Market, Firm, and Project-level Effects on the Innovation Impact of FP RTD Projects*

Nicholas S. Vonortas**

ABSTRACT

This paper explores the determinants of the innovation impact of publicly funded R&D projects along three broad dimensions, namely project, firm and market-related factors. In addition to these factors we examine the attributes of the research result per se and aspects of the commercialization process. The observations from empirical and qualitative analyses are based on R&D projects funded by the Fifth and Sixth Research Framework Programmes of the European Union. Firm size, prior experience, innovation culture, the nature of the project itself, explicit intension to commercialize, consortium management and strategy are the factors with the strongest effect on project success, defined in terms of product/process innovation and/or technical knowledge creation. The paper provides important implications for the organization, objectives, and management of public programmes that fund R&D and for project and participant selection.

KEYWORDS: Framework Programme, impact assessment, public R&D project, commercialization

1. INTRODUCTION

A swath of studies over the past couple of decades have underlined a widely held impression that the Research Framework Programmes of the European Union have played an important role in developing the European knowledge base and have pointed at significant levels of additionality and Eu-

* This paper draws extensively on Wolfgang Polt, Nicholas Vonortas, and Robbert Fisher (2008) "Innovation Impact: An Analysis of the Impact of Publicly Funded FP5 and FP6 Projects on Innovation.", Final Report, DG Enterprise, European Commission, Brussels, chapter 5.

** Director, Center for International Science and Technology Policy, International Science & Technology Policy Program, The Elliot School of International Affairs, The George Washington University, vonortas@gwe.edu

ropean added value.[1] Much lesser agreement exists on the extent and type of direct contribution to the performance, especially in terms of innovation, of the organizations participating in the research projects funded by those programmes. While it should be stressed that the production of potential commercial products and services has never been the core mission of the Framework Programmes, there is a strong interest in intensifying the connection between EU-funded research activity and innovation. Closer connection, it is argued, will help achieve the Lisbon objectives of enhanced international competitiveness, employment, and social welfare.

Even though R&D is a core activity and a starting point (albeit not the only one) for innovation, the link between the two is not straightforward. The commercial exploitation of research results stemming from an R&D project is a complex process governed by a multitude of factors, including the internal dynamics of the project itself, the motives and the innovation-related capabilities of the participants in the project and the characteristics of the market environment towards which the prospective innovation is directed (Sakakibara, 2002; Rothaermel and Deeds, 2004).

This paper reports the results of an extensive research effort to explore those complex links by examining the factors underlying the innovation impact of collaborative research and development (R&D) projects under the Fifth and Sixth Framework Programmes (FP5, FP6)[2]. The innovation impacts of publicly funded R&D projects were examined along three broad directions, namely market, firm, and project-related factors (Doz, 1996; Hagedoorn and Roijakkers, 2006). The basic proposition for investigation was that: (a) the ways a project is managed; (b) the resources, experience and capabilities of partners; (c) market conditions; (d) the character of the commercialization effort and problems confronted during the process; and (e) the nature of the technology resulting from the project significantly affect the innovation impacts of FP-funded R&D projects.

To explore and test this proposition we utilized both quantitative and qualitative analyses. The former was based on survey responses regarding collaborative R&D behavior and outcomes collected through massive data collection effort in a pan-European scale for the purposes of the InnoImpact study (see other references in this special issue). The field survey consisted of two questionnaires, one for industrial firms and one for research organizations (i.e. universities, research institutes, etc) that were known (through the CORDIS database) to have been involved in FP5 and/or FP6. Qualitative information was based on a large number of case studies of individual project participants.

The remainder of this paper is organized as follows: the next section presents some basic concepts and sketches out the research model of the study. The third section provides an overview of the results of the quantitative analysis. The fourth section does the same for the qualitative analysis. Finally, the last section synthesizes the results and concludes.

[1] "Five-Year Assessment of the European Union Research Framework Programmes.", DG Research, 2004 and 2009.

[2] See footnote 1. Note that due to space limitations we refrain from the presentation of methodological details for both the quantitative and qualitative analyses. We rather concentrate on the presentation of research results. The interested reader in the analytical methodology and detailed variable exposition can consult the (extended) final report and other documents of the InnoImpact study from the website and from the authors of this paper.

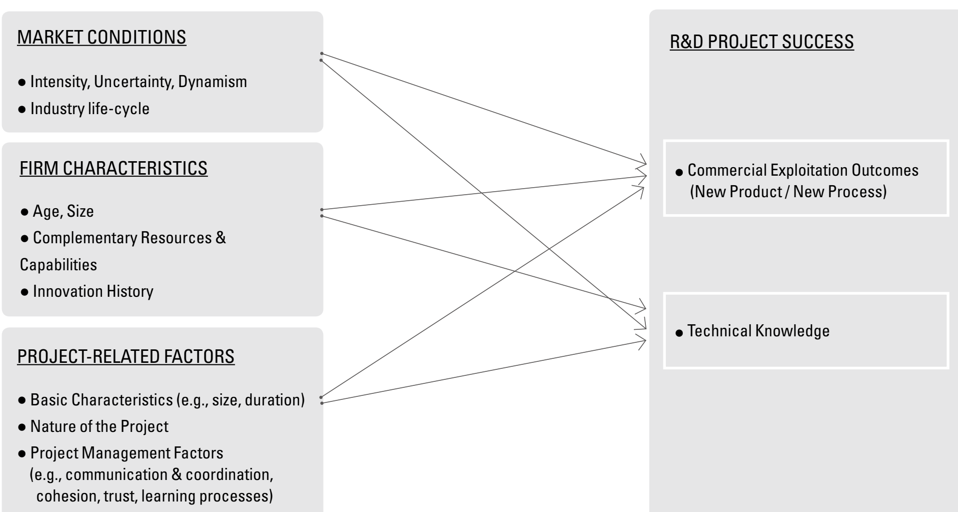
2. BASIC CONCEPTS: INNOVATION IMPACT, PROJECT SUCCESS

Innovation impact is conceived to consist of commercially exploited outputs (products, services, production processes) and the technical knowledge obtained by the responding organization as a result of its involvement in a specific cooperative R&D project. Taken together, product/process innovation and/or the creation of new technical knowledge will be considered to constitute project success. We examine the determinants of project success along the dimensions of market, firm, and project-related factors. We also examine the effects on project success of attributes of the research result per se and of aspects of the relevant commercialization process.

Project-related factors refer to "structural" features, such as the thematic area of a given project, the size of the consortium that has undertaken the research work, and management aspects of the project. The latter include social and behavioural features in the management of the project team, such as communication, coordination mechanisms, and team learning (Edmondson, 1999; Mathieu et al, 2008). Moreover, in this category we include management rules and practices imposed by the Commission to govern the setup and workings of research consortia. Firm-related factors pertain to the resources, experience, and innovation-related competencies of the partners involved in the project (Damanpour, 1991; Ajuja and Katila, 2004). Included are factors such as firm size and age, previous experience in innovation activities, resources and skills for innovation, etc. Market-related factors involve the characteristics of the industry and market to which the partners in a research consortium belong. To the extent that market conditions are dynamic and highly competitive, a firm will be motivated to seriously engage in innovation activities as a way to confront market pressures, and therefore is more likely to commit resources toward the implementation of the joint R&D efforts as well as demonstrate strong interest in project success (Park et al, 2002). Finally, the likelihood that a project results in product or process innovation is also influenced by the character of the commercialization process, the ensuing difficulties and the attributes of the research result.

The following diagram schematically depicts the relations implied by the arguments given above.

FIGURE 1 Research Model



3. EMPIRICAL ANALYSIS AND RESULTS

Two separate questionnaires were developed, one for the participating industrial firms and another one for the research organizations (ROs) (universities, research institutes, etc.). Here, we concentrate on the results from the enterprise questionnaire. Both sets of data have been analyzed with similar methodologies (i.e., confirmatory factor analysis, logistic and OLS regression), however, and occasionally we may refer to the results from the RO sample as well. In total, 3379 enterprises across EU Member States provided data, whereas the second sample consisted of 1981 ROs. Both samples suffered from a very large proportion of missing data. As a result, the effective sample sizes used for the substantive analyses were much lower[3].

3.1 Variables

Project success (the dependent variable of the study) was conceptualized to comprise two dimensions: product or process innovation and technical knowledge creation. We measured innovation with two dummy variables, indicating whether the project resulted in product and process innovation. Technical knowledge creation was measured with a three-item Likert-type scale, measuring the significance of knowledge-oriented outcomes, such as development of tools and techniques, and prototypes. These outcomes embody knowledge of a technical nature that can provide the basis for further development leading (eventually) to commercialization. Concerning the independent variables (i.e., market, firm, and project-related factors), we utilized objective measures (e.g., for firm age or firm size), dummy-coded variables (e.g., for the use of patents), or Likert-type scales (e.g., for communication practices or learning processes)[4].

3.2 Results

We examined the effects of three sets of factors, namely: market related, firm related, and project related factors on project success (i.e., new product or process innovation, and technical knowledge). The impact of the three sets of factors on product/process innovation was assessed using logistic regression analysis, whereas their impact on the production of technical knowledge was assessed using ordinary regression (OLS)[5]. The results presented here are based on the three different dependent variables of the study, namely: product innovation, process innovation, and technical knowledge.

Product Innovation: The most statistically significant factors influencing product innovation were the basic firm characteristics (marginally significant), the innovation history of the organization, the nature of the project, and the role of the respondent in the project (i.e., manager or producer or user of the technology) Among these, the nature of the project appears to be the one with the most signifi-

[3] Specifically, the effective sample size for the analysis of product and process innovation as dependent variables consisted of 280 observations, whereas for technical knowledge was 526 cases.

[4] The use of a single instrument (participant survey) to collect all variables poses the threat of common method bias. Harman's single factor test indicated that common method bias was not a serious issue in our data.

[5] Logistic regression was particularly appropriate since product and process innovation were measured through dummy-coded variables. Conversely, OLS regression was utilized for technical knowledge since this was measured through a Likert-type scale.

cant contribution. The lack of significant contribution of firm resources and capabilities and project management (as sets of variables) is notable.

The history of innovation protection through "complex" technologies was found to positively and significantly affect the odds of the project resulting in product innovation for the participant enterprise. It appears, therefore, that the more a firm utilizes "complexity of technology" and keeps qualified people in the firm as a general means to protect its innovations, the more likely it is to come up with product innovation as a result of its involvement in an FP project. Moreover, firms that have engaged in past intramural R&D were approximately 10 times more likely than other firms to produce product innovation in FP-financed R&D projects. This is a very strong result; in fact, it is the strongest coefficient found with respect to product innovation. It suggests that firm history in R&D activity, particularly in-house research, plays a key role in the development of product innovation. Moreover, as compared to firms with a history of FP-financed R&D activity, firms that participated in FP programme focal projects for the first time were found to be more than twice as likely to report project success in terms of product innovation.

Furthermore, the extent to which the set-up and rules imposed by the EC, regarding partners' selection and negotiations, are perceived as facilitating project success appeared to exert a positive influence on the likelihood for product innovation. This finding should not be interpreted to imply a causal relationship between EU rules and product innovation, but rather those firms with prior exposure the provisions and rules set by the Commission experienced no difficulty in this particular regard to achieve innovation. Additionally, projects having commercial objectives and projects considered risky were also found to be more likely to result in product innovation. In contrast, projects focusing on the exploration of "new" technological areas were significantly less likely to produce innovative products. We found support for the possibility of an inverted U-shaped relationship between innovation and the extent to which a project is risky or exploring "new areas". Our results suggested that projects driven and motivated by clear commercial objectives which are also not extremely risky were more likely to result in success in terms of product innovation.

Process Innovation: The most statistically significant factors affecting process innovation included industry effects (insignificant for product innovation), firms' innovation history, the role of the respondent in the project, and project management features. The nature of the project appeared to be the one with the most significant contributions, in agreement with the case of product innovation. The contribution of firm resources and capabilities on process innovation was not significant.

More specifically, firm size was found to be positively and significantly related to process innovation. Larger firms were somewhat more likely to engage in process innovation. A firm's capacity to "introduce new products speedily" was found to be negatively associated with process innovation. In contrast, the coefficient for "integration capabilities" was found positive and significant. In the extant literature on innovation, it is consistently argued that the capacity for integrating internal and external to the firm activities and functions is a critical prerequisite for implementing innovation. Our finding is clearly in line with this argument. Also, we found a significant and negative coefficient for "innovation protection through legal means". This variable refers to the use of patents and other IPR-related means for protecting the firm's innovative position. A possible explanation here is that patenting mostly refers to products that can be imitated by rival firms; in contrast, process innovation, which usually reflects tacit knowledge, is more difficult to imitate thereby decreasing the need for patent protection. Process innovation is also more difficult to be patented.

As with the case of product innovation, the set of variables reflecting a firm's "innovation history" is clearly the most important in explaining variation in process innovation. In particular, we found that a firm that has engaged in "extramural R&D" was about twice as likely to report process innovation because of its participation in the FP project. Similarly, we found strong positive coefficients for the "introduction of process innovation in the past three years", and for the "percentage of turnover from new/improved products introduced in the past three years". It is therefore reasonable to argue that firms experienced in innovation activities, both process and product innovations, are more likely to report process innovation as an outcome of the FP project. Interestingly, those firms that engaged in innovation activities by imitating others were found less likely to report process innovation. The final significant coefficient in this set is the positive effect of "first participation in FP". This is consistent with the result obtained for product innovation; there is strong evidence that "newcomers" in FP programmes are more likely to engage in projects that ultimately prove successful.

Regarding the nature of the project, those projects "building on past R&D activities" and those that are characterized as "new area" and "complex" were more likely to result in process innovation. Recall that, with respect to product innovation, we have evidenced that "risky" projects were more successful whereas "new area" projects were less likely to be successful.

Technical Knowledge: Technical knowledge is the other dimension of project success examined in this study. It represents an intangible output of an FP project, one that is indirect in the sense that its immediate consequence is not directly manifested in the market place. Nevertheless, such intangible knowledge can be very significant as it contributes to the participating firms' capacity for future innovation.

The factors with the greatest statistically significant effect on technical knowledge were "firm resources and capabilities" and the "nature of the project". Specifically, firm resources and capabilities as a set accounted for a relatively large proportion of explained variance (together with the "project nature" set). However, of the individual coefficients, only "legal means as a means for innovation protection" was found positive and significant. Regarding the nature of the project, several variables were statistical significant predictors of technical knowledge creation (e.g., a dummy variable indicating whether the project idea has been generated by industrial partners, the number of industrial partners in the consortium, variables indicating whether projects "built on past R&D activities", had clear "commercial objectives", or characterized as "risky").

Concerning project management effects, the coefficient of "clear project objectives" was found to be negative and significant. New technical knowledge creation is a complex process of exploration and discovery, where clear objectives set out from the beginning do not always prove valid or productive. Other significant coefficients indicated positive effects on technical knowledge of "cohesion and trust" and "learning processes" within the project team. Finally, in relation to market effects, and in contrast to product and process innovation, we found "dynamism" in customer preferences to have a positive influence on technical knowledge creation. Volatility in customer preferences appeared to induce the development of new technological knowledge. Table 1 summarizes the results of the quantitative analysis. For reasons of completeness, the last two columns report the obtained results for ROs.

TABLE 3 17 Results of Quantitative Analysis

Ind. Variables	Product	Process	Technical Knowledge	Product	Process
MARKET-RELATED					
Market environment: dynamism in customer preferences			+		
Emerging prospective field				-	-
FIRM-RELATED					
"Basic"					
Size class		+			
EU(27)				+	
"Firm's resources and capabilities"					
Capacity for "speed"		-			
Integration capability		+			
Innovation protection: legal means		-	+		
Innovation protection: "complex" technology	+				
"Firm's innovation history"					
Intramural R&D in the past 3 years	+				
Extramural R&D in the past 3 years	+	+			
Development of new or improved goods and services introduced in the past 3 years: (ROs sample only)					+
Creation of spin-off introduced in the past 3 years: (ROs sample only)					+
Product Innov (New-To-The-Market) introduced in the past 3 years: Industry / Patents introduced in the past 3 years: (ROs sample only)					-
Product Innov (New-To-The–Firm) introduced in the past 3 years: Industry / IPR introduced in the past 3 years: (ROs sample only)		-		-	
New Process Innovation introduced in the past 3 years: Industry / Award licenses to firms introduced in the past 3 years: (ROs sample only)		+			
Innovation performance (% turnover from new/improved products)		+			
First participation in FP? (yes/no)	+	+			
PROJECT-RELATED					
"Basic"					
FP - FP6 (vs.FP5)		+			
Proj_type					
Fraction - % of partners from industry			+		
"Eu rules"					
Practices in line with EU rules					+
EU rules' impact on: partner selection/negotiations	+		+		
"Nature" of the project					
IDEA - The project's idea comes from industrial partners (yes/no)			+		
PAST-RD - The project builds on past R&D activities (yes/no)		+	+		
Project objectives: commercial	+		+		
Project objectives: funding & reduce risk					+
Project objectives: "technological"				+	+
Project objectives: "networking"			-		
Nature of project: "risky"	+		+		
Nature of project: "new area"	-	+			-
Nature of project: "complex"		+			

Ind. Variables	Product	Process	Technical Knowledge	Product	Process
Role - Respondent is manager/ or user/ or technology producer (yes/no)	+	+			
"Project management"					
# of partners having worked with				+	
# of partners having not worked with				-	
Clear project objectives			-		+
Communication (within team)					-
Cohesion/Trust			+		
Learning within team: Intuition		-			
Learning within team: Interpretation			+		+
Learning within team: Integration					

3.3 Discussion and Conclusions

We hypothesized that market conditions, specifically the intensity of competition, the velocity of customer preferences, and the stage of the life-cycle of the relevant market at the time of the project would be significantly related to project success. We found limited support for these hypotheses. A plausible explanation is that the very nature of the projects undertaken in the Framework Programme is of the "technology-push" variety rather than "technology-pull". In other words, it may be that the typical project is driven by a promising emerging technology, usually in its very early stage of development, and for which there is no clear market opportunity for exploiting it, at least in the short to medium term. As such, the partners are driven by a motive to explore rather than exploit a technology, which presumably is not mature enough for prospective commercialization. In such circumstances market conditions may be largely "irrelevant".

With respect to basic firm characteristics, particularly in regards to age and size of the responding organization, we do find a significant and positive coefficient for firm size with respect to process innovation. The result may indicate that larger firms are more inclined to pursue process innovation, presumably as they have more pressing needs to optimize their large-scale productive operations.

We hypothesized that the extent to which a firm is endowed with innovation-related capabilities will be positively associated with the likelihood of reporting project success. Specifically, we hypothesized that capabilities connected with marketing, the ability to develop and introduce new products speedily, the capacity to integrate internal and external technological developments into the firm activities, and the firm's ability to protect its innovative position (through legal or competitive means, or by the very complexity of its technology) will positively influence the likelihood that the project does indeed result in success. We have not found statistically significant support for this hypothesis.

Regarding the coefficient of legal means of innovation protection, we find a negative coefficient with respect to process innovation and a positive one with respect to technical knowledge. The negative effect is perhaps explained by recognizing that process innovation, as highly idiosyncratic and tacit to the firm, does not need protection through legal means. In contrast, the positive coefficient is in line with expectations: firms having the resources and experience to protect their innovations through patents and other IPR-related legal means have the motive to pursue the development of technical knowledge, which they can subsequently protect from possible imitation in the hope they can develop it into a concrete product or process innovation. Finally, we find a significant positive coefficient for the effect of the capability to protect innovation through complex technology on product innovation. Being able to keep qualified people in-house and developing complex technologies that competitors find it difficult to imitate implies that the firm has valuable technological capabilities that would allow it to pick promising R&D projects to participate and contribute substantively towards their success.

We also hypothesized that a firm's experience with R&D and innovation-related activities (innovation history) will be positively associated to project success. We find support for this hypothesis. First, we observe that experience in both intramural and extramural R&D positively affects product innovation. Extramural R&D also positively influences process innovation. Past innovation performance, as manifested in the percentage of turnover attributed to new products introduced in "the past three years" also has a positive effect on process innovation (a positive effect on product innovation would be more likely, however). In addition, we observe that firms that have a history of imitation (i.e., introduction of new-to-the-firm products, as opposed to new-to-the-market innovations) are less likely to report process innovation. This implies that a "history" of imitation in fact inhibits the likelihood for project success.

A rather intriguing finding pertains to the positive effect of first-time participation in FP projects on both product and process innovation. One would be tempted to consider this to imply that "newcomers" are more motivated to drive FP projects to success. Whether the indirect implication that "getting too comfortable" with FP funding inversely affects the chances of project success is reasonable to consider needs to be balanced against the positive effects of past experience reported herein.

Regarding the effects of EU rules, we argued that their principal value is to allow the efficient and effective management and monitoring of a vast portfolio of projects by the EU authorities. At the level of the individual project, their value is to create an administrative platform, within which internal activities are developed, implemented, and monitored. These rules serve as the official mechanisms by which the project manager is made accountable to the sponsor. Accordingly, the positive coefficients found with respect to EU rules' impact on partner selection, negotiation on product innovation and on technical knowledge suggests that those partners that are comfortable with those kinds of rules are able to select the best possible partners, thereby increasing the odds of success.

The nature of the project appears to be a very important determinant of project success. First, projects that are driven by commercial objectives from the outset are found more likely to result in product innovation and to lead to technical knowledge creation. In contrast, projects aiming at networking seem less successful in terms of generating new knowledge. The nature of a project, in terms of being risky, exploring a new technological area, or being scientifically complex, influences project success in important ways. First, the degree of risk positively affects product innovation and knowledge creation, but, in both cases, the degree of project risk exhibits an inverse U-shaped relationship to the dependent variables: excessive risk appears to lead to diminishing returns as it relates to the likelihood for product innovation and knowledge creation.

Taken as a whole, our results provide support to the notion that the nature of a project affects, to an important extent, its subsequent success. We obtain strong evidence that projects which are commercially driven, risky, complex, and in new areas (for process innovation) tend to be more successful. Projects that build on past R&D activities are more likely to result in process innovation and to technical knowledge creation.

In contrast, the management aspects of project implementation appear to be less decisive to project success. This is somewhat puzzling and very much moderated in the next Section by our qualitative analysis results. More specifically, clear and agreed upon objectives are found to have a negative impact on technical knowledge. This may suggest that clear objectives from the very beginning of a project could leave little room for creative exploration and experimentation, thus limiting opportunities for novel results. In contrast, we estimate positive effects for cohesion and trust and interpretative learning on technical knowledge creation.

Limited support was also found for the effect of aspects of the commercialization process on project success, including issues of intellectual property protection. Similar results were found regarding basic project characteristics.

Finally, in relation to attributes of the technology resulting from a project, we find that the extent to which the technology resulting from a project is expected to have a relatively short life cycle and the extent to which it is distant (or unrelated) to the firm's existing stock of competencies there is a decreased likelihood of process innovation.

4. QUALITATIVE ANALYSIS AND RESULTS

4.1 Project-Level Characteristics for Project Success

Main Managerial Activities During Project Planning and Set Up: Case studies could distinguish between three types of participants (Yin, 2003; Eisenhardt and Graebner, 2007). Ad-hoc project participants are organizations where the strategic role of the EU funded RTD projects were rather insignificant. Focused project exploiters carefully evaluate opportunities in Framework Programmes and are characterized by a strong reputation in their technology field. Project coordinators, quite naturally, show a strong strategic alignment of their activities with the core subject of the project. They initiate a project idea, formulate a coherent proposal outline, and identify and contact appropriate partners with the objective of "setting a research agenda", "exploiting a new technology field" or "bringing a science-based innovation to the market". The coordinator has the opportunity to shape and implement projects with high degree of control and ownership. The coordinator should also mobilize resources in order to bring the project to a successful conclusion. The strategic criticality of the R&D project seems to be low in the case of ad-hoc participants and high for focused project participants and project coordinators.

Interviewed coordinators strongly emphasized the importance of project planning and set up so as to ensure a strong team committed to the common goals of the project. In spite of this fact, at the end of projects, almost all interviewees referred to some partners that were perceived as not having contributed relevantly and "seemed to have come along by accident". Successful projects shared a positive assessment of the capabilities of the coordinator both as R&D performer and as administrator. Each of these capabilities thus seems necessary but not sufficient for success, as there were cases where even such 'well-managed' projects failed at the level of innovation outcomes, due to e.g., insufficiency of the R&D results, rights conflicts between partners beyond the control of the coordinator or the project frameworks, or changing market conditions that rendered project outcomes obsolete.

Implementation: During the implementation of the RTD projects, the importance of project management cannot be underestimated. It refers to the continuous support and follow-up on the part of the coordinator with respect to the scientific and administrative obligations contracted between the project consortium and the EU. Particularly important factors, in a cross section of all case studies included immediate follow up on delays, pressure on partners not delivering, decisive exclusion of non-responding or dormant partners combined with efficient reallocation of resources, consistent and well anticipated preparation of all meetings and interactions, and operating with internal project quality managers who had an exclusive role of monitoring quality and progress. A perceived problem is the balancing act between performing R&D and simultaneously catering to the management obligations. The latter are not always a top priority, let alone a core competence of an R&D performer coordinator. Hence, project management was many times referred to as "weak" by interviewees leading to delays jeopardizing the intended return from the project.

Project Dissemination, Evaluation and Closure: Dissemination was seen with mixed feelings among the interviewees; from "a core activity" (research organizations) or "very important for image building" (among larger companies) or still "an opportunity to make ourselves known" (among SMEs), to "an activity without substance" or "a half-hearted and insufficient effort to reach a market" (firms irrespective of size). In parallel, very little information came out regarding evaluation and closure procedures. If at all referred to, interviewees declared that there is no real evaluation, no such thing as a formalized post-project evaluation to recount the pros and cons of the project.

Experience also varies widely with what actually happens after the project ends. Some partners decide to couple for further exploition of some of the results. In other cases, partners seem to roll the ball between them, expecting that the other party will take the next step towards some kind of follow on of the project efforts. In other cases still, the output of a project is exploited by a partner in collaboration with a third party. Thus, one could talk about a 'fuzzy back-end' of the EU RTD projects, as of the more established 'fuzzy front-end' of R&D (Reid and deBrentani, 2004). Only that the back-end fuzz is about confusion concerning the exploitation of the results and not about a breeding ground for creativity as in the front-end. In some instances, interviewees blamed the rules of the funding instruments for allowing for too much free interpretation about what a successful end of project phase means, and for allowing legal problems to surface too easily. The back-end fuzz is also the major reason behind the fact that even well-managed projects might 'stumble' towards the end and therefore result in no significant innovation impact.

4.2 Enabling and Inhibiting Factors for Project Success

Regarding project level enabling factors for effectively running the project and achieving its technical and commercial objectives, case analysis informed a number of issues, including:

- Strong customer involvement;
- Complementarity among partners;
- Core partners. Successful exploitation of results often materializes from the continued individual or collaborative action between such core partners;

To a large extent the inhibiting factors are the antipodes to the enabling ones. The cases did, however, identify a few stand-alone issues. In several of the less successful cases, managers emphasized the lack of market focus and market understanding as a dominant failure factor. Compared to research organizations, firm interviewees strongly emphasized the need for enhancing the exploitation part in the FP-funded RTD projects. This enhanced exploitation focus did not necessarily mean to emphasize commercialization of a new product or process coming directly out of the project. Rather it meant to, firstly, follow through and fulfil all those tests and applications that are contracted in the projects without making time and budget concessions, and, secondly, to integrate more market building activities in the projects. An R&D director in a large-sized company with a long and successful track record of innovation, suggested that if indeed commercialization of the outcomes and 'innovation impact' is part of the objective in a project's future foreseeable, then market scanning, market planning and market build-up activities must be fully recognized and integrated, in parallel, into the R&D process.

FP project rules impose a specific structure on all analysed project cases. Interviewees generally perceived these rules as complex and not easily integrated with "normal" project management processes. They also considered that the rules are more adapted to the situation of a research organization than to those of the private sector. Rules were reported to change frequently without a generally understood rationale for the change. The rules were said to be weak when it comes to support rights and protection issues. Finally, it was also more generally perceived that the EU rules put projects in a kind of straightjacket that in some cases acts unfavourably with respect to achieving the most relevant and significant results. On the other hand, this created a difficulty for adapting the project to changing circumstances beyond the control or reach of the original set up and rationale for the project.

4.3 Firm-Level Characteristics for Project Success

Planning & Set-up: Factors Related to Mission, Strategy and Goals: In general, successful projects were strongly characterized by clarity of mission for R&D, strategic alignment of the project, in particular (although not necessarily high strategic importance), and explicit goals of what the studied organizations expected from these projects.

In terms of mission, we found firms, especially SMEs, which developed and adhered to innovation-related missions. Most SMEs generally reported a strong strategic alignment with the project and explicit goals related to innovation outputs. In larger companies, mission was rarely referred to in the context of the EU FP projects. Generally speaking, and because of the often more marginal role of the projects, larger companies often reported weaker strategic alignment and less explicit goals. If goals were clear, they would typically be limited to the internal dimension of the projects, e.g., developing new knowledge or building partnerships. The role of missions in Research Organizations was much less apparent. Although it was difficult to relate it to innovation impact, strength of leadership was a distinguishing factor among research organizations. ROs with strong leadership, indeed, produced some successful projects in our sample, but so did ROs where this dimension was less apparent. What stood out was that some ROs operated with a close-to-firm type of leadership with strong mission statements, clear strategies, tangible and measurable goals, participative management, and gave importance to marketing and image building activities beyond the purely scientific dimension.

Implementation: Factors Related to Age, Size, and Resource Base: Analysts have typically grouped together the factors of age, size and resource base, with the conceptual correlation being that older means larger, which, in turn, means richer in resources relevant for conducting R&D. However, at least when it comes to companies, there was no perfect fit between this equation and the success of the EU-funded RTD projects. In particular, this concerns the size dimension.

Small-sized firms (<50 employees) often remain too focused on a core technology and too centred on research (compared to on development) in order to be able to sustain market-driven development and commercialization in their own right. Medium-sized firms (between 50 and 500 employees) seemed to be best positioned to reap innovation benefits from the projects. On the one hand, these organizations can have a critical mass in themselves for conducting both Research and Development in a focused area. On the other, they are often either established players in their industry or quickly growing ones that have overcome the threshold of successful commercialization of a first generation of innovation-based products or process technology. Generally speaking, these companies also have explicit strategies and goals for innovation; it is here that most of the "focused project exploiters" are found. Hence, these firms often take a leading role in projects, and are most frequently found as co-ordinators, in parallel with the Research Organizations.

Large-sized firms in our case study sample presented the least successful project participation from the point of view of product or process innovation. For reasons already mentioned, such as weaker strategic alignment, larger distance from core activity, objective of exploration and not exploitation, or lack of overview and internalized control, large firms either scope intangible outcomes or reported failure of the projects. The intangible outcomes might concern learning / knowledge / networking / pre-competitive control outcomes. Project failures seemed to relate to a combination of lack of strategy for the examined projects, poor internal integration, and poor engagement and commitment to the management procedures in the consortium. Cases of successful innovation among large companies in our set were identified when large R&D-driven organizations mobilized their resources and capabilities and engaged whole-heartedly in EU-funded RTD projects.

The issue of building up a broader innovation culture came out as an important underpinning factor behind product and process innovation success in some of the case studies (Hargadon and Sutton, 2000). It can be characterized as a set of shared values, beliefs and behaviour that guide the way that activities and process should function in order to gain competitive advantage from innovation at a moment 't', and that are reinforced and readapted dynamically in order to provide this advantage over time (moment t+1, t+2, ...). Several of the older companies indeed showed a long path of innovation-based growth and development.

In many of the case studies, the reputation of coordinators and/or partners as reliable, knowledgeable, cooperative and efficient managers and/or R&D partners was frequently advanced as a factor influencing positively project success. Either self-estimated by the interviewees, or attributed to other partners, this goodwill (or social capital; see Adler and Kwon, 2002) once it has been achieved, and as long as it can be sustained, provides a number of advantages to its possessors that also spill over to the collaborating partners and the project itself. These advantages include high probability of being granted relevant projects over time, strong bargaining power vis-à-vis the EU, relative ease in attracting excellent partners to new consortia, relative ease of making partners adhere and align to project objectives and management structures and relatively strong dissemination impact of results due to the presence and the weight of a prestigious-built-on-merit organization.

With very few exceptions, interviewees emphasized access to knowledge as a central reason for joining projects in the first place. Most of them were also quite satisfied with the knowledge output from the projects. However, it was not really possible to extract and conceptualize a learning capability adapted to the context of the EU-funded RTD projects. Good practice includes mainstream knowledge management activities such as rotation of personnel between the project and the normal duties in order to maximize the learning effect, setting and deploying explicit objectives of extracting knowledge from the projects, and activating resources and processes of technology scanning and watch in these projects as well. When learning from the projects was discussed, many interviewees referred to the importance of learning how to participate in the FP projects and adapt to the different rules and regulations. Organizations in the case sample that reported a greater satisfaction with the EU framework were also more successful innovators.

4.4 Dissemination, Evaluation and Closure

As already discussed, the extent to which commercialization is an issue and a goal within the FP RTD projects, from an institutional viewpoint, seems to be seriously questioned in the studied organizations. An intriguing finding from the case studies is that the organizations that are best positioned to commercialize an innovation, i.e., large firms with a full blown marketing and sales organization, were much less inclined to do so compared to a number of highly committed-to-commercialization SMEs. Hence, if the benefit that the projects could have from the participation of big companies are not fully leveraged, then commercialization process can turn out to be somewhat sub-optimized and progress (or not) with resources that are not at the height of the innovation to be commercialized. It was also striking that few interviewees referred to combining the outcome of the EU project with some other institutional, national or regional incentive for commercialization, such as seed or incubation money for start-ups or spin-offs. Many FP-funded projects seem to exist in quite some isolation and are not always integrated in a bigger R&D picture.

4.5 Industry and Market Characteristics for Project Success

Case studies distinguished among four classes of organizations:

1. Enterprises operating in monopolistic/oligopolistic markets with high technology/ innovation intensity. About one third of the case studies were in this class which encompasses enterprises in a wide range of sectors: from aerospace with satellite communications industries to optics with technical surface producers, from automotive safety to engineering of e-papers displays, from communication and information systems to manufacturing of aeronautical parts, from information and communication technologies to pharmaceutical, cosmetics and health products, from robotized automation systems to aero transportation management. With very few exceptions, the companies are large and typically produce non-standardized products.

These enterprises tend to be R&D-intensive with long experience with FP projects. The latter are perceived to decrease the cost of R&D, increase innovative opportunities, help monitor competitors and gain visibility. The long experience with EU funding of most these enterprises has created links between the projects in the different Framework Programmes (chains of FP projects). The few companies, especially the smaller ones that are not well experienced in FP projects, initially use European projects as networking opportunities. Consistent and direct commercial exploitation is rare amongst these companies. The low rate of direct innovative successes is pronounced in projects where direct competitors participate (horizontal collaboration).

2. Enterprises operating in monopolistic/oligopolistic markets with low technology/ innovtion intensity. Included here are companies in geographically localized markets or in mature highly concentrated markets. They represent the smallest share of the analyzed cases (less than one fifth of

the total). These enterprises belong to sectors with markets rather conservative and saturated. They range from those involved in environment services in waste management to rail transportation solutions, from lubrication automation to energy plants production, from process industry of paper and pulp to direct energy production. FP-funded R&D projects have a minor role in the overall company strategy, due to the marginal relevance of innovation in these sectors in general. Small enterprises that do not have experience with EU funding participate if the project is very close to the core business. In some cases an overweighting of public and European funding in the overall R&D investment strategy of the company can be observed. For most, FP projects have offered at least indirect gains such as networking opportunities, development of standards and creation of databases. Direct commercial exploitation is fairly unlikely, especially in projects with horizontal collaboration.

3. Enterprises operating in competitive markets with high technology/innovation intensity. These enterprises serve markets such as satellite navigation solutions, consultancy in IT solutions in banking and commerce, automation and robotics, software for industrial applications, quality and risk management services, advanced recycling technologies, laser technologies. They represent 29% of the analyzed cases. Standardization of products and services is low and customization relies on R&D added value. Many enterprises in this category show a strong involvement in Framework Programmes and a strategic role of EU funds in R&D process. The FP R&D funding is well integrated with the company research activity. FP projects are mainly carried out to make applied research and to exploit the innovative results coming from it. The opportunity of networking has a secondary role, especially for the largest firms. In many cases innovation and commercial output are concrete.

4. Enterprises operating in competitive markets with low technology/innovation intensity. About a quarter of the cases are enterprises in competitive markets with low technology and innovation intensity. Examples of these sectors are chemistry for surface protection of industrial components, telecommunications through private phone switchboards, injection plastic moulding presses, glass solutions for indoors and outdoors areas, surface processing, design and building of machineries for the automotive sector, industrial plastic products and prefabricated structures. Medium to long product life cycles and high product standardization characterize such sectors. Many of these organizations have a very close network of partners to collaborate with in research activities. In the case of the small part of enterprises that base their activity on R&D and have long experience in FP projects, the European projects have become a structural instrument of financing the company development, technological development through networking and acquiring qualified competences.

For the remaining enterprises in this class the FP projects funds are not part of an integrated research activity. For some, the EU-funded research is essentially the only type of research activity. For others with structured research shaped by market needs, the EU projects represents only an occasional instrument not primary devoted to fund research activities. In this class of enterprises a great number of projects have been successful in terms of product/process innovation, but a good part has not reached the commercial exploitation phases. Commercial exploitation occurred in cases more connected to the core activity of the company and in those cases involving end-users.

5. SUMMARY CONCLUSIONS

The empirical analysis provided very weak support for the proposition that market conditions strongly influence the various aspects of project success (product-process innovation, technical knowledge creation). A plausible explanation is that the very nature of the projects undertaken in the Framework Programme is of the "technology-push" variety rather than "technology-pull". In other words, it may be that the typical project is driven by a promising emerging technology, usually in its very early stage of development, and for which there is no clear market opportunity for exploiting it, at least in the short to medium term. As such, the partners are driven by a motive to explore rather than exploit a technology, which presumably is not mature enough for prospective commercialization. In such circumstances market conditions may be largely "irrelevant"6.

Another plausible explanation is that the measures used to capture market conditions in the survey were specified at an aggregate level not allowing for expressing the differences between and across sectors and technological trajectories. The analysis of case studies, for instance, indicated differences in behavior among enterprises in four types of markets. Companies operating in competitive markets with high technology/innovation intensity tended to make better and more direct use of FP projects in their commercialization plans. Many of enterprises in this category show a strong involvement in Framework Programmes and a strategic role of EU funds in R&D process. The FP R&D funding is well integrated with the company research activity. FP projects are mainly carried out to make applied research and to exploit the innovative results coming from it. In contrast, FP projects seemed much less directly linked to innovation plans and competitiveness for enterprises in other types of sectors. The reasons varied by the type of competitive situation and type of technology in the sector. For enterprises in monopolistic/oligopolistic sectors with high technology/innovation intensity, examples of direct and consistent commercial exploitation of FP project results are fairly rare even though these companies tend to be well experienced with FP projects. Exploitation, when it happened, was in niche markets. For enterprises in monopolistic/oligopolistic sectors with low technology/innovation intensity FP-funded R&D projects seemingly have a minor role in the overall company strategy, largely due to the marginal relevance of innovation in these sectors. For most such companies FP projects have offered at least indirect gains such as networking opportunities and development of standards, creation of databases. Direct commercial exploitation is fairly unlikely. Finally, for enterprises in competitive sectors with low technology/innovation intensity, the answers vary. In the case of the small part of enterprises, which base their activity on R&D and have long experience in FP projects, the European projects have become a structural instrument of financing the company's development, technological development through networking and acquisition of qualified competences. For the remaining enterprises of this class the FP project funds are not part of an integrated research activity.

The empirical analysis has also indicated a positive effect of firm size on process innovation, but

[6] Differences between sectors or broad thematic areas are expected, of course. For example, R&D projects in the IST programme are often considered to be closer to the market than, for instance, life sciences. Still, the variation within the IST programme is quite significant, with many projects looking at futuristic technologies or standards which are not directly applicable to the market.

not on product innovation or the production of technical knowledge from FP projects. This may indicate that larger firms are more inclined to pursue process innovation; presumably, as they have more pressing needs to optimize their large-scale productive operations.

Case study analysis showed a more variegated picture. SMEs reported a generally strong strategic alignment with FP projects and explicit goals related to innovation outputs such as developing a prototype, developing a patentable technology, or developing a complementary technology that will enhance competitiveness. Medium-sized companies seemed well placed to reap the largest innovation benefits from FP project participation, as these organizations can achieve critical mass for R&D in a focused area. They are often either established players in their industry or quickly growing players that have overcome the threshold of successful commercialization for a first generation of innovation-based product or process technology. Generally speaking, these companies have explicit strategies and goals for innovation. They often take a leading role in projects, and are most frequently found as coordinators, in parallel with Research Organizations. Small sized firms (<50 employees), on the other hand, often remain too focused on a core technology and too centred on research (compared to on development) in order to be able to sustain market-driven development and commercialization in their own right.

It is noteworthy that the organizations presumably best positioned to commercialize an innovation, i.e., that large firms with a full blown marketing and sales organization, were much less inclined to do so compared to a number of highly committed-to-commercialization SMEs. In larger companies, mission was rarely referred to in the context of the EU FP projects. Because of the often more marginal role of FP projects, larger companies often reported weaker strategic alignment and less explicit goals. If goals were clear, they would typically be very focused and limited to project dimensions such as developing new knowledge, building partnerships, or exploring a new technology area. Only exceptionally interviewees in larger companies referred to the external dimension of market-related goals.

A rather intriguing finding of the empirical analysis pertains to the positive effect of first-time participation in FP projects on both product and process innovation. One would be tempted to attribute this to greater motivation of “newcomers”. There is no reason to believe that they are systematically more capable of driving FP projects to success than repeat participants. Or, there may be a tentative link here with the size findings above: SMEs will, on average, tend to participate less, and many of them only once.

A strong empirical result is that prior experience of an organization with R&D, both intramural and extramural, positively and significantly affects the likelihood of obtaining product innovation from FP projects. Extramural R&D and past innovation experience also positively influence process innovation. Past innovation performance also has a positive effect on process innovation. In contrast, firms that have a history of imitative strategy (i.e., introduction of new-to-the-firm products, as opposed to new-to-the-market innovations) are relatively less likely to report process innovation. Overall, the results concerning the “innovation history” of both firms and research organizations largely confirm the hypothesis of a positive association between prior innovation experience and project success.

Case analysis corroborated this result by showing that building up a broader innovation culture was an important underpinning factor behind product and process innovation success. Firms with an explicit R&D / innovation structure and model proved more successful in producing innovation results.

The nature of the project appears to be a very important determinant of project success. Strong empirical evidence was obtained that projects that are commercially driven, risky, complex, and in new areas (for process innovation) tend to be more successful. A project idea generated by industrial partners positively affects knowledge creation. Projects that build on past R&D activities are more likely to result in process innovation and technical knowledge creation.

Experience with innovation activity, in terms of conducting both intramural and extramural R&D, was a common characteristic among case study organizations. From there and onwards, successful projects were strongly characterized by clarity of mission for R&D in general, strategic alignment of the project, and explicit goals of what the participating organizations expected from the project.

Both the empirical and the qualitative analysis showed a strong relationship between explicit intension to commercialize from the outset of the R&D project and project success. Yet, the extent to which commercialization is an issue and explicit goal within the FP RTD projects, from an institutional viewpoint, seems to be seriously questioned by a significant number of the interviewed organizations.

Dissemination was seen with mixed feelings among the interviewees. Opinions about dissemination ranged from "a core activity", or "very important for image building" or still "an opportunity to make ourselves known", to statements such as "an activity without substance", or "a half-hearted and insufficient effort to reach a market" (firms irrespective of size).

What happens after the research project ends varies widely. Some partners decide to 'couple' for further exploitation of some of the results without necessarily informing the other partners. In other cases there is indecision about who will roll the ball next. Other times EU project 'n' generates the conditions for a proposal for EU project 'n+1', which, if leading to accumulated knowledge or a further exploitation of the results, can be seen as a positive outcome of a project. In other cases still, the outcome of a project is exploited by one partner, in conjunction with some other organization that was not part of the initial project.

Before the project consortium splits up, it is critical that it draws out a plan for commercializing the outcome. Unfortunately, many projects end up in a kind of dead-end with respect to commercialization. The cases indicated a gap between an inability of companies to commercialize the project output due to a lack of full R&D chain control and an incapacity, or even strategic misalignment from the side of the research organizations, to enter into spin-off or spin-out activities. A potentially logical bridge over this gap would be the SME. But SMEs that had taken on this bridging role are weary of the risk involved. They call upon the larger companies to commit to the risk-sharing mechanism in the EU collaborative projects by providing access to specific internal resources, act as pilot market (i.e., customer) for the new product/process/service, or even financially support a spin-off activity. Many of the Research Organizations studies have also developed specific collaboration structures with SMEs. A critical issue that was also often mentioned as a party spoiler in commercialization was the unclear situation around intellectual property protection.

Case study interviewees emphasized the importance of management during the implementation of the R&D projects. They referred to the continuous support and follow-up on the part of the coordinator with respect to the scientific and administrative obligations contracted between the project consortium and the EU.

Successful projects shared a positive assessment of the capabilities of the coordinator, both as an R&D performer and as an administrator. Each of these capabilities seem necessary but not sufficient for success, as there were cases where even such well-managed projects failed at the level of innovation outcomes, due to e.g., insufficiency of the R&D results, rights conflicts between partners beyond the control of the coordinator or the frameworks of the instruments, or changing market conditions rendering project outcomes obsolete.

Interviewees indicated a wide disparity of motives for participation, which affect the likelihood of project success. Coordinators naturally show a strong strategic alignment of their activities with the core subject of the project. Non-coordinators vary widely in their motives to participate. Some vet the projects carefully, others join because they have known the partners from before, while others join with no real intention to connect the project to their core activities. The ability of the coordinator to align interests is critical.

Finally, the positive effect of EU rules on partner selection and negotiation were found to have on product innovation and technical knowledge does not imply that these rules have a direct effect on project success. It does, however, suggest that the organizations most comfortable with those kinds of rules are able to select the best possible partners, hence increasing the odds of success.

References

Adler, P. S. and S-W. Kwon. "Social capital: prospects for a new concept.", *Academy of Management Review*(2002), Vol. 27, pp. 17-40.

Ahuja, G. and R. Katila. "Where do resources come from? The role of idiosyncratic situations.", *Strategic Management Journal*(2004) Vol. 25, pp. 887-907.

Damanpour, F. "Organizational innovation: A meta-analysis of effects of terminants and moderators.", *Academy of Management Journal*(1991), Vol. 34, pp. 555-590.

Doz, Y. L. "The evolution of cooperation in strategic alliances: Initial conditions or learning processes?" *Strategic Management Journal*(1996), Vol. 17, pp. 55-83.

Edmondson, A. C. "Psychological safety and learning behavior in work teams.", *Administrative Science Quarterly*(1999), Vol. 44, pp. 350-383.

Eisenhardt, K. M. and M. E. Graebner. "Theory building from cases: Opportunities & challenges.", *Academy of Management Journal*(2007) Vol. 50,, pp. 25-32.

Hagedoorn, J. and N. Roijakkers. "Inter-firm R&D partnering in pharmaceutical biotechnology since 1975: Trends, patterns, and networks.", *Research policy*(2006), Vol. 35, pp. 431-446.

Hargadon, A. and R. I. Sutton. "Building an innovation factory.", *Harvard Business Review*(2000), May-June,, pp. 157-166.

Mathieu, J. E., M. T. Maynard, T. Rapp and L. Gilson. "Team effectiveness 1997-2007: A review of recent advancements and a glimpse into the future.", *Journal of Management*(2008), Vol. 34, pp. 410-476.

Park, S. H., R. Chen and S. Gallagher. "Firm resources as moderators of the relationship between market growth and strategic alliances in semiconductor start ups.", *Academy of Management Journal*(2002), Vol. 45, pp. 527-545.

Reid, S. E. and U. de Brentani. "The fuzzy front end of new product development for discontinuous innovations: A theoretical model.", *Journal of Product Innovation Management*(2004), Vol. 21, pp. 170–184.

Rothaermel, F. T. and D. L. Deeds. "Exploration and exploitation alliances in biotechnology: A system of new product development." *Strategic Management Journal*(2004), Vol. 25, pp. 201-221.

Sakakibara, M. "Formation of R & D consortia: Industry and company effects", *Strategic Management Journal*(2002), Vol. 23, pp. 1033-1050.

Yin, R. S. *"Case Study Research: Design and Methods."*, 3rd edition, Sage Publications, 2003