Catalysts and barriers: Factors that Affect the Performance of University-Industry Collaborations

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This paper explores whether and how different organizational structures of the collaboration, reflecting different involvement and power of both parts across different phases and activities of the collaboration, lead to different performance outcomes Our analysis considers various dimensions of performance, from the perspective of both partners, and relies on 30 in-depth, semi-structured case studies of university-industry collaborative projects. Among other things our results suggest that while different involvement of the parts in the origin and execution of the R&D collaboration influence the scientific and technological achievements of the collaboration and likelihood of use developed knowledge, imbalance power in the appropriation of early or later collaboration's results is associated with negative evaluations from both parts. In particular, collaborations based on university-invented patents technologies get more negative evaluations.

1. Introduction

R&D collaboration between university and industry maybe one of the most successful knowledge transfer mechanisms between universities and business firms (Kline and Rosenberg, 1986; Cohen et al., 2002; Caloghirou et al., 2003). However, these collaborations involve several coordination challenges, as the existing institutional differences in the research objectives and incentives of both parts need to be successfully addressed by the structure of the collaboration (Dasgupta and David, 1994; Rosenberg and Nelson, 1994). The organizational structure of the collaboration reflects the specific arrangement that both parties found for a specific labour division, for a balance between academic and industrial objectives and benefits, and for a balance between appropriation by the participating firm and public diffusion of results (Barnes et al., 2002; Foray and Steinmueller, 2003). Understanding how the R&D university-industry collaboration project organizational structure (design) influence the performance of the collaboration is of importance for R&D managers that need to decide on the investment in this type of collaboration to extent the knowledge base of their companies, but it is also for policy-makers that increasingly finance university-industry collaborative projects. This study explores whether and how different organizational structures of the collaboration, reflecting specific involvement and power of both parts across different phases and aspects of the collaboration, lead to different performance outcomes.

The influence of university collaboration on the firms' innovative performance has been extensively examined in the literature (eg. George et al., 2002; Belderbos et al., 2004). Some studies also focus on the examination on the performance of research collaborations. Certain characteristics of the collaborating parties were found to influence the performance of collaborations such as the composition of research teams and the degree of prior experience in collaboration (Hall et al., 2001; Baba et al., 2008; Bercovitz and Feldman, 2011), as well as the absorptive capacity, the learning efforts and the knowledge breadth of firms (Caloghirou et al., 2003; Zhang at al., 2007).

Most of these studies focus on somehow exogenous performance measures such as the probability to patent and amount of licensing royalties (Bercovitz and Feldman, 2011; Baba et al., 2008) or on the general pattern of perceptions to this collaboration (Hall et al., 2001; Bruneel et al., 2010). Consequently, the systematic and empiric examination of how the organizational structure of collaboration, encompassing a specific form of labour, knowledge and power division, influence collaboration performance has been almost neglected in the literature.

The different organizational structure of the collaboration, defining the forms of knowledge production and sharing, is influenced by the anticipated coordination costs and expected appropriation concerns (Gulati and Singh, 1998) and it may influence the firms innovative performance (Rogers and Bozeman, 2001; Jung et al., 2010; Sampson, 2007). The knowledge objectives of the collaboration, the design of labour division and knowledge exchange (communication), sharing of collaborative results and disclosure are determinant aspects of collaboration and consequently of collaboration performance (Foray and Steinmueller, 2003; Artz and Brush, 2000; Jung et al., 2010; Yamakawa et al., 2011). In other words, the relative power of one of the parts across different phases and activities of the collaborative project may affect the performance of the collaboration (Ramaseshan and Loo, 1998). Still, how these organizational structure that reflect the specific agreement of the parts on how to produce and share knowledge influence the outcomes of the collaboration has not yet been examined.

Our study aims to contribute to the literature in three important aspects. First, university-industry collaborations may provide different types of outcomes from knowledge advances to new products to the market, but also improvement of firms efficiency, and satisfaction of the parties involved in the collaboration that may be determinant on their engagement in future collaborations with these or other partners. In this study, performance of collaborations is broadly understood in terms of knowledge and technology advances, level of knowledge absorption by firms, commercialization of new products and subjective evaluation by the involved parts.

Second, in the literature the examination of university-industry collaboration performance has focused on policy programme evaluation (eg. Laredo, 1995;) as well as on the examination of general patterns of perceptions of individual researchers and managers based on their experience and social shared reality (Hall et al., 2001; Bruneel et al., 2010). These studies have mainly used survey data to examine the general pattern of perceptions on those relations and relate these patterns with specific characteristics of the respondents. This paper is an attempt to address how organizational collaborative arrangements that may create power imbalances influence performance in university-industry collaboration, by studying the performance in actual collaborations. In particular, we will rely on 30 case study data on actual university-industry collaborations to the development of a specific knowledge and/or technology, as well as on survey data collected via two questionnaires—one addressing industrial researchers and the other academic researchers— conducted in the Netherlands. In this manner, we will examine in detail the unidentified relationships between the dynamism of each collaboration in terms of the exchanges between parties and specific results of that work (Eisenhardt, 1989).

Third, the organizational structure of R&D collaboration reflects the arrangements of the parties found that conceal their motivations, expectations and concerns for a collaborative process of knowledge production and sharing, hence it may take several different arrangements (Foray and Steinmueller, 2003; Sampson, 2007; Zang et al., 2007). By examining several characteristics of the organizational structure of collaborations that may create power imbalances within the collaboration (such as the origin of the project in terms of who had the idea for the collaboration and how it relates previous scientific and technological knowledge, the relative role of firms and universities in the design and performance of R&D, the financing sources of the R&D project, the intensity and forms of knowledge transfer between university and firms), we attempt to examine the association between the organizational structure of the collaboration and performance of the collaboration.

Our results suggest that the organizational structure of the collaboration is associated with the collaboration performance. While different involvement of the parts in the origin and execution of the R&D collaboration influence the scientific and technological achievements of the collaboration, and likelihood of use of developed knowledge, imbalance power in the appropriation of early or later collaboration results is associated with negative evaluations from both parts. In particular, collaborations based on university-invented patents technologies get more negative evaluations. Additionally, our results consistently with the existing literature shows that having earlier experiences positively influences the positive evaluation of new collaboration for both parties, however when the projects results are of different value for each partner, we see larger discrepancies between the evaluations of both parties than among inexperienced collaborations.

The reminder of this paper is structured as follows. Section 2 reviews how in the literature university-industry collaboration performance has been measured, as well as how organizational structure of the collaboration may influence its performance. Section 3 describes the data and methodology used in this study. Section 4 presents the empirical results, and section 5 concludes the paper.

2. Organizational structure of the collaboration and collaboration Performance

2.1. Performance of R&D collaborations

Despite university-industry collaborations being regarded as one of the most successful knowledge transfer mechanisms (Kline and Rosenberg, 1986; Cohen et al., 2002; Caloghirou et al., 2003), relatively few research efforts have been put in exploring their performance. This may be related to the difficulty to define and measure performance of R&D projects, especially when they are collaborations between university and industry.

The outcomes of a university-industry collaboration may be several. Performance of a R&D collaboration may relate to technology/knowledge advances achieved against what has planned or intended, the ability to transfer knowledge between the parties involved, to development and commercialization of a new product, and to the perceptions of the parties involved on the success of the collaboration. Indeed, depending from the partner involved in the evaluation of the performance, the criteria may be different or have a different weight on the final evaluation. For example, university researchers might weight strongly the achievement of knowledge and technology advances (Rosenberg and Nelson, 1994), the firm and policy-makers the development and commercialization of new products (Dasgupta and David, 1994; Agrawal and Henderson, 2002), the research sponsors may instead give a special attention to the ability of the collaboration to achieve knowledge and technology advances and to transfer that knowledge among the parties involved (Bozeman, 1994; Laredo, 1995).

Hence performance may be defined as (a) the level of scientific and technological achievements, (b) the degree to which firms make use of knowledge that was developed, and (c) the subjective evaluation of the success of the by both parties involved. The examination of these issues may require the use of multiple case-studies data at the level of individual collaboration because information on the dynamism and structure of the exchanges between parties and specific results of each collaboration is required (Hall et al., 2001; Rogers and Bozeman, 2001).

In the literature instead, the examination of performance of research collaboration tends to focus on somehow exogenous performance measures such as the probability to patent and amount of licensing royalties (Bercovitz and Feldman, 2011; Baba et al., 2008) or on the general pattern of perceptions, in particular on the barriers perceived to this collaboration (Hall et al., 2001; Bruneel et al., 2010). These studies provide us with evidence on how different research teams of research objectives may influence performance as well as on how the barriers perceived to this collaboration relate to specific characteristics of the respondents. The literature on perceptual experience has shown that human representation is highly dependent on the initial viewpoint of the observed but it evolves with experience (Christou and Bulthoff, 2000), as well as that perceptions may be based on a socially shared reality because they seem to converge with the group criteria (John and Robins, 1994). However, independently of how accurate perceptions reflect previous experience and social shared reality, focus on perceptions or on somehow exogenous measured of collaboration performance do not permit to improve our understanding of how the structure of each collaborative project may affect performance of that collaboration.

How different types of arrangements may be associated with different types of performance is of particular interest for future design of collaboration and for their evaluation, hence for industry R&D managers, university researchers as well as for research sponsors. Next, we will review the existing literature on how the organizational structure of collaboration may influence collaboration's performance.

2.2. Organizational structure of Collaborations

The organizational structure of the collaboration reflects the specific arrangement that both parties found for knowledge production and sharing (Barnes et al., 2002; Foray and Steinmueller, 2003). It defines a specific labour division, a balance between academic and industrial objectives and benefits, and a balance between appropriation by the participating firm and of public diffusion of results (Foray and

Steinmueller, 2003). In other words, the organizational structure accommodates the expected coordination costs and expected concerns of each partner (Gulati and Singh, 1998). Additionally, it may also reveal power imbalance within the collaboration that may influence the collaboration outcomes. Hence, the examination of the organizational design of the collaboration—origin of the project in terms of who had the idea for the collaboration and how it relates previous scientific and technological knowledge, the relative role of firms and universities in the design and performance of R&D, how the R&D project was financed, the early definition of specific IPR rules, and the degree and the forms of knowledge transfer between university and firms—also characterizes the form in which motivations, expectations and concerns has been accommodated (Foray and Steinmueller, 2003; Kingsley et al., 1996).

Collaboration performance may be dependent on whether or not the collaborative research is close to the in-house R&D effort of the firm (Lee, 2000; Caloghirou et al., 2003). As the effect of exploration versus exploitation orientation of the collaboration on firms' performance seems to depend on the firms' innovation capabilities and strategies (Yamakawa et al., 2011). The origin of the project in terms of who had the idea for the project may reveal a specific research interest of one of the parties.

The relative role of firms and universities in the design, performance and financing of R&D may define specific levels of involvement and power of each of part across the different phases of the project and consequently influence the locus of knowledge development, the type of outcome and performance of the project. When firms are involved in the performance of the R&D activities, they might be more likely to define the outcomes of the collaboration, as well as more likely to absorb (acknowledge the value) and use the knowledge developed in the project. Moreover, their involvement in performance may reflect a more applied research focus and objectives. When financing the collaboration, firms may be expecting a shorter return than when the collaboration is financed by research sponsorships or by university resources and funds, and consequently, their relative power within the collaboration may be made more assertive. In particular, the existence of IPR stipulations from the beginning of the project may reveal the accommodation of the firms concerns towards the sharing of collaboration outcomes (Bruneel et al., 2010).

The intensity of interaction during the project affects communication and trust within the project, and consequently the performance of the collaboration (Ramaseshan and Loo, 1998). In particular, experience and breadth of interaction may enhance the ability of firms to use knowledge developed during the collaboration (Cohen et al., 2002; Bruneel et al., 2010). Indeed, the forms of communication and interaction used during the collaboration is a integer part of the project design that may also reflect the goals, labour and power division and the appropriation concerns of the parties.

The organizational structure of collaborations is also characterized by the form in which the collaboration is managed not only in terms of joint problem-solving but also of conflict resolution (Artz and Brush, 2000). The performance of projects that have suffered specific cultural or technical problems during its performance may be different from those that have not suffered those issues, as both parties may have experience delicate conflictual and power imbalance situations. Several studies have shown that the absence of knowledge appropriation problems is associated with better performing collaborations (Caloghirou et al., 2003; Foray and Steinmueller, 2003). The forms of conflict resolution may however evolve over time throughout the collaboration (Artz and Brush, 2000). Therefore, a great power imbalance among the parties may affect collaborations that build on previous university knowledge that has been patented at the beginning of the collaboration by the industry partner.

Finally, the characteristics of university researchers and its research group in terms of experience in collaboration and in being engaged in applied knowledge may affect the specific goals of the collaboration as well as its outcomes (Lam, 2005; Baba et al., 2008; Bercovitz and Feldman, 2011). Similarly, the research and technology and relational competences of the firm may affect the design and the performance of the collaborative project. Indeed, several studies have shown that existence of prior experience in collaboration and level of absorptive capabilities and the knowledge breadth of the firms seem also to play a role on the level of difficulty faced by firms in acquiring and assimilating basic knowledge and consequently on the performance of the university-industry collaboration (Hall et al., 2001; Zhang at al., 2007). Additionally, the firm's effort to learn from the collaboration seems to affect the collaboration success (Caloghirou et al., 2003).

On the basis of the considerations above, the following aspects of organizational structure of the collaboration may underlie different levels of involvement and power of parties across different phases and activities of the collaboration: 1) different levels of involvement of university and industry in the originating phase of the collaborative project, 2) different levels of involvement of university and industry in the implementation phase of the collaborative project, 3) forms of funding the collaborative project, 4) intensity and form of interaction and knowledge exchange during the projects, 5) problems and conflicts affecting the project. Finally, the characteristics of the both parties are also relevant to understand different levels of collaborative performance in particular 6) the previous collaborative experiences of both parties, and 7) the R&D characteristics of both parties.

3. Data and Methodology

The objective of this study is to explore how different university-industry collaboration performance measures relate the organizational structure of the collaborative projects that underlies specific levels of involvement and power of university and industry across different phases and activities of the collaboration. In order to look inside of the back box of the organizational structure of the collaborative projects, we rely on multiple case-study data. This section describes the methodology we used to collect and analyse the data.

We conducted 30 case studies of university-industry collaboration. The unit of analysis in the case study is the piece of knowledge developed or co-developed at university, and transferred to firms, independently on whether or not it has been commercialised. The main strategy to identify cases has been to interview chairs of some research departments in the faculties of mechanical engineering, biotechnology, chemistry, applied physics and electrical engineering in two technical universities in the Netherlands (Eindhoven and Delft). The chairs were asked to name relevant technology transfer projects, and to provide contacts to the people involved in the projects they mentioned. Additionally, we consulted national electronic libraries for PhD theses finished in the last five years, we interviewed the directors of the university's TTOs, and we identified professors with a large number of industrial patents.

The cases were chosen independently of their relative weight on the population of university innovations, on the basis of several criteria. Since our study is still exploratory we were interested in having cases that could span widely on the motivational space that we have outlined in the previous section. Accordingly, we chose cases that show variety in terms of the forms of funding, diversity concerning the scientific disciplines involved, and diversity in terms of the origin and development of the inventions (university-driven research; the firm addressing the university with the idea; results from on-going collaborative project). Thus, nineteen cases were collected at the University of Eindhoven, three at the University of Leiden, and eight at the Delft University.

Data on the cases was collected on the basis of interviews with those involved in the project both at firms and at university. In average, each case involved at least three interviews. We complemented this with secondary sources of information on the cases we studied, such as theses, public information provided by the collaborating partners, and funding organisations (if applicable). To allow for codification and statistical comparison of the cases, we developed a standardised protocol for collecting data from university researchers and industrial researchers and managers participating in the specific cases. This protocol included over 200 questions and it focuses on the following elements of the process of knowledge transfer between university and firms (Kingsley *et al.*, 1996; Bozeman, 2000; Bercovitz and Feldman, 2006): i) characteristics of innovation developed; ii) identification of the origin of the project; iii) design and performance of the research and development project; iv) degree and the forms of knowledge transfer between university and firms; v) impact of the knowledge transfer process; vi) the main characteristics of university researchers, and of participating firms.

Based on this case study evidence, we examine how different levels of performance relate to the organizational structure of the collaboration, reflecting specific level of involvement and power of parties across different activities and phases of the collaboration.

As seen in section 2.1., there are multiple performance measures, depending on the interests of different parties involved in the evaluation of the project. Consequently, for this study, we rely the following different concepts of performance of R&D collaborations (a) the level of scientific and technological achievements, (b) the degree to which firms make use of knowledge that was developed, and (c) the subjective evaluation of the success of the collaboration by both parties involved.

Concerning the organizational structure of the collaboration, as seen in section 2.2, we will consider the level of involvement and power of university and industry across different phases and activities of the project: 1) different levels of involvement of university and industry in the originating phase of the collaborative project, 2) different levels of involvement of university and industry in the implementation phase of the collaborative project, 3) forms of funding the collaborative project, 4) specific forms of interaction and knowledge exchange during the projects, 5) problems and conflicts affecting the project. Additionally, the characteristics of the both parties are also relevant to understand different levels of collaborative performance in particular 6) the previous collaborative experiences of both parties, and 7) the R&D characteristics of both parties.

Table 1 provides the description of the variables used on the analysis.

[Insert Table 1 about here]

Our research approach, using semi-structured case studies, inherently creates restrictions in terms of the number of observations. Therefore we build on results from the non-parametric Spearman's correlation coefficients and Mann-Whitney T-tests.

4. The Organizational Structure and Performance of University-Industry Collaborations

In this section we examine how the organizational structure of university-industry collaborative projects are associated with the performance of the collaboration. In particular, we take a broad concept of performance and we consider the scientific and technological outcomes; the level of absorption (acknowledge the value) and use of developed knowledge; commercialisation of knowledge developed in the project, and the subjective overall evaluation done by firms and university of the collaborative project. Table 2 provides information on the different performance measures of our 30 cases.

[Insert Table 2 about here]

In two out of the thirty cases, the collaborative project did not achieve the scientific or technological objectives (e.g. those defined when starting the project), while in four cases the outcomes were above the expected ones. In seventeen cases, projects led to commercialisation or to plan to commercialise new products. Despite these good outcomes, universities overall evaluate 26 projects as fully positive, while firms are more critical and only report the same level of satisfaction in 21 of the 30 cases. We now move to the analysis of the relationship between performance on the one hand and the characteristics of collaborative projects on the other. Table 3 reports the Spearman's correlation coefficients for significant non-parametric Mann-Whitney T-test differences.

[Insert Table 3 about here]

Generally, the project's *scientific or technical outcomes* (Table 3, column 1) are more likely to match or to be above the defined ones, if the idea for the project comes from university research activities rather from firms' project development activities or from previous collaborative projects. Typically, such projects do not run smoothly as they encounter unexpected and severe technical problems while being carried out. Moreover, the scientific and technological outcomes of collaborative projects seem to be positively associated with frequency of interaction between university and industry during the project, and negatively associated with project that applies for competitive grants.

The four projects that exceeded the aimed *scientific or technological outcomes* tended to be initiated by a university. In three out of these four cases, the project was initiated by researchers with previous industrial experience, reflecting the importance of labour mobility and research collaboration for collaboration. Despite the fact that the industrial partners participating in these four projects being quite knowledgeable, they might not have had the capabilities to identify and plan the required research in order to achieve the project' results. All these four projects were considered to be successful by both firms and universities, and their results were used (by either participating or non-participating firms in the R&D project). Three of these projects focused on substitutes to existing technologies. Concerning financing, one project was mainly undertaken with research grants, other one with a mix of research grants, firms and university resources, and the third with both grants and firms' money, while the remaining one was funded only by the participating partner. In two cases, projects led to plans for launching new product, in the two other projects, results were less ready to commercialised and instead led to products development projects.

Concerning the *level of knowledge transfer to firms*, we consider three different levels of performance: knowledge has been transferred (but the firm may not recognise the value nor decide to use it), knowledge has been absorbed (the firm has acknowledge the value of the knowledge but may decide not to use it), knowledge has been used (in further research, further product development, process improvement, or in commercialization of new products). The outcomes of collaborative projects, which were patented, used by firms in further product development research and had an impact on the research objectives of firms and universities, were all used by participating or non-participating firms in the collaborative project.

In particular, our results (Table 3, column 2) suggest that knowledge is more likely to be absorbed and used by *participating* firms, when the idea for the project comes from industrial project development activities and technological problems faced by firms, often proposed by part-time professors. Moreover, this seems more likely when participating firms join on the design, performance of R&D and university provides feedback and advice on R&D activities of the firms. Knowledge developed in the project is more likely to be used by participating firm, when these firms invest in learning and knowledge transfer through a large number of channels, especially through labour mobility and meetings, and partially finance the project (and consequently set formal or informal contractual stipulations about the ownership of the research results). Knowledge is more likely to be used by participating firms, when the R&D project did *not* encounter severe or unexpected technical and scientific problems while being carried out.

In one third of cases (11), *non-participating* firms used the knowledge developed in a collaborative research project. Knowledge absorbed and used by non-participating firms is often associated with spin off creation, since the knowledge developed in the project does not fit the core technological capabilities and product line of the participating firms. Moreover, it is associated with cases in which other firms join later the project either to provide specific equipment and material, to perform small parts of the project or to participate in the exploitation of knowledge produced in the project. For example, in one case, the customers of the participating firm join on the testing of the prototype developed in the project and then soon after they adopt the product. In other case, an non-participating firm learns about the unexpected scientific and technological developments of the project, because it participates in other projects financed by the same research council, and it asks to be integrated in the project.

Results (Table 3, column 3) suggest that knowledge is more likely to be absorbed and used by *non-participating firms*, when participating firms are not involved in the design and performance of R&D, and financing is mostly assure by other sources such as research grants (except for two cases in which participating firms financed most of the project). As firms are less involved in developing of R&D, knowledge transfer tends to occur through prototypes rather than through meetings. Institutional and organisational barriers resulting from the different incentives and objectives frameworks of industry and university do not seem to be the reason for non-participating firms to benefit from the projects. Indeed, despite knowledge developed being also absorbed/ used by non-(originally) participating firm, participating firms are willing to keep further collaboration with the same university researchers. Often the reason for *non-participating firms* to use the knowledge developed rather than the *participating* ones refers to the fact that the knowledge developed was or became outside of their core business.

Other measure of performance of university-industry R&D projects refers to whether or not the project led to the *commercialization* of new products. Commercialisation of knowledge developed in the project (Table 3, column 4) is associated with results of collaborative multi-disciplinary projects that lead to the publication of several patents, as well as with the industrial employment of university researchers involved in the development project. Commercialisation is also more likely when participating firms do not own a research lab, and when university research group has a great number of published patents. Consequently, collaborative research focused on very applied technological issues, even that often requiring the development and test of proof of concepts. Market dynamics may have also prevented commercialisation (3 cases).

Finally, we look at the overall, *subjective evaluation* done by the parties involved in the project on its success. *University evaluation* (Table 3, column 5) of the collaboration with industry is more likely to be positive in multi-disciplinary projects, when university was involved in the development and test of a proof of concept, while the industrial partner provided access to equipment and materials and feedback on university research work, but did not participate on the design, performance or the finance of the project. University researchers, with large collaborative experience, also with the same firm, are more likely to rate positive the collaborative project. Instead, they tend to evaluate projects as not completely satisfactory when they involve the use of university knowledge that has been patented (either by the university or by the firm in the beginning of the project). Projects in which there were relational problems derived from the different objectives and incentives frameworks of university and industry occur during the project are more likely to be evaluated as non satisfactory.

Curiously, *firm's evaluation* is based on the same criteria as university evaluation (Table 3, column 6). Firm's evaluation of collaboration with university is also more likely to be positive, when projects were proposed by university, and in which university was involved in the development and testing of a proof of concept. Firms also evaluate positively projects with high level of interaction between university and industry, as well as with few relational problems due to cultural and organisational differences between the two organisations. Firms recognise the university efforts and competences and evaluate positively projects that suffered several technical and scientific problems during development. In particular, firms evaluate positively projects set up with university departments with who they had had previous collaborations. Finally, they also tend to evaluate projects as not completely satisfactory when they involve the use of university knowledge that has been patented (either by the university or by the firm in the beginning of the project).

In 5 projects, there were *differences in the overall evaluation* by university and firms of their collaborative project. In most cases, university rated projects higher than firms. This mismatch seems to underlie different expectations from the project (Table 3, column 7). These projects were initiated as follow-up of previous collaborative projects with the same partners, financed fully or partly by public research grants, and implemented by university with a low level of interaction among the parties. This mismatch is not associated with severe technical problems during development. Hence projects set to access public sponsoring for exploring interesting new R&D opportunities emerged from previous collaboration are likely to be differently evaluated by the two parties eventually by the different efforts and expectations put by both parties. Indeed, differences in the potential uses of the research results by the two parties—they feed further university research, but not firms' product development—are likely to bring along disparity on the evaluation.

6. Discussion and Conclusion

This paper has aimed at examining whether and how different organizational structures of the collaboration, reflecting different involvement and power of each partner across different phases and activities of the collaboration, lead to differences in the performance of collaborations. We relied on 30 case-studies to look inside of the back box of the organizational structure of the collaborative projects and examine how it relates with different performance measures. In particular, taking a broad view on performance, we used different measures of performance (a) the level of scientific and technological achievements, (b) the degree to which firms make use of knowledge that was developed, and (c) the subjective evaluation of the success of the collaborative project by both parties involved.

Our findings suggest that the organizational structure is associated with the performance of the collaboration. University-driven original ideas tend to be associated with project that are more likely to develop outcomes that match or are above to the previously defined ones. Typically, such projects do not run smoothly as they encounter unexpected and severe technical problems while being carried out, and they do not rely only on public research grants. Industrial-driven performing projects, dealing with technological problems related to product development, in which firms participate in the design, performance and finance of R&D activities, as well as invest in several means especially labour mobility to learn and to transfer knowledge, are more likely to lead to results that are absorbed and used by participating firms. Moreover, our evidence shows how university and industry have similar evaluation criteria and how evaluation depends positively on their experience to collaborate: Both parties tend to evaluate positively multi-disciplinary collaborative projects in which the project's original idea was from university, the objective was the development and test of proof of concepts, and there was a great level of interaction between parties. Instead, both parties then to evaluate worst collaborations based on university-invented patents technologies. Mismatch in evaluation of university and firms seems associated with (implicit) differences in the expectations at the outset of the project. These differences are more likely when projects are initiated to develop further some findings of previous collaboration and access to public research grants, when R&D is developed by the university with a low level of interaction with the industrial partner, and when the project's results have different a value for the parties involved.

Thus, our results stress that whether the project is originated from a university or an industry idea does not influence the level of knowledge transfer to the firms or with the possibility of commercialization of developed knowledge; instead it may influence the level of scientific and technological achievements of the projects and the prospective of technological spillovers to other fields. Indeed, university-driven original research ideas, though being more risky and troublesome, allows unexpected fruitful developments with potential high spillovers to other fields. The use and commercialization of knowledge developed in collaborative research projects seems dependent on the features and attitudes on the side of industry. Involvement of firm in the execution and financing of the R&D collaborative project, intense interaction and communication throughout the project, and firms' investment in reproducing and using knowledge developed in the project are strongly associated with their ability to use and to commercialise knowledge. Hence, participating or non-participating firms may need to invest in capability building and in knowledge transfer through several channels, in particular labour mobility. Still, firms that have the competences to use and develop further the knowledge created in the project seem more likely to use the knowledge developed in the project. Furthermore, consistently with the existing literature, our results suggest that having earlier experiences positively influences the positive evaluation of new collaboration for both parties, however when the projects results are of different value for each partner, we see larger discrepancies between the evaluations of both parties than among inexperienced collaborations.

In sum, our results suggest that the organizational structure of the collaboration is associated with the collaboration performance. While different involvement of the parties in the origin and execution of the R&D collaboration influence the scientific and technological achievements of the collaboration, and likelihood of use of developed knowledge, imbalance power in the appropriation of early or later collaboration results as well as imbalance in the expectations of continuation collaborations are associated with negative evaluations from both parties.

Interesting as they are, it has to be noted that these findings are subject to some limitations. First, this study has focused university-industry collaboration rather than on multi-party collaborations. Second, our analysis relies on a small sample of university-industry collaborative projects. Thus, further research is needed, to expand the size of the sample and exploit different methods of enquiry. Finally, it would be interesting to analyse the extent to what these results can be generalized to other countries given that cross-country differences may exists between specific academic and industrial contexts.

Keeping in mind these limitations, we nevertheless argue that our evidence allows us to draw some policy and managerial implications.

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Table 1. Description of variables characterizing university-industry collaborative projects

Measures of Performance	
Objectives achieved	Equals 0 if the project's scientific and technological outcomes do not meet the objectives, 1 the outcomes match the objectives, and 2 the outcomes surpass the objectives
Knowledge transfer to participating firm	Equals 0 if the knowledge was transferred but not absorbed by the participating firm; 1 if the knowledge was transferred and absorbed; 2 if the knowledge was transferred, absorbed and used
Knowledge transfer to third parties	Equals 0 if the knowledge was transferred but not absorbed by third parties; 1 if the knowledge was transferred and absorbed; 2 if the knowledge was transferred, absorbed and used
Commercialization of inventions	Equals 1 if the project led to the commercialisation or to plans for the commercialisation of a new product, 0 otherwise
University Evaluation	Equals 0 if the university evaluates the project as not completely satisfactory, 1 if positive and satisfactory
Firm Evaluation	Equals 0 if the firm evaluates the project as not completely satisfactory, 1 as positive and satisfactory
Consensus on evaluations	Equals 1 if the evaluations of the university and the firm are similar, 0 if not
ORGANIZATIONAL STRUCTURE OF COLLABORATION	
Origin of collaborative project	
University idea	Equals 1 if the project idea originates from a university proposal; 0 if the project idea originates from an industry proposal
Follow-up collaboration	Equals 1 if the origin of the project is attributed to previous/on-going collaboration; 0 otherwise
Based on earlier university invented patent	Equals 1 if the origin of the project is attributed to previous patents based on university knowledge, 0 otherwise
Financing of the collaborative project	
Private financing	Equals 1 if mainly public financing; 2 both public and private financing; 3 mainly private financing
Public grants	Equals 1 if the project was carried out with public research grants; 0 otherwise
Exclusively public funding	Equals 1 if the project was financed only with public money being either grants or university resources; 0 otherwise
Labour and Knowledge division in the project	
Firms' share in execution	Equals 1 if R&D project is mainly performed by the university; 2 industry participates on the project performance; 3 project mainly performed by the firm
University feedback role	Equals 1 if the university provided only advice and feedback to the R&D activities performed by the firm
Frequency of interactions	Equals 1 if interactions among the parties occurred often; 0 if these interactions occurred occasionally
Multidisciplinarity	Number of disciplines involved in the project. It takes values from 1 to 6
Ex-ante IPR agreements	Equals 1 if the parties agreed in specific IPR stipulations before the contract; 0 otherwise
N new patents	Number of patents resulting from the project. It takes values from
Problems during project development	
Technical problems experienced	Equals 1 if the project encountered severe technical problems in implementing technological principles; 0 otherwise
Cultural differences surfaced	Equals 1 if the project suffered from a misalignment of the cultures in university and industry; 0 otherwise
Channels of knowledge transfer used	
Exchange activities	Equals 1 if mobility of researchers or students was used to support knowledge transfer; 0 otherwise
Technical project meetings	Equals 1 if meetings were used to support knowledge transfer; 0 otherwise
Employment	Equals 1 if employment of university researchers or students was used to support knowledge transfer; 0 otherwise
Prototype	Equals 1 if prototypes developed by the university was used to support knowledge transfer; 0 otherwise
University advisory role	Equals 1 if university provided advice and feedback on firms' RD activities to support knowledge transfer
N_channels	Number of channels of knowledge transfer used. It takes the value from 0 to 3. Being 3 all the cases with more than 3 channels
Characteristics of the university research group	

University patent stock	Count of the number of patents of the research group in the last 5 years. It takes values from 0 to 65
Previous experience with partner	Equals 1 if the university department had previous collaborative experience with the same firm
Characteristics of the participating firms	
Firms' R&D capabilities	Equals 1 if the firm is able to evaluate; plan and undertake the required R&D activities for accomplish the project's objectives; 0 otherwise
Firms' collaborative experience	Equals 1 if the firm's experience in interacting with universities mainly through students' trainships; 2 the firm is also used to interact through Master thesis; 3 the firm interacts with university also through collaborative research projects
Firm has R&D laboratory	Equals 1 if the firm has an R&D lab; 0 the firm does not have one.
Firms' knowledge capabilities	Equals 1 if the firm had the competences to use and develop further the knowledge developed in the project; 0 the firm does not have these competences

Table 2. Various performance levels of the cases

	Below objectives	*Match objectives*	*Exceed objectives*
Achieved outcomes	2	24	4

	Neither absorbed or used	*Absorbed, not used*	*Absorbed and used*
Firms participating in project	5	3	22
Third parties (non-participating firms)	17	2	11

	Negative or neutral	*Positive*
Overall university evaluation	4	26
Overall firm evaluation	9	21

	Different evaluation	*Consensus*
Discrepancies in evaluation	5	25

	Not commercialized	*Commercialized*
Knowledge commercialization	13	17

Table 3. Spearman's Correlation coefficient for significant non-parametric Mann-Whitney T-test differences between the characteristics of collaborative projects with different performance levels

	(1) Objectives achieved	(2) Knowledge transfer to participating firm	(3) Knowledge transfer to third parties	(4) Commer-cialization of inventions	(5) University Evaluation	(6) Firm Evaluation	(7) Consensus on evaluations
Origin of collaborative project							
University idea	0.479**	-0.0.91*				0.279	
Follow-up collaboration	-0.264					-0.257	-0.402*
Based on earlier university invented patent			-0.285		-0.523**	-0.267	
Financing of the collaborative project							
Private financing		0.423**	-0.397*		-0.334*		0.304
Public grants	-0.310*						-0.239
Exclusively public funding		-0.613**	0.295				-0.280
Labour and knowledge division in the project							
Firms' share in execution		0.413*	-0.594**		-0.326*		
University feedback role		0.390*	-0.407*				
Frequency of interactions	0.241		-0.328*	-0.281		0.269	0.398*
Multidisciplinarity				0.422*	0.299		
Ex-ante IPR agreements		0.406*	-0.228				-0.316*
N new patents				0.266			
Problems during project development							
Technical problems experienced	0.496**	-0.309*	0.246			0.386*	0.365*
Cultural differences surfaced			-0.428**	-0.235	-0.539**	-0.400*	
Channels of knowledge transfer used							
Exchange activities		0.557**					
Technical project meetings		0.477**	-0.475**	-0.302			
Employment			0.308*	0.375*			
Prototype			0.515**	0.247			
University advisory role			-0.357*				
N_channels		0.499**					
Characteristics of the university research group							
University patent stock				0.284			
Previous experience with partner			0.516**		0.429**		-0.270
Characteristics of the participating firms							
Firms' R&D capabilities	-0.496**	0.269	-0.246				
Firms' collaborative experience		0.263					
Firm has R&D laboratory			-0.297	-0.279	-0.257		
Firms' knowledge capabilities		0.359*					

Note: One-Tail significance ** 1%, * 5%, nothing 10%.