13	(0.25)	0.00	(0.24)				
Retention of qualified personnel:								
High (reference)								
Low	0.03	(0.31)	0.21	(0.29)				
NA or missing	-0.09	(0.35)	-0.19	(0.33)				
Complexity:								
High (reference)								
Low	0.04	(0.23)	0.08	(0.22)				
Information missing	-0.17	(0.34)	0.14	(0.31)				
Industry *(ref: manufacturing)*								
Research	0.19	(0.46)	0.28	(0.45)				
Services	-0.15	(0.16)	0.01	(0.15)				
Other	-0.28	(0.20)	-0.18	(0.19)				
Log-likelihood	-2263.89				-2344.43			
LR test (102 d.f.) of global fit	570.80***				562.76***			
Pseudo R^2	0.11				0.11			

*** 1% level significance ** 5% level significance * 10% level significance

Test of I.I.A for Model (1):

The IIA assumption is not rejected by a Hausman test:

The p-value of the test of H_0: "$\beta_{1u} = \beta_{1c}$ if 2 excluded" is 0.988

The p-value of the test of H_0: "$\beta_{2u} = \beta_{2c}$ if 1 excluded" is 0.990

The IIA assumption is not rejected by the Small-Hsiao test:

The p-value of the test of H_0: "$\beta_{1u} = \beta_{1c}$ if 2 excluded" is 0.623

The p-value of the test of H_0: "$\beta_{2u} = \beta_{2c}$ if 1 excluded" is 0.479

Additional statistics for the firm-level RE in Model (2):

- Predicted mean of the random effects:

$\zeta_{j1} = 6.53\times10^{-17}$ $\zeta_{j2} = 6.20\times10^{-17}$

- Covariance matrix:

$$\begin{pmatrix} cov(\zeta_{j1},\zeta_{j2}) & \sigma_{\zeta_{j1}} \\ \sigma_{\zeta_{j2}} & \end{pmatrix} = \begin{pmatrix} 1.09\times10^{-14} & 3.90\times10^{-15} \\ 4.85\times10^{-14} & \end{pmatrix}$$

where ζ_{jk} denotes the firm-specific random effect for multinomial logit alternative k.

- Correlation coefficient:

$\rho_{12} = corr(\zeta_{j1}, \zeta_{j2}) = 0.79$