Multilevel institutional analyses of firm benefits from R&D collaboration

Authors: Prince C. Oguguo, Isabel Maria Bodas Freitas, Corine Genet

Affiliation (for all three authors): Grenoble Ecole de Management - Univ Grenoble Alpes ComUE.
12 Rue Pierre Semard, 38000 Grenoble, France

Highlights

- National collaborative logics affect the benefits a firm will derive from publicly sponsored R&D collaboration.
- In higher collaboration logics, firms will see greater advances in organizational and product/technology development.
- However, these firms will see lesser network benefits when they operate in countries with greater collaboration logics.
- Collaboration logics may be fostered by design of innovation policy, and by encouraging knowledge-revealing practices.

Abstract

Open innovation research has extensively shown that open innovation strategies influence firms' performance. It has, however, mostly neglected that the larger institutional context may influence these benefits. To address this gap in the literature, we investigate how the national institutional context influences the benefits a firm may derive from R&D collaborations. Building on institutional theory, we propose that in a national institutional context, a specific collaboration logic develops, underpinned by the design of policy support for innovation as well as knowledge-revealing practices amongst firms. This collaboration logic influences the ability of firms to benefit from R&D collaboration. We theorize that these effects occur due to the influence of national collaboration logics on the nature of firm interaction and organization for innovation. Relying on multilevel analyses of data on 601 European firms, we find that in countries where collaboration logics have been fostered by policy design and knowledge-revealing practices, firms attain greater organizational and product development benefits from R&D collaboration, but relatively lesser networking benefits. We discuss the policy implications of these results.

Keywords: open innovation, institutions, R&D collaboration, innovation policy, policy mix

1 INTRODUCTION

Rapid technological advances and the ever-present demand for innovation requires that a firm has timely access to diverse streams of knowledge and to highly skilled knowledge workers who are able to develop, use and recombine that knowledge (West and Bogers, 2014). Firms therefore adopt open innovation strategies – that is, they rely on “inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation” (Chesbrough et al., 2006: 1). Extensive evidence suggests that firms often benefit more from sharing knowledge, ideas and resources and working with customers (Urban and von Hippel, 1988), supply chain partners (Hobday et al., 2005), universities (Oliver, 2004) and even other competing firms (Grant and Baden-Fuller, 2004), than they would from working in isolation (Felin and Zenger, 2014). However, benefits from open innovation are not identical across firms (Rothaermel and Alexandre, 2009; Wadhwa et al., 2017). As a result, scholars have sought to understand how these benefits vary and why some firms achieve greater benefits than others.

Firms’ benefits from collaborative innovation have been shown to depend to a great deal on factors under the direct control of a firm or its partners, such as partner selection (Diestre and Rajagopalan, 2012), the nature of the knowledge being shared (Wang, 2016) or the degree of trust among partners (Zaheer et al., 1998). Apart from these, the larger institutional context in which the firm operates may influence a firm’s ability to learn and benefit from collaboration (Pahnke et al., 2015; Vasudeva et al., 2013b). Indeed, differences in the ability of firms to leverage their network’s resources were found across national contexts with different degrees of corporatist logics (Vasudeva et al., 2013a). This may be so because linkages are “developed to solve economic, technical, and strategic problems for their (partners) as they also develop, produce, and market goods, services, and knowledge” (Osborn and Hagedoorn, 1997: 272).

Despite these contributions stressing the role of national context in influencing firms’ behaviour and performance in inter-organizational collaborations, studies examining the implications of national institutions on open innovation outcomes at the firm level have been few and far between (Santos, 2015; West et al., 2014). Therefore, recent reviews have called for a multilevel perspective when examining open innovation strategies and their benefits (Bogers et al., 2017). This study is an attempt to take a multilevel perspective and account for the national context of firms in the analysis of open innovation.

Using a multilevel perspective, we can conceptualize benefits from collaboration as dependent on the characteristics of the firm, the collaboration partnership, as well as on the characteristics of the larger institutional context of the firm. In particular, we argue that the degree to which knowledge-revealing practices are diffused in the ecosystem and the extent to which national innovation policy design encourage collaborative practices significantly affect the benefits a firm will derive from R&D collaboration. This permits us to extend open innovation scholarship from relating national institutions

to aggregate outcomes (Varsakelis, 2001) to considering the effect of the national institutional context on firms' performance. In addition, this knowledge may provide policymakers with information on how to redesign innovation policies and restructure policy mixes in a way that enhances the ability of national firms to benefit from open innovation. It also provides managers with an understanding of the most likely benefits that they can expect when relying on open innovation in different countries.

Relying on a sample of 601 firms in different European countries, and controlling for several characteristics of the firm, the collaboration team and the role of the firm on the project, this study investigates whether and how the prevalent open and collaborative logic in a country influences the benefits a firm gets from that collaboration. Results from multilevel analyses suggest that firms experience greater organizational as well as product and technology development benefits in countries where an open and collaborative logic for innovation development is relatively more established, whereas networking benefits are greater in firms operating in countries where collaborative and open logic is less established.

The paper is organized as follows. In Section 2, we review extant literature, define an analytical framework and develop hypotheses to examine the influence of national context on firms' benefits from R&D collaborations. Section 3 describes the data and our methodological procedure, and Section 4 presents the empirical findings. We discuss these findings in Section 5. Finally, Section 6 concludes the paper with an examination of the implications and our contribution to research on open innovation.

2 LITERATURE REVIEW AND HYPOTHESES

There is robust evidence that R&D collaboration enhances innovative performance for various types of firms (Dittrich and Duysters, 2007; Faems et al., 2005; Nieto and Santamaría, 2007). Furthermore, these benefits are of numerous types (Human and Proven, 1997; Caloghirou et al., 2004; Howard et al., 2016). Among the most commonly identified and studied benefits are those related to the enlargement of a firm's network (Antikainen et al., 2010; Fuentelsaz et al., 2015), advances in the work routines, processes and organizational structures of the firm (Dittrich and Duysters, 2007), and the product and technology advances obtained (Snow et al., 2011). Thus, in this study, we will focus on the network, organizational, and product and technology benefits of R&D collaboration. Each of these types of benefits reflect the objectives of different levels of analysis (Bogers et al., 2017), and some existing studies have examined these benefits together (Caloghirou et al., 2004; Chesbrough and Appleyard, 2007; Human and Provan, 1997). By studying these three types of benefits together, one can also account for how national institutions may influence the resources and capabilities of firms to perform in each of the steps/phases of open innovation as identified by West and Bogers (2014): obtaining¹, integrating² and commercializing

¹ To identify and obtain new knowledge and opportunities, firms must be able to access exchange partners with relatively low communication and control costs (Schulze et al., 2014). In other words, firms need to have a portfolio of trusted partners, and prior experience in managing interfirm collaboration. Changes observed at the level of the network thus reflect the benefits firms gain from R&D collaboration, not only because they may open new market and technology opportunities, but also because they will create more opportunities to obtain new knowledge and to engage in open innovation.

innovation³. Consistent with prior literature, this paper will focus on network, organizational, and product and technology benefits from R&D collaboration.

Although this extant literature has provided extensive evidence of how benefits on firms' benefits from collaborative innovation are associated with the characteristics and strategies of the focal firm and its partners, or characteristics of the collaborative project (Diestre and Rajagopalan, 2012; Wang, 2016; Zaheer et al., 1998). Few studies have engaged in analyzing the role of national context in explaining firms' performance in inter-organizational collaborations (Santos, 2015; West et al., 2014). This study is thus an attempt to examine the extent to which the institutional contexts, in which firms operate, explain heterogeneity of firms' benefits from R&D collaboration with external partners.

2.1 Analytical Framework

This study draws on institutional theory to provide an in-depth explanation of the effect of firms' institutional context on the benefits they may derive from collaboration for innovation. Institutional theory emphasizes how norms, shared expectations and logics create an environment that orients actors towards the development of certain practices, skills and competences (Freeman, 1995; Tolbert et al., 2011). Institutions may thus be understood as defining the effective ways to get things done when social cooperation is required (Nelson and Nelson, 2002; Nelson and Sampat, 2001). As organizations in an ecosystem share a specific logic, this institutional logic may be understood as "the lens through which members view reality" (Pahnke et al., 2015: 3). Empirical evidence tends to support this thesis. There is evidence that differences in national norms, regulations and policies are associated with differences in production technologies (Delmas, 2002), in the forms of interacting and relating within the ecosystem (Gittelman, 2006), as well as in the level of performance and survival of firms (Thomas, 1994; Chesbrough, 1999). The link between, on the one hand, organizations' strategies and performance and, on the other, their institutional contexts seems to rest on the fact that they share a similar logic in analyzing challenges, defining objectives and strategies, and outlining how to achieve expected outcomes, both internally and with external actors. In other words, it seems that organizations sharing a

² Having identified and accessed relevant external knowledge, firms need to integrate that knowledge into their products and processes (West and Bogers, 2014). To learn and integrate external knowledge, the firm must often adapt its organizational structure through changes in work structures and processes, and through the establishment of new roles, task forces or cross-functional teams (Chiaroni et al., 2011; Dittrich and Duysters, 2007). Organizational changes experienced during collaboration may shake off organizational inertia (Dittrich and Duysters, 2007) and may cause the firm to operate more effectively in their current and potential markets. In addition, these changes may facilitate future processes of integration of external or collaboratively developed knowledge.

³ The process of integration may lead to commercialization if it permits firms to advance in the development of technologies and products. Collaboration permits firms to share costs, knowledge and efforts in advancing technologies and products (Un et al., 2010). These advances in products and technologies will foster the commercialization of new or improved products, which are the ultimate benefit expected from R&D collaboration. The knowledge and technologies developed in this collaboration may lead to further collaboration in the future, as they may present new directions for problem-solving, solution search and consequently the development of yet more products and technologies (Khanagha et al., 2016; Nickerson and Zenger, 2004).

similar institutional context develop shared views and logics which in turn shape the forms in which these organizations operate, how they relate with external actors (Marquis and Lounsbury, 2007; Thornton and Ocasio, 2008), as well as their overall performance (Wan and Hoskisson, 2003).

As the objective of this study is to understand how institutional embedding influences the benefits firms derive from collaboration for innovation, we focus on identifying institutions that reflect the shared logic for open innovation. Institutions have been characterized as formal when they are the result of conscious coordinated planning, such as government policies and laws. They are described as informal when they are the result of an uncoordinated evolutionary process resulting from culturally transmitted patterns of thought or practice, such as culture or norms (Dequech, 2009; Nelson and Sampat, 2001; Scott, 2003; Stephan et al., 2015). To account for these two types of institutions shaping the shared logic for open innovation, we consider the degree to which the national policy mix for innovation encourages collaborative practices, and the degree to which knowledge-revealing practices are diffused in the country. Hence, with the objective of gaining a better understanding of the effect of institutional embedding on firms' benefits from open innovation, we examine how the design of these institutional characteristics influences the benefits of R&D collaborations for firms. We will argue that the design of public financial incentives for business enterprise R&D (PIBERD) and diffusion of knowledge-revealing practices (KRP) in national ecosystems describe a national logic of open innovation since they influence the forms in which firms organize for innovation and how they interact with external actors.

2.2 Hypotheses development

2.2.1 Innovation policy design and the benefits from a public sponsored R&D collaboration

Generally, a government may incentivize business innovation using direct grants for innovation or indirect tax incentives (OECD, 2016, 2008). Although both direct grants and indirect incentives may bear the same price tag, they create different incentives for firm behavior (Guellec and Potterie, 2000). Hence, they not only often create different incentives for firms' investment in R&D (Busom et al., 2014; Tasse, 1996), but they may also create different incentives for open innovation (Herstad et al., 2010).

To ensure consistency with EU state aid rules, direct grants in the EU are often provided to consortia as opposed to individual firms (Bird & Bird Brussels, 2015; Czarnitzki et al., 2007). In addition, it is often more difficult for politicians and policymakers to sell to the public on the idea of giving some tax-generated revenue to a private firm than the idea of a reduced tax bill for these private firms to support innovation (Nishimura and Okamuro, 2011). As a result, the provision of direct grants for innovation is often bundled with requirements to collaborate as well as government-sponsored support systems to facilitate collaboration for technological development as a means of facilitating knowledge spillovers in the economy, as well as of reducing cost and risk sharing (Czarnitzki et al., 2007; Nishimura and Okamuro, 2011). As Veltri et al., (2009: 37) observe of EU countries, "Governments usually use competitive R&D programs, for the direct funding of private R&D, requiring that applicant companies cooperate with public research activities, either in universities or other public research organizations". The design of direct publicly funded R&D support programs thus often facilitates the development of complex innovation systems by making firms more likely to form networks with other firms and

universities, and may encourage finding applications for complex scientific discoveries (European Commission, 2003; Nishimura and Okamuro, 2011; Santos and Mendonça, 2017).

Hence, in countries where PIBERD is mostly provided through direct grants, firms desiring to benefit from public sponsoring for R&D need to seek out collaboration with other partners more often than in countries where PIBERD is mainly provided through tax credits. Eventually, some of these collaborations may proceed with public support, while others will take off even when the desired public funding is not received (Feldman and Kelley, 2006). In addition, new non-sponsored collaborations may follow sponsored ones and vice versa, since the collaboration logic is already developed amongst firm actors. As a consequence, policies encouraging collaboration in the R&D phase may facilitate the development of complex innovation systems that might otherwise be difficult to achieve, especially when industrial applications for complex scientific discoveries are envisaged (Martin and Scott, 2000; Nishimura and Okamuro, 2011). Conversely, in countries where PIBERD is mostly designed and provided using tax credits, fewer incentives to collaborate are created. By their nature, indirect tax credits are delivered to individual firms that file a claim with eligible expenses for eligible project types. There is no incentive to collaborate if expenses are not eligible to be claimed (Bodas Freitas et al., 2017). Thus, despite both policy instruments creating incentives for innovation, direct grants and indirect tax credits seem to provide incentives for different forms of organizing and interacting for innovation.

In addition, the literature on policy-mix argues that as different policy instruments interact, their expected impact on firms' behavior and performance may be different from the one it has been designed for (Flanagan et al., 2011). Certain combinations of policy instruments may complement, attenuate or have no effect on each other (Cunningham et al., 2013). The interaction effect occurs at firm level by leveraging firms' different R&D projects, by creating incentives to replace internal efforts with public funding or by the inability of firms to manage and integrate internal R&D efforts organized and managed using different governance modes. Empirical analyses, examining the effect of tax credits and direct public support simultaneous on firms' innovation suggest that indeed policy instruments seem to interact. For instance, Guerzoni and Raiteri (2015) show that the effect of tax credits and direct support for R&D on firms' innovation and their returns depend on whether the firm benefits from one or both types of support.

In sum, the form in which PIBERD is delivered – mainly through direct grants or indirect tax credits – seems to provide incentives for the development of different shared logics on how to access public money, how to leverage R&D investment costs and, consequently, how to organize for innovation. Thus, besides differences in the level of public support for innovation, national differences in the use of direct grants and indirect tax credits to support R&D may explain differences in the ability of firms to reap benefits from R&D collaboration.

We now discuss how the design of innovation policies in a country, relying more on direct grants or on tax credits, influence the network, organizational, and product development benefits that firms get from R&D collaboration.

A firm engaging in a large R&D collaboration will possibly find itself interacting with partners with whom it has little or no prior relationship. Extending its network of contacts and exploiting this network in

future innovation activities may ultimately depend, however, on the prevailing national incentives and logic of how to organize for R&D and innovation. In national contexts where PIBERD is primarily provided as direct grants rather than indirect tax credits, the prevailing logic for accessing public sponsorship will be through collaboration. Hence, in these countries, firms may have significant impetus to expand and advance their networks. In such contexts, firms will be more likely to already rely on networks for organizing innovation development and, as a result, the potential for expansion of the network will be significantly diminished. This argument is supported by evidence from an empirical analysis of firms in the US, Europe and Japan, which shows diminishing returns from interfirm collaboration in firms with greater collaboration experience (Sampson, 2005). Furthermore, evidence from the biotechnology industry (Powell et al., 1999) suggests diminishing returns for network benefits due to hidden costs related to communication and coordination of increasingly large and complex network relationships, beyond a certain network size. Hence, further R&D collaboration may be less effective in extending the network of contacts and partners for firms active in contexts where public support for innovation has typically been provided through direct grants than for those active in contexts where the design of PIBERD does not encourage interaction and collaboration.

Regardless of whether the firm is collaborating with new organizations, the objective of a sponsored R&D collaboration is to solve new technological problems. Given the unique nature of each technological problem, new forms of organizing various R&D tasks and managing interactions among the different teams will need to be defined (Nickerson and Zenger, 2004). In the process of establishing forms for coordinating work and interaction among partner organizations, firms may question the relevance of different practices for accomplishing certain objectives (Schøtt and Jensen, 2016). In addition, by interacting bilaterally with various partners, each with specific organizational structures and technological competences, firms will be exposed to many alternative forms of organization. These experiences may sensitize firms to new organizational solutions, and provide firms with knowledge on readapting organizational structures and work organization forms (Howard et al., 2016). Furthermore, in the pursuit of the R&D collaboration, new technological knowledge is developed. The integration of this knowledge into a firm's products and R&D projects may require not just training but also the adaptation of the firm's organizational structure or working processes (Bianchi et al., 2011b, 2011a).

In countries where PIBERD is mostly provided as direct grants rather than as indirect tax credits, firms are more likely to have greater experience interacting with other organizations for innovation. Through such experiences, firms may develop competences in pursuing organizational change to adapt their internal structures to their actual projects, technologies and partners. Indeed, evidence suggests that firms that have been exposed to greater levels of collaborative innovation will have developed capabilities that enable them rapidly learn and organize or reconfigure their practices and work processes (Grant and Baden-Fuller, 2004; Schøtt and Jensen, 2016). Considering that firms' market and technological contexts are not static, and firms' innovation activities also evolve in terms of available resources and partners, the need for firms to engage in organizational change is ever-present (Nonaka, 1994; Schøtt and Jensen, 2016).

Conversely, in countries where PIBERD is mostly provided through tax credits, firms will be less likely to have interacted with other organizations for research and innovation development, and will thus have

had less need to constantly readapt their work and knowledge dissemination routines to fit new projects with external partners (Howard et al., 2016; Powell, 1998). Consequently, they may be less likely to have developed capabilities for organizational adaptation in an open context (Powell, 1998). Hence, while it is possible for firms in these countries to have been exposed to new organizational formats and to evaluate internal organizational structures, the relatively lesser collaborative experience may negatively impact the expected organizational benefits from collaboration.

Finally, the reification of new knowledge into products is not a straightforward process, but depends on the absorptive capacity of the firm as well as its ability to seek out and access relevant knowledge from networks (Grant and Baden-Fuller, 2004; Nickerson and Zenger, 2004). As mentioned earlier, in countries where PIBERD is mainly provided through grants, firms are more likely to have greater experience interacting with other organizations and relying on a network of partners to access complementary resources and inputs for innovation development (Czarnitzki et al., 2007). During the process of integration of new, collaboratively developed knowledge, they count on learning, knowledge dissemination and internal work processes to leverage that knowledge to advance their products (Powell, 1998). In addition, firms may have further developed learning capabilities, which would be crucial in the process of integration of collaboratively developed or external knowledge. Conversely, where PIBERD is primarily realized through tax credits, the established logic for innovation organization would place less emphasis on collaboration and networking to access knowledge and innovation opportunities, and hence experience with external knowledge integration would be less (Howard et al., 2016; West and Bogers, 2014).

Based on these considerations we expect that, in national contexts where PIBERD is mostly provided through direct grants, firms will have developed the capability to learn from collaboration, and hence experience larger benefits in terms of product and technology advances, as well as organizational adaptation, but will be less likely to benefit from an expansion of their network. Thus, we hypothesize that:

***H1:** In national contexts where the design of public support for firm innovation relies more on direct grants than on indirect tax credits, firms will realize higher benefits in terms of new product and technology development, as well as organizational adaptation, but relatively lower network benefits.*

2.2.2 Diffusion of knowledge-revealing practices and the benefits from a public sponsored R&D collaboration

Diffusion of organizational forms and management practices in a country seems to result from an evolutionary process based on actors' perceptions of social and economic gains (Cantwell et al., 2010; Zucker, 1987). Hence, the level of diffusion of certain practices in a country reflects the degree to which these are recognized as the more efficient way to deal with the conditions presented by the institutional set-up (Dequech, 2009).

Recent evidence suggests that some firms engage in selectively revealing knowledge as part of their innovation strategy. This decision to freely disclose knowledge appears to be associated with the expectation that such knowledge will be used, modified and advanced by another organization, and will then eventually return in the form of disclosed knowledge or spillovers (Alexy et al., 2013). Scientific

publications are one means by which firms reveal their knowledge (Powell et al., 1999). As agents act in their perceived best interests in the absence of formal sanctions to enforce certain behavior (Dequech, 2009), the degree of diffusion of university-industry co-publication practices may reflect an underlying pattern of tolerance for the potential risk of knowledge leakage. The decision to collaborate for innovation involves balancing the benefits in terms of costs and time, the risk of knowledge leakage, and the risk of not being able to appropriate value created in the collaboration. These concerns are particularly relevant in the case of university-industry collaboration, as often the subject of collaboration is less immediately applicable and consequently the opportunities for spillover are greater (Czarnitzki et al., 2007; Dasgupta and David, 1994; Perkmann and Walsh, 2009). In addition, academics operate under a different institutional logic than industrial researchers (Merton, 1973; Stephan, 1996). The university system is rooted in norms of science that strongly encourage the open dissemination of knowledge, whereas firms are driven by incentives to appropriate knowledge for competitive advantage (Dasgupta and David, 1994). In this context, a firm deciding to co-author a publication of research results with an academic collaborator arguably results from a spillover of university norms to an industry partner, corresponding to the 'traditional' channel of interaction between Public Research Organizations (PROs) and Industry (Dutrénit and Arza, 2010). However, other explanations exist. For instance, publications may enhance firm reputation in the scientific community, allowing it to attract top talent, as well as signal to potential collaborators, investors and competitors the technical capabilities of the firm (Perkmann and Walsh, 2009; Powell et al., 1999).

In countries where KRP is relatively more widespread, firms may therefore consider revealing part of their technological puzzle and/or their plan to address the puzzle, in the expectation that knowledge revealing may encourage other firms or networks to engage with the puzzle, and that they in turn will also reveal at least part of the knowledge they develop (Alexy et al., 2013; von Hippel and von Krogh, 2003). Given the use of this mix of revealing and protecting knowledge on one hand, and seeking out disclosed knowledge on the other, countries where knowledge revealing is relatively more common will likely have evolved structural elements such as innovation intermediaries, technology markets and services, and intellectual property rules to facilitate further open innovation (Wang et al., 2012). Therefore, in countries where knowledge revealing is a relatively more common practice, the shared logic for innovation development will be somewhat more in line with the 'private-collective' innovation model proposed by von Hippel and von Krogh (2003), where organizations mix revealing and protecting knowledge in the pursuit of new technologies and products. Furthermore, in these countries, firms are likely to have developed competences that enable them to more effectively distinguish knowledge that needs to be kept proprietary from knowledge that becomes more valuable to the firm when diffused. The perceived cost of knowledge diffusion is therefore likely to be smaller than in countries where these KRP is less common (Abramo et al., 2009; Alexy et al., 2013).

Conversely, in countries where knowledge revealing is less widespread, the private model of innovation, where the results of innovation efforts are kept proprietary, is more likely to prevail. In this context, firms will be less likely to anticipate gains in knowledge-revealing and will thus seek to organize innovation development in a less collaborative and more contractual manner (Vasudeva, Zaheer and Hernandez, 2012). In these countries, where the shared logic of KRP is less established, firms refrain from

contributing to common pools of knowledge and efforts for collaborative scientific and technological advances.

We now discuss how the national level of diffusion of KRP influence the network, organizational, and product development benefits that firms get from R&D collaboration.

In national contexts where the shared logic of organizing innovation activities involves blending both revealing and protecting strategies, firms are likely to have developed competences in reaching out to external partners and exploiting structural elements available to support knowledge exchange to develop already advanced collaborative networks to a greater extent than in countries where these practices are less established. In these countries, there will thus be less room for firms improve their use of networks for innovation development and firms may consequently gain little, in terms of updating and expanding their networks, from participating in R&D collaboration when compared to firms in countries where knowledge revealing is not common.

The degree to which firms benefit in terms of organizational adaptation may also depend on the degree to which KRP are relatively established in the country. In contexts where KRP is widespread, firms will be more likely to have developed capabilities to adapt their organizational structure and routines to the evolution of their networks (Henkel et al., 2014). This is because the more common KRP is, the more likely it is that firms will have developed organizational structures that permit them to organize and learn through a mix of activities where knowledge protection and/or disclosure are at times encouraged. This results in firms being able to codify and internalize complementary knowledge for onward transformation into new knowledge and technologies (Alexy et al., 2013; Oliver, 2004). Firms in these contexts will therefore have developed the capability to learn and advance their routines, processes and organization when exposed to better practices by their network partners, or when technological or network development demands such organizational changes (Powell et al., 1996; Schøtt and Jensen, 2016).

Conversely, in national contexts where firms mainly view innovation activities as proprietary activities, exchanges may occur, but they would often need to involve complex contracts (Jarvenpaa and Välikangas, 2014). The sort of trust that facilitates such inter-organizational relationships (without resorting to highly complicated contractual agreements) takes time to build and would be largely non-existent in a context where these sorts of exchanges are underdeveloped (Zaheer et al., 1998). Hence, in this context, organizational inertia would be more likely to predominate. Also, being less involved in mixing knowledge revealing and protecting strategies, firms' experience and competences for organizational adaptation would be less advanced (Alexy et al., 2013).

Finally, firms operating in countries where knowledge revealing is considered a valid and relevant strategy for innovation development will have developed competences to access, integrate and apply revealed knowledge to their own solution search and product/technology development projects (Alexy et al., 2013; Oliver, 2004). These firms would thus be able to codify, internalize and externalize knowledge, as well as foster internal and external experimentation with the aim of improving their product and technology portfolios (Nonaka, 1994). These capabilities would further increase the

likelihood that firms would advance their products and technologies through participation in R&D collaboration and also increase their effectiveness at achieving this during R&D collaboration.

Based on the above, we hypothesize that:

H2: *In national contexts where knowledge-revealing practices are relatively more common, firms will realize higher benefits in terms of new product and technology development, and organizational adaptation, but relatively lower network benefits.*

3 DATA DESCRIPTION AND METHODOLOGY

To examine the effect of national embedding on the benefits derived from collaborative innovation, this study relies primarily on data from a 2011 survey of firms that took part in the 7th Framework Programme for Research and Technological Development (FP7), funded by the European Commission (EC). FP7 provided funding for precompetitive research and technological development projects. The program aimed to support capacity building and the development of external networks amongst different types of organizations – primarily firms, universities, public research organizations and consultants. FP7 had a budget of over €50 billion for the period covering 2007 to 2013, and was a key part of the EC's strategy to make the EU a global leader in R&D. Our use of data from FP7 allowed us to analyze project benefits for firms that had been exposed to largely the same supranational treatment across countries. While data has been collected in 2011, international R&D collaborations are nowadays still sponsored in quite similar terms as in FP7 under the EU's Horizon 2020 project. In addition, the European Commission is in the process of developing its successor, Horizon Europe. It is therefore clear that programs like FP7 will continue to remain the normalcy in the EU for the foreseeable future. Hence, examining benefits from participation in international R&D collaboration is still quite relevant to policymakers developing the next European innovation program, who are no doubt seeking to learn from past experiences.

Organizations participating in FP7 projects were awarded grants to cover a percentage of the costs of the different project activities. Co-funding rates were assigned according to the activity (Research and Development, Demonstration, Management, and Other) and the type of organizational partner. Small and medium enterprises (SME), and education and research organizations enjoyed a favorable co-funding rate (75%) for research and technological development activities; other organizations benefited from 50% co-funding. SMEs also received a special flat rate of 60% of direct costs to cover their overheads. Hence, FP7 attracted firms, including new technology-based firms, looking for opportunities to access finance, get support for technological development, and develop and expand existing network linkages.

In this original survey, 8,926 firms were contacted by email between May and August 2011, comprising the full population of firms in the FP7. Respondents were asked to complete a questionnaire online. The primary purpose of the survey was to determine the contribution of FP7 to firm innovation benefits as assessed by the firm. The survey also asked questions pertaining to the motives and strategies of the firm, as well as other questions to determine the nature of the consortium the firm belonged to for FP7

and questions to determine firm characteristics, such as size and industry. 1,301 responses were received. Of these, 436 responded to less than 20% of the questionnaire and provided no information on firm size, industry or country, and were therefore excluded from our analysis. Firms in countries outside of the EU were also dropped since there were very few firms per country (Albania, Bosnia and Herzegovina, Brazil, Canada, China, Iceland, India, Indonesia, Israel, Jordan, Mexico, Norway, Moldova, Russia, Serbia, South Africa, Switzerland, FYR Macedonia, Turkey and the USA). Considering our interest in national context, we also excluded from our analysis EU countries for which we had too few observations (≤ 10). This excluded Bulgaria (1), Croatia (3), Cyprus (5), Czech Republic (10), Estonia (3), Hungary (9), Latvia (3), Lithuania (2), Luxembourg (1), Slovakia (2) and Slovenia (6). Finally, we excluded countries for which national-level data on government support for business enterprise R&D used in our analysis were unavailable. Thus, we dropped Romania (13), Poland (16) and Sweden (31), leaving a total of 601 firms included in our final analysis. Based on a Chi-square test ($p=0.7842 > 0.05$) we fail to reject the hypothesis that there is no significant difference between the sample and the population distribution (see Table 1).

Insert Table 1 about here

3.1 Dependent variables

Benefits from participation in the FP7-funded R&D collaboration. The survey asked the firms to evaluate on a five-point Likert scale⁴ the effect of their FP7 project (or in the case of multiple, their most successful FP7 project) on firm performance in terms of network, organizational adaptation and technological and product advances, which we expect firms to have experienced based on the literature (Human and Proven, 1997; Caloghirou et al., 2004; Howard et al., 2016; Chesbrough, 2003). A factor analysis with VARIMAX rotation and a cut-off Eigenvalue of 1 confirms the items in each variable, as reported in Table 2. In addition, the factor analysis suggests that these three factors collectively explain 86% of the variance in the data. These factors represent a firm's evaluation of the contribution of FP7 to firm performance in building and developing networks of partners, reorganizing work organization and processes as well as knowledge management systems in the firm, and developing or refining technologies, products and services respectively. Based on this information, three ordinal variables – *Network benefits*, *Organizational benefits* and *Product development benefits* – were created by summing the respective items. We took 3, contribution of the EU project as 'important', as the threshold for high contribution, and defined the level of the benefits as follows:

The variable took the value of 2 if:

$$\sum i_{value} \geq n_{items} \times 3 \quad (1)$$

⁴ Respondents were asked to rank each benefit in the order of 'not achieved', 'contribution not important', 'contribution somewhat important', 'contribution important', 'contribution very important'.

The variable took the value of 1 if:

$$0 < \sum i_{value} < n_{items} \times 3 \quad (2)$$

The variable took the value of 0 if

$$\sum i_{value} = 0 \quad (3)$$

Where:

i_{value} = the numerical score on each item

n_{items} = the number of items used to measure a benefit

Hence, the three benefit variables take values of 0 to 2, with 0 representing benefits that were not achieved, 1 represented contributions that were evaluated as being low, and 2 represented contributions that were evaluated as being high.

Insert Table 2 about here

3.2 Independent variables

Design of the national innovation policy mix. To capture information on the differences in national public incentives for open and collaborative R&D, we account for the form which PIBERD is designed. The variable *PIBERD ratio* reports the ratio of level of PIBERD provided through direct grants to the level PIBERD provided through indirect tax incentives. This variable, being a ratio, reports the degree to which both instruments are used in a country. Countries with larger ratios are those in which public R&D and innovation support is mostly provided through direct incentives, while countries with smaller ratios are those in which public support is mainly constituted by indirect tax credits. Since this is a national-level variable, it does not account for the fact that some firms in our sample may have received both types of incentives in the past, nor is that the intention (we return to this issue in the robustness section, where we provide further results controlling for firms' use of different instruments).

Diffusion of knowledge-revealing practices (KRP). To capture the shared logic in the ecosystem for openness, we focus on the extent of knowledge-revealing behavior in the country. In the process of collaborative knowledge development, new scientific and technological knowledge is developed, and making it public through publication reflects the disclosure willingness of the parties involved in developing that knowledge. As publications are mainly an output of academics, we obtained data on public-private co-publications at the country level from the EC's 2010 Innovation Union Scoreboard (now known as the European Innovation Scoreboard). The variable *diffusion of KRP* provides an indication of

how widespread KRP are in a national context. It is a continuous variable that indicates the number of public-private co-authored research publications per million of the population of research articles. The definition of the "private sector" excludes the private medical and health sector. Publications are assigned to the country/countries in which the business companies or other private sector organizations are located. Although the ratio of collaborative publications may not reflect the full extent of knowledge-revealing logic in a country, comparatively, in countries with higher levels of public-private co-publications, firms are more likely to share a stronger culture of knowledge revealing than in countries with lower levels of co-publications. Other studies have similarly used co-publications to measure willingness to reveal knowledge to the ecosystem. For example, Powell et al. (1996) argue that highly visible scientific publications have been used to signal the knowledge accumulated in a firm to investors and top talent. Similarly, this metric has been used to indicate an external expression of knowledge accumulation by a firm (Baba et al., 2009), and collaboration between industry and academic researchers in tissue engineering (Murray, 2002).

3.3 Control variables

Other factors may influence firms' ability to benefit from publicly sponsored R&D collaborations. We thus control for several firm and project characteristics. In addition, we include other national factors that may provide alternative explanations for the relationship we aim to test.

3.3.1 Firm characteristics

We control for firm size, based on number of employees, since this may influence a firm's ability to innovate in different market structures and industries (Acs and Audretsch, 1987). The variable *size* is ordinal and ranges from 1 to 6, where 1 is 0-50 employees and 6 is greater than 1000 employees.

Next, we account for whether firms are start-ups. Start-ups have less financial capacity and organizational capabilities, and participation in sponsored R&D collaborations may provide such firms with opportunities to access otherwise inaccessible resources (Hall, 2002). The variable *start-up* is a dichotomous variable that distinguishes start-ups (two years old or younger) from older firms (older than two years).

R&D-intensive firms may have greater absorptive capacity to better exploit and appropriate the results of publicly sponsored R&D collaboration (Ritala and Hurmelinna-Laukkanen, 2013). We therefore control for the R&D intensity of the firm (Cohen and Levinthal, 1989). The variable *R&D intensity* is an ordinal variable ranging from 1 to 8, where 1 represents 0% of firm revenue invested in R&D, and 8 represents 40% or more of firm revenue invested in R&D.

We also control for firm strategy, considering that this has a significant effect on the innovation success of a firm (Ritter and Gemünden, 2004). The survey asked firms to indicate the importance of each of 31

activities to their innovation strategy in the last four years⁵. A principal component analysis with VARIMAX rotation subsequently identified five factors (composed of 17 items) with Eigenvalue greater than 1, shown in Table 3. Based on this information, we created five dichotomous composite variables that identified the presence of five different management strategies. We took 3 (a rating of the activity for the firm's innovation strategy as 'important') as the threshold for strategies' high importance, and defined the variables as follows:

Strategy takes value 1 if:

$$\sum i_{value} \geq n_{items} \times 3 \quad (4)$$

Strategy takes value 0 if:

$$0 \leq \sum i_{value} < n_{items} \times 3 \quad (5)$$

The five dichotomous strategy variables created are the following. *Product strategy* indicates the importance of activities related to the development and improvement of products and technologies for the firm. *Knowledge management strategy* indicates the importance to a firm's strategy of improving activities pertaining to the development and flow of new knowledge internally, and the accessing and integration of externally sourced knowledge. *Cost efficiency strategy* indicates the importance of cost savings and waste reduction to a firm's strategy. *Openness strategy* indicates the importance of maintaining R&D networks and access to the latest scientific developments to a firm's innovation strategy. *Supply chain strategy* indicates the importance of concerted efforts to strengthen the positioning of a firm in its supply chain through differentiation from competitors or closer integration with customers.

Insert Table 3 about here

Finally, we include industry fixed effects to control for industry-level variations that may influence innovation success. A firm's industry sector has been shown to have a direct impact on the innovation outcomes of different types of firms (Acs and Audretsch, 1987; Malerba, 2002).

3.3.2 Project characteristics

We control for the role of the firm in its FP7 consortium to account for differences in outcomes due to the firm's role as coordinator or as a partner. The dichotomous variable *role* takes value 1 if the firm was

⁵ Possible responses were presented in a four-point Likert scale, with assigned numerical values: 1 ('not important'), 2 ('somewhat important'), 3 ('important') and 4 ('very important').

a partner of the project and 0 if the firm was project coordinator. Coordinating firms will have greater influence over the direction of the project and may thus steer the course to ensure that the project objectives are most closely aligned with their own interests.

Considering empirical evidence from the literature that firm-university collaboration may affect innovation success (Baba et al., 2009; Giuliani and Arza, 2009), we control for the presence of a university partner in the consortium to account for interaction between firms and their university partners (Dutrénit and Arza, 2010) in their FP7 consortium using the dichotomous variable *university*.

Finally, as empirical research on R&D policy has shown that a firm's level of effort in learning from a collaborative project may significantly depend on its motives for participation (Veugelers, 2012), we have also controlled for firms' FP7 project participation motives. The survey asked firms about their motives for participating in that FP7 project. A factor analysis identified three motives driving firms in this project, as shown in Table 3 (nine items). Based on this information, we created three composite dichotomous variables using the same procedure as the composite variables for strategies in equations 4-5. The variable *finance motive* refers to the motivation to access financial support; *network motive* refers to the motivation to build and improve collaboration networks; while *technology motive* refers to the motivation to acquire support for developing and maintaining technological leadership.

3.3.3 Country characteristics

While our account focuses on shared logics of knowledge-revealing and public incentives for innovation, we recognize that alternative national characteristics may explain differences in firms' abilities to learn and benefit from R&D collaboration. We therefore control for the relative level of PIBERD using the variable *PIBERD/GDP*. This variable reports government support for BERD as a percentage of GDP. Empirical evidence suggests that such support can significantly positively influence innovation outcomes (Hall and Van Reenen, 2000).

Next, the level of trust in the country may also affect the performance of a firm by creating an environment in which firm activities related to the FP7 program are regarded as more or less legitimate (Mueller et al., 2013; Scott, 2003). We note that, although all the countries included in our analysis were members of the EU, the level of public trust in EU organizations and initiatives varies across countries. Thus, we account for the level of public trust in the program funding organization (EU), which may reflect cultural-cognitive perceptions that may spillover to the funded program initiative itself (FP7). The variable *EU trust* measures the degree of national trust in the EU, based on data from the 2010 EUROBAROMETER survey. In that survey, approximately 1000 respondents in each EU country were asked whether they tended to trust or not trust the EU. The variable *EU trust* measures the percentage of these respondents that claim to trust the EU as an institution. Finally, we account for systematic differences in economic environment, risk, regulation, performance and other unobserved factors by using a mixed effect estimation approach, as will be discussed in the following section.

Table 4 reports the descriptive statistics of all the study variables. Table 5 reports the correlation coefficients amongst all other variables. The correlation coefficients do not raise any concern of multicollinearity.

Insert Table 4 about here

Insert Table 5 about here

3.4 Data analyses strategy

Since firms in our sample are nested in different countries, we consider that unobserved variables at the country-level might lead to correlations in our error terms. Consequently, we have used a multi-level model where we account for country-level variance as a random variable in addition to country fixed effects. Our firms are also nested in industries; however, industries are global, not nested in countries, especially in Europe. Still, the industrial activities in which firms operate influence their innovation opportunities, and possibilities of appropriation (Malerba and Orsenigo, 1997). Therefore, we account for industrial sector grouping as a fixed effect variable. In the robustness section, we report results using a multi-level model in which firms are nested in industries, which are nested in countries. Finally, since the dependent variables are ordinal, we estimate our model using ordered probit regressions.

4. RESULTS

Table 6 shows the results of the multilevel ordered probit random intercept models with network benefits, organizational benefits and product development benefits as dependent variables. Results provide some support for all hypotheses.

Insert Table 6 about here

The coefficient of PIBERD ratio is negative and significant (-1.462, $p<0.001$) for network benefits, positive and significant (2.378, $p<0.001$) for product and technological development benefits, and for organizational benefits (1.028, $p<0.01$). This result supports the proposition in H1 that, in countries where innovation policymakers make greater use of direct grants instead of tax incentives, firms are more likely to have developed competences that permit them to leverage the organizational and

product/technological development benefits of R&D collaboration, but would consequently see less advances in the network benefits.

The coefficient of diffusion of KRP is negative and significant for network benefits (-0.0153 , $p < 0.001$), positive and significant (0.0228 , $p < 0.001$) for product and technology development benefits, and positive and weakly significant for organizational benefits (0.00521 , $p < 0.1$). This suggests some support for H2, which proposed that, in countries where selective KRP is more diffused, firms are more likely to achieve organizational and product/technology advances from participation in R&D collaboration than in countries where those practices are less diffused.

To better understand the effect of policy design and degree of diffusion of KRP, we estimated the predictive probabilities for each level of benefits: no benefit, some benefits, and high benefits. The predictive probabilities are plotted in figures 1-6 at different levels of the independent variables. First, we comment the first three figures that plot the relationship between the predicted probabilities for different levels of network, organizational and product development benefits based on changing PIBERD ratio.

Figure 1 shows that the predicted probability for *no network benefit* increases and the predicted probability for *high network benefits* decrease with increasing PIBERD ratio. The predicted probability for *some network benefits* curves downward around the middle of the second quartile. Figure 2 shows that the predicted probabilities for *no organizational benefit* which decreases with increasing PIBERD ratio, while the predicted probability for *high organizational* benefits increases quite steeply. The predicted probabilities for some organizational benefits curves downward around the end of the first quartile. Figure 3 shows that the predicted probability for *some product development benefits* approaches a U-shape relationship with PIBERD ratio. Instead, the predicted probability for *high product development benefits* increases with increasing PIBERD ratio and flattens out just below a 0.8 probability around the average. Predicted probabilities for *no product development benefit* are low, and relatively stable, only showing considerable decrease for very high values of PIBERD ratio.

We now comment the figures 4 to 6 that plot relationship between the predicted probabilities for different levels of network, organizational and product development benefits and the level of diffusion of KRP.

Figure 4 shows that the predicted probability for *no network benefit* steadily increases with KRP while the probability for *high network benefit* decreases. The predicted probability for *some network benefits* shows a very flat inverted U-shaped relationship with KRP. Figure 5 shows that the predicted probabilities for *no organizational benefit* decreases with the level of diffusion of KRP, while the predicted probabilities for *high organizational* benefits increases, and *some organizational benefits* increase at a much lower rate. Figure 6 shows that the predicted probability for *no product development benefit* is very low and decreasing with KRP reaching almost 0 in the third quartile. Instead the predicted probability for *high product development benefits* increases steeply with KRP. The predicted probability for *some product development benefits* slopes quickly downwards as it nears the average.

Insert Figures 1-6 about here

The controls for firm characteristics behaved as follows. Knowledge management strategies significantly and positively explained the variation of all three benefits, consistent with findings from other studies that also place knowledge as a central resource in open innovation (Roy and Sarkar, 2016). Supply chain and product strategies significantly and positively predict benefits in product development. Also, an openness strategy significantly implies greater benefits in networking, suggesting that firms seeking out collaborations are more likely to find them than firms that do not. Only cost efficiency strategies were nonsignificant for the three types of benefits we consider. Firm size did not have any significant relationship with the benefits of open innovation, except for networking benefits, where the relationship was negative. This is consistent with other research (Lee et al., 2010) that shows SMEs are often better positioned to benefit from networking in open innovation than larger firms. Neither R&D intensity nor the age of the firm (start-up) had a fully significant effect on the three benefits we consider. Finally, a firm's industrial sector does not appear to have much relevance to network or product development benefits, but firms in knowledge-intensive services appear to significantly outperform other firms on organizational benefits.

The controls for project characteristics behaved as follows. Firms that joined FP7 to gain financial incentives for R&D were more likely to record higher gains in network and organizational benefits than other firms. This relationship did not spill over to product development benefits, however. By contrast, firms that were motivated to network did see greater gains across all three benefits. This is consistent with research that shows that taking advantage of policy support systems for networking (in this case FP7) significantly predicts all-round innovation success (Nishimura and Okamuro, 2011). Firms that showed high motivation to develop technology and products were more likely to see gains in network benefits but did not actually see much gain in product development or organizational benefits. This result suggests that at least with regard to product or technology development, firm strategy, rather than motive has greater relevance.

Also, as expected, the coefficients for the variable *role* are all significant and negative, implying that firms that have coordination roles in their consortiums and hence greater leverage in decision-making perform better on all benefits than firms that do not have such a coordination role (cf: Powell et al., 1999). Finally, having a university partner in the consortium influenced the degree of organizational benefits from sponsored R&D collaboration. Having a university partner in the consortium did not, however, show any relationship to network or product development benefits. This result suggests that indeed not all innovations are science-based (Caraça et al., 2009) and that organizational learning may be fostered through interaction with organizations with distant organizational structures (Howard et al., 2016).

National variables showed strong association with all three benefits from sponsored R&D collaboration, although the directionality differed across benefits. Firms in countries with greater trust in the EU tended to show lower gains in network benefits, but higher gains in organizational and product development benefits. Perhaps firms in countries that more readily trust the EU have a more positive attitude towards interaction with foreign organizations and are consequently more likely to be experienced in relying on

networks for innovation development. On the other hand, firms in countries with greater PIBERD as a share of GDP exhibited the reverse relationship, where greater support for BERD led to greater networking benefits for firms but lower organizational and product development benefits, suggesting that from an institutional perspective, the way PIBERD is administered is at least as relevant than the total outlay.

4.1. Robustness check

We perform several tests of the robustness of our results. The results of these tests are available upon request from the authors.

We have re-estimated our models using alternative estimation methods. First, we re-estimate our main model, but assuming that industries are nested in countries. Second, we consider that the three dependent variables are related because they measure firm innovation outcomes and thus have strong conceptual linkage. Correlation coefficients (all coefficients > 0.3) lend some support this consideration. We therefore estimate the ordinal probit regressions using a conditional mixed process (CMP).⁶ Third, we estimate the achievement of each benefit individually using a non-multilevel ordered probit where in-country correlation is only accounted for by fixed effects and clustered standard errors. The results of these alternative estimation methods provide support to our hypotheses.

Next, we consider that the benefits from grants for R&D may depend on whether the firm has recently benefited from other public support for innovation (Guerzoni and Raiteri, 2015). In the survey, we have information on whether firms in the last 4 years have benefited from tax credits. We rerun our main model including a dichotomous variable that capture that information. Results hold. Still firms that use of tax credits do not seem to experience significantly different network, organizational or product and technology benefits from the FP7 collaboration. This result hints that firms operating in different institutional environment use public support in different manners. Alternatively, it may that the form in which European innovation support interacts with national tax credits is not the same as form in which national direct grants and national tax credits interact.

Third, we test if our main results hold when we focus on firms with different technological and organizational characteristics. First, we split the sample between firms that invest strongly in R&D (more than 20% of their sales) and those that invest relatively less (those that spend less than 20%). These subsamples respectively represent 58% and 42% of observations. Results hold fully for the subsample of firms that spend less than 20% of their sales in R&D. By contrast, in the subsample of firms that spend more than 20%, we find only the effect of national institutions on network benefits to be significant (and

⁶ The CMP framework is an extension of Zellner's Seemingly Unrelated Regressions (SURs) (Zellner, 1962). SURs are a system of equations in which the error terms are possibly linked, and the dependent variables may be related. Unlike when the equations are estimated separately, the SUR procedure allows the error terms to correlate. CMP estimation permits the use of maximum likelihood estimation, unlike classical SUR modelling which is restricted to ordinary least squares estimation (see Roodman, 2011, for a formal conceptual description of CMP estimation).

negative). This suggests that firms that invest strongly in R&D develop strong organizational and network learning capabilities from external partners, and while participation in sponsored R&D collaborations forms part of their strategy, such work may merely accelerate other ongoing individual and collective projects. Thus, they are not likely to recognize high gains from public sponsored R&D collaboration. We also divide our sample between larger and smaller firms in terms of number of employees, creating one subsample of firms with less than 100 employees and another of firms with more than 100 employees. In this case, these subsamples respectively represent 71% and 29% of observations. We note that firms with less than 50 employees represent 65% of our total sample. Results hold fully for the subsample of smaller firms. For larger firms, the results hold for organizational benefits and product development benefits, but not for network benefits. This suggests that large firms, which have greater capabilities and resources to identify the value and use the new knowledge developed in collaboration with external partners.

Finally, we test for common method bias. While the survey questions are posed in a direct and objective way, and refer to objective processes and strategies, the full questionnaire was completed by one individual per firm, and several questions use a Likert scale. We apply Harman's single-factor test (Podsakoff et al., 2003), and find that two factors explain 82% of total variance⁷.

5. DISCUSSION

We used data on 601 European firms that participated in the EU's FP7 program to examine how the national institutional context influences the benefits a firm may derive from that public sponsored R&D collaboration. We distinguish three types of benefits a firm may obtain from participating in open innovation based on collaborative contribution: building or expand a network of partners (network benefits), reorganizing work and process structures (organizational benefits), and developing or refining products and technologies (product development benefits). We examined the direct effect of the design of public financial incentives for business expenditure on R&D, and of the degree of diffusion of knowledge-revealing practices across different these three types of benefits. We analyzed the data using multilevel models and we put our results to several sensitivity tests.

Our results suggest that firms attain greater product development, and to a lesser extent, greater organizational benefits from R&D collaboration in countries where collaboration logics have been fostered by the design of policy mix for business R&D and by diffusion of knowledge-revealing practices. Networking benefits, by contrast, are greater amongst firms active in countries where collaboration logic is relatively less developed and established. More specifically, firms that experienced greater product, technology and organizational benefits from participating in FP7 sponsored R&D collaboration are those operating in contexts where public R&D support is mostly provided through direct grants rather than tax

⁷ One includes national trust in the EU, all motives and some strategies. The other includes PIBERD ratio, knowledge-revealing practices, firm size, firm R&D intensity, participation of university in the consortium, some strategies and, with a negative sign, network benefits.

incentives, as well as where publication of collaborative knowledge outcomes are relatively more widespread.

Taken together, the results suggest that in countries where firms are more exposed to institutional and economic incentives for organizing innovation activities through interaction with other organizations and sharing scientific findings, firms are more likely to develop capabilities that allow them to leverage a network of partners to access resources and inputs to advance their technological and product development projects. In doing so, logics develop that facilitate inter-organizational collaboration (without resorting to highly complicated contractual agreements) and greater tolerance for knowledge leakage (Alexy et al., 2013; Wadhwa et al., 2017). Operating in countries with relatively strong collaboration logics, firms find fewer opportunities to further advance their network through participation in each additional R&D collaboration but are well placed to advance their organization and products/technologies.

Our results also hint that firm strategy rather than motive is more important for the attainment of product development benefits. While this result calls for further research to investigate the other forms of R&D collaborations, we consider that it is the case that the implementation of these large international R&D collaborations involves communication barriers and are likely to suffer from high transaction costs limiting the possibility to develop very novel technologies without a put-together strategy, regardless of intention (Wagner et al., 2019).

6. CONCLUSION

To address questions regarding the wider context of open innovation performance, this study set out to understand whether and how the national institutional context might influence the benefits a firm can derive from R&D collaboration. Building on institutional theory, we proposed that, in a national institutional context, a collaboration logic develops, underpinned by the design of policy support for innovation as well as knowledge-revealing practices amongst firms. We examine our expectations empirically relying on data from 601 firms that benefitted from EU FP7 support. Our results suggest the existence of a country-level collaborative logic that influences firm performance in collaborative innovation irrespective of firm size, age, strategies or motivations among other factors. By shaping the nature of interactions in the ecosystem and the preferred choices for organizing innovation, this national collaborative logic may influence the ability of firms to benefit from R&D collaboration.

These results provide three main contributions to the literature. First, we contribute to open innovation theory by extending prior analyses of the effect of national institutions on the benefits firms reap from open innovation. We move beyond the aggregate level (Varsakelis, 2001), where analysis has been done on the effect of national institutions on national-level aggregate R&D outcomes, by using a multilevel perspective in which cross-country differences in firm-level gains from R&D collaboration are analyzed as resulting from differences in firm strategy and organization, collaborative project characteristics, and the institutional context in which the firm operates. We thus respond to recent calls to further open innovation research at the macro level, using multilevel analyses (Bogers et al., 2017; West et al., 2014).

Second, we contribute to the literature on innovation policy, by examining whether and how the form in which public support for R&D is designed and delivered influences the degree to which firms learn from R&D collaboration. We show that, *ceteris paribus*, in countries where direct grants rather than tax credits are used to deliver R&D support, firms tend to experience greater organizational and product benefits. While the literature has provided evidence that different policy instruments may lead to different investment decisions and performance at the firm level (Busom et al., 2014; Czarnitzki et al., 2007), it has been mostly silent regarding the leveraging effect that national policy mix for R&D support creates for firm-level gains from sponsored R&D collaboration.

Third, we contribute to the institutional theory literature. We add to this body of literature by providing evidence that a national collaborative logic may develop reflecting the existing economic and institutional incentives for specific forms of organization and management. In addition, our results suggest that, despite the high relatedness of network, organizational and product/technology innovation benefits of participating in R&D collaboration (Caloghirou et al., 2004), firms' national institutional settings may influence the probability and degree of attainment of each benefit differently. In other words, while the process of innovation may involve a technological and organizational learning process within the firm and across its network (Anand and Khanna, 2000; Costa and Mendonça, 2019), the national institutional logic may leverage or limit the ability of firms to gain network, organizational and product innovation benefits from participating in R&D collaboration.

Our findings suggest some policy implications. First, while tax credits have been shown to create additionality in firms' R&D investments and on firms' innovation outputs (Bodas Freitas et al., 2017), our results suggest that in countries where grants are preferred to tax credits as an instrument to support and encourage firms' R&D activities, a national collaborative logic may be encouraged, which favors firms to reap product and organization benefits of open innovation. Thus, two countries pursuing the same policy objective using a similar amount of resources but relying on different forms of delivery are likely to observe differences in firms' behavior and performance in response to R&D sponsored activities. Finally, our findings relating to the effects of knowledge-revealing practices on R&D collaboration suggest that it is crucial for policymakers to boost knowledge sharing practices in all the domains. In particular, when it comes to public sponsored university-industry collaborations, it is important to give consideration to more fostering the publication of the knowledge outcomes and avoid a single-minded preference for proprietary outcomes such as patents or prototypes, whose economic value may be more easily measured (Caraça et al., 2009).

This study is not without limitations and addressing them may open new research directions. First, this study relies on survey data on firms that benefitted from the EU FP7 program to examine whether there were systematic national differences in the extent of the benefits that firms experienced from participating in this public supported R&D collaboration and if those differences were explained by the national openness logic. Instead, our data does not allow us to examine the impact of participation in FP7 on firms' performance, which would require a different research design and different data.

Second, we have measured outcomes of the R&D collaboration based on a cross-sectional survey. Future studies might consider secondary sources to track benefits, such as sales for product development benefits, response time for organizational benefits, and contract complexity for network benefits.

Third, to get a clearer and more longitudinal perspective of the effects of national institutional context on firms' R&D collaboration participation benefits, future research could aim at getting information on the long-term effects of participating in R&D sponsored collaboration. Also, our analysis focuses on the relevance of one specific aspect of the institutional setting, the national collaborative logic, it would be interesting to understand the effect of other aspects of the national institutional setting related to national vision and efforts towards a more social and/or environmentally friendly society. In addition, efforts could be made to examine the long-term effect of the R&D collaborations on the firm and on its industrial partners, investigating if heterogeneity could be explained by the national institutional context.

Fourth, publicly sponsored R&D collaboration has been shown to differ from non-sponsored collaboration in several aspects: type of R&D activities undertaken, form and intensity of interaction amongst partners, and administrative burden entailed (Matt et al., 2012). Given the nature of our data, we cannot make pronouncements on those differences. Future research is needed to establish whether national institutions affect the benefits of non-publicly sponsored collaborations in a similar manner.

Finally, due to the nature of our sample, comprising only firms in wealthy European countries, we cannot be certain that these results will be generalizable to less advanced economies, or to non-European cultural contexts.

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Table 1: Population and sample distribution by country

	Population (%)	Sample (%)
Germany	15.3	20.3
United Kingdom	11.6	12.2
France	9.7	9.5
Italy	9.4	13.0
Spain	8.3	13.5
The Netherlands	5.3	8.2
Belgium	3.9	4.8
Austria	2.9	3.0
Greece	2.5	2.2
Denmark	2.2	4.7
Finland	1.8	2.5
Portugal	1.7	1.7
Ireland	1.5	3.3

Table 2: Composite items of dependent variables*

Benefits	Items
<i>Network benefits</i>	Introduced changes in the external relationships of your company (e.g., put in place collaborations or alliances; outsourced some activities)
	Built a network of partners for setting up future consortia
	Improved the image of your company as a technologically active company
	Accessed new European and international markets
<i>Organizational benefits</i>	Introduced changes in the forms of organizing work within the company (e.g., decentralization, business re-engineering, cross-functional teams)
	Introduced new Knowledge Management practices (e.g., improved use of internal competences, incentivized creativity and performance)
<i>Product development benefits</i>	Developed new technologies and product lines previously not at the core of your business
	Refined technologies and product lines at the core of your business
	Improved the understanding of foundations of particular phenomena with relevance for future product development
	Introduced a product that was new to your market (i.e., not existent in the market yet)
	Introduced new product design
	Introduced a service that was new to your market (i.e., not existent in the market yet)
	Introduced a product or service design that was new to your company but that already existed in your market

**Respondents were asked the question: 'With reference to your FP7 project, please indicate if during the last 4 years your company achieved any of the following results and to what extent that specific FP7 project contributed to their achievement.'*

Table 3: Strategy and motive variables and composite items*

Strategy	Items
<i>Product strategy</i>	Developing new product designs or improve existing designs
	Developing highly customized products through interaction with customers
	Integrating diverse external information and technologies into new multi-technology products
<i>Knowledge management strategy</i>	Adopting more efficient management information systems
	Introducing new or improving existing incentives (financial or non-financial) to motivate the creativity and productivity of employees and teams
	Improving teamwork design to enhance teams' creativity and output
	Improving the information flows across teams and departments
	Monitoring and improving the work organization and labour division
<i>Cost efficiency strategy</i>	Revising practices for searching and using information from sources external to the company
	Developing environmentally friendly products and services
	Reducing the use of input and energy
<i>Openness strategy</i>	Adopting more efficient equipment
	Keeping updated on scientific knowledge developments
<i>Supply chain strategy</i>	Keeping research collaborations with university or public research organizations
	Certifying (or maintaining certification) with ISO 9000 or ISO14001
	Negotiating or restructuring the position in the supply chain
Motive	Adopting standards developed by your largest customers (related to design, production, delivery or post-sale processes)
<i>Finance motive</i>	Obtaining financial support for the development of a new technology or product line
	Obtaining financial support for the refinement of existing technologies and products lines
<i>Network motive</i>	Enlarging the network of partners (including suppliers or customers)

	Improving the image of the company towards stakeholders
	Gaining early access to knowledge and networking resources in a specific technological area
	Networking with other important players
<i>Technology motive</i>	Maintaining industry technological leadership
	Developing competencies in a technological field expected to be important for your business
	Acquiring knowledge or technical support for solving technological problems

**Strategy: Respondents were asked the question: "How important have the following activities been for the innovation strategy of your company in the last 4 years?"*

**Motive: Respondents were asked the question: "Please indicate how important the following motivations were for your company to apply for financial support under FP7."*

Table 4: Summary statistics of dichotomous and continuous variables

	Variable	Mean	Std. Dev.	Min	Max
<i>Benefits of collaborative innovation</i>	Network benefits	1.32	0.52	0	2
	Organizational benefits	0.76	0.65	0	2
	Product development benefits	1.05	0.37	0	2
<i>Institutional collaborative logic</i>	Diffusion of Knowledge revealing practices	47.33	29.32	8.70	123.20
	PIBERD ratio	2.12	2.67	0.13	7.00
<i>Firm strategy</i>	Knowledge management strategy	0.26	0.44	0	1
	Cost efficiency strategy	0.37	0.48	0	1
	Supply chain strategy	0.24	0.43	0	1
	Product strategy	0.67	0.47	0	1
	Openness strategy	0.81	0.39	0	1
<i>Other firm characteristics</i>	Size	2.15	1.83	1	6
	R&D intensity	5.14	2.15	1	8
	Start-up	1.93	0.25	0	1
<i>Firm motives</i>	Finance motive	0.63	0.48	0	1
	Network motive	0.68	0.47	0	1
	Technology motive	0.63	0.48	0	1
<i>Other project characteristics</i>	Role	1.82	0.39	0	1
	University	0.89	0.31	0	1
<i>National characteristics</i>	PIBERD/GDP	0.11	0.05	0.02	0.24
	EU trust	0.41	0.10	0.20	0.61

Table 5: Pearson correlation coefficients for independent and control variables

	KRP	P-mix	KMS	CES	SCS	PS	OS	Size	RI	SU	FM	NM	TM	Role	Univ	P/GDP	ET
Diffusion of KRP (KRP)	1.00																
PIBERD ratio (P-mix)	0.10	1.00															
Knowledge management strategy (KBS)	-0.05	-0.01	1.00														
Cost efficiency strategy (CES)	0.03	0.03	0.32	1.00													
Supply chain strategy (SCS)	-0.06	0.01	0.32	0.36	1.00												
Product strategy (PS)	0.01	0.08	0.17	0.27	0.23	1.00											
Openness strategy (OS)	-0.10	-0.04	0.12	0.08	0.04	0.11	1.00										
Size	0.02	0.04	0.03	0.28	0.23	0.13	0.12	1.00									
R&D intensity (RI)	0.01	-0.02	-0.05	-0.17	-0.15	0.03	0.16	-0.32	1.00								
Start-up (SU)	0.11	0.04	-0.02	-0.02	-0.04	-0.02	0.03	0.05	0.01	1.00							
Finance motive (FM)	-0.02	0.02	0.03	0.01	0.10	0.15	0.05	-0.03	0.14	0.03	1.00						
Network motive (NM)	-0.10	-0.09	0.15	0.03	0.13	-0.03	0.20	0.01	0.08	0.00	0.14	1.00					
Technology motive (TM)	0.03	-0.03	0.12	0.12	0.18	0.19	0.14	0.10	0.05	-0.01	0.27	0.32	1.00				
Role	0.11	0.08	0.03	0.05	0.01	0.08	-0.05	-0.16	0.08	-0.04	0.03	-0.08	-0.02	1.00			
University	0.04	0.04	0.00	-0.05	-0.05	-0.01	0.02	-0.03	0.10	0.10	0.07	0.03	0.00	0.06	1.00		
PIBERD/GDP (P/GDP)	0.00	-0.29	-0.06	-0.02	-0.02	-0.10	0.00	0.12	0.02	0.08	-0.07	0.00	-0.02	-0.04	0.00	1.00	
EU trust (ET)	0.27	-0.17	-0.02	0.13	0.03	0.10	0.00	0.04	0.01	-0.04	0.03	0.10	0.06	0.06	-0.03	-0.11	1.00

Table 6: Random intercept multilevel estimation of the benefits of participation in funded R&D collaboration

	(1) Network benefits		(2) Organizational benefits		(3) Product development benefits	
Diffusion of KRP	-0.0153***	(0.00322)	0.00521~	(0.00298)	0.0228***	(0.00331)
PIBERD ratio	-1.462***	(0.333)	1.028**	(0.328)	2.378***	(0.351)
Knowledge management strategy	0.365***	(0.0839)	0.519***	(0.154)	0.462**	(0.168)
Cost-efficiency strategy	-0.0302	(0.110)	0.0503	(0.0886)	-0.0508	(0.193)
Supply-chain strategy	-0.0296	(0.161)	0.201	(0.149)	0.245*	(0.120)
Product strategy	0.142	(0.112)	0.127	(0.0911)	0.595***	(0.169)
Openness strategy	0.286*	(0.123)	0.0278	(0.0896)	0.0903	(0.123)
Size	-0.135***	(0.0364)	-0.00185	(0.0406)	-0.0250	(0.0275)
R&D Intensity	0.0286	(0.0340)	-0.0143	(0.0323)	0.0120	(0.0279)
Start-up	-0.309~	(0.184)	-0.351	(0.245)	0.0655	(0.246)
Finance motive	0.227*	(0.0960)	0.261**	(0.0798)	0.117	(0.163)
Network motive	0.647***	(0.152)	0.593***	(0.126)	0.344*	(0.135)
Technology motive	0.498***	(0.126)	0.136	(0.110)	0.0823	(0.177)
Role	-0.445**	(0.169)	-0.176*	(0.0760)	-0.453***	(0.101)
University	0.242	(0.163)	0.409*	(0.170)	-0.0655	(0.239)
PIBERD/GDP	14.05***	(2.220)	-6.899*	(3.011)	-14.04***	(2.906)
EU trust	-0.987**	(0.356)	1.845***	(0.248)	2.083***	(0.396)
<i>Industry</i>						
Mid-high technology	-0.138	(0.143)	-0.138	(0.129)	-0.165	(0.162)
Knowledge-intensive services	0.107	(0.165)	0.372**	(0.131)	0.113	(0.161)
/						
cut1	-2.473***	(0.416)	1.120***	(0.388)	0.800***	(0.409)
cut2	0.451**	(0.352)	2.910***	(0.367)	4.245***	(0.472)
τ^2 Country intercept	9.90e ⁻³⁵	(2.55e ⁻³⁴)	6.59e ⁻³⁴	(5.50e ⁻³⁴)	5.90e ⁻³³	(1.56e ⁻³³)
Observations	599		601		600	

Robust standard errors (clustered by country) in parentheses

~ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Country fixed effects are included in this model

τ^2 is the residual variance of the distribution of the varying effects

Mean-variance adaptive Gauss-Hermite quadrature with 7 integration points was used for each set of random effects

Figure 1: Predicted probabilities of the effect of PIBERD ratio on obtaining network benefits.

Figure 2: Predicted probabilities of the effect of PIBERD ratio on obtaining organizational benefits.

Figure 3: Predicted probabilities of the effect of PIBERD ratio on obtaining product development benefits.

Figure 4: Predicted probabilities of the effect of diffusion of KRP on obtaining network benefits.

Figure 5: Predicted probabilities of the effect of diffusion of KRP on obtaining organizational benefits

Figure 6: Predicted probabilities of the effect of diffusion of KRP on obtaining product development benefits.