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When birds of a feather don't flock together: diversity and innovation outcomes in international R&D collaborations

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When Birds of a Feather Don't Flock Together:

Diversity and Innovation Outcomes in International R&D Collaborations

Abstract

Collaboration is a key to success. Nonetheless, collaboration dynamics are affected by partner compatibility, which, in turn, is strongly affected by team member diversity. Studies on team diversity have shown significant variation in the magnitude, significance, and causal direction of the correlations. We examine how international R&D teams collaborate, investigating the impact of team diversity on innovation. We focus on institutional diversity to analyze how, together with the duration of the collaboration, it affects innovation outcomes. We argue that institutional diversity hampers effective knowledge sharing and negatively affects innovation outcomes. However, this negative effect is mitigated by the duration of the R&D collaboration. The longer the diverse actors collaborate, the more likely they are to overcome the barriers of institutional diversity and find effective modes of collaboration for knowledge transfer and innovation. We test our hypotheses in the context of 3,658 clinical trial projects conducted between 2001 and 2015.

Keywords

International R&D Collaboration, Institutional diversity, Innovation outcomes, Pharmaceutical Industry, Diversity

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1. Introduction

The management literature unanimously recognizes that collaboration is a key to success. Organizational theory conceives of collaboration as one of the fundamental reasons for the very existence of organizations (e.g., Barnard, 1938). The innovation management literature indicates that innovation outcomes stem from effective collaboration both within and between firms (Smith et al., 1995; Ardito et al., 2018). From the interorganizational viewpoint, the stream of open innovation has created avenues of research based on the determinants and outcomes of collaboration between different organizations (Chesbrough et al., 2006). Studies on R&D collaboration have focused on teams and networks (Becker and Dietz, 2004), because innovation stems from the effective creation and sharing of knowledge, and R&D teams or networks can facilitate such knowledge flows. R&D collaboration is sought at the intraorganizational level, through teams, or at the interorganizational level, through networks, but innovation outcomes depend on how effective the collaboration is in advancing knowledge sharing, knowledge accumulation, and the creation of new knowledge (Kogut, 2000).

Studies on networks point to their role as sources of knowledge and knowledge sharing. Formal and informal networks – both interpersonal and interorganizational – are critical in the knowledge-sharing process. Knowledge producers and recipients are more likely to engage in knowledge transfer when they are embedded in a network or team (Tortoriello et al., 2012). Scholars have highlighted the direct effect of networks on knowledge transfer (e.g., Reagans and McEvily, 2003) and have shed light on the network mechanisms that affect knowledge transfer, knowledge sharing, and innovation (Swan et al., 1999; Tsai, 2001; Gupta and Polonski, 2014). Strong interpersonal ties between the actors in a network enhance access to their personal knowledge, because individuals who communicate frequently or who have an emotional tie will more likely share their knowledge compared to those who connect

rarely and are more emotionally detached (Reagans and McEvily, 2003). The dynamics of R&D networks may lead to positive innovation outcomes (e.g., Ahuja, 2000), but they can also lead to the failure to collaborate, and hence, the failure of the innovation output (e.g., Dacin et al., 1997).

These dynamics are mostly affected by the partners' compatibility, which, in turn, is strongly affected by the team members' diversity. Studies on team diversity have shown significant variations in the magnitude, statistical significance, and causal direction of the correlations. The dominant view is that network diversity is positively associated with innovation (Nieto and Santamaria, 2007; Van Beers and Zand, 2014; Faems et al., 2005), but some studies suggest that this may not necessarily be the case (Lin, 2014; Sandberg et al., 2015). Indeed, diversity has been shown to have both positive and negative effects on team performance (Van Knippenberg et al., 2013; Jackson & Joshi, 2011). Considering team creativity and innovation, the team members' diversity in knowledge and expertise may constitute increased availability of better informational resources. Cognitive diversity may be associated with idea generation and creativity (Farr et al., 2003). On the other hand, an excessive level of diversity may cause disparate mental models, interpersonal tensions and hinder the team's ability to develop creative outcomes (Khedhaouria and Jamal, 2015).

In the field of innovation management, the general consensus is that team diversity favors the exploration of innovative solutions via the availability of more heterogeneous sources of knowledge (March, 1991). Nevertheless, whether these innovative solutions are developed and exploited, with a consequent positive impact on innovation performance, is still debated. The "double-edged sword of diversity" (Milliken and Martins, 1996, p. 403) favors the opportunity for creativity, while at the same time increasing the likelihood that team members will feel dissatisfied and detached from the group (Bassett-Jones, 2005). Several studies have tried to reconcile this paradox by focusing on the impact of cultural diversity on team

performance. They assume that diversity in cultural background is particularly salient (Stahl et al., 2009), because it affects the team members' beliefs, attitudes, and mindsets (Van Knippenberg et al., 2013). This observation is certainly relevant in international R&D teams. Indeed, international R&D teams are heterogeneous not only due to geographical factors, but they also link team members belonging to different types of organizations. It is the case, for example, quadruple helix environments, in which government, industry, academia and individual participants collaborate to achieve joint innovative outcomes (Del Giudice et al., 2016). Team members' cultural backgrounds are not independent from their own organizational contexts. Interorganizational teams are, thus, formed by team members who represent different institutional backgrounds that are linked to their own organizations. The resulting institutional diversity (DiMaggio and Powell, 1991; Messeni Petruzzelli and Rotolo, 2015) may hinder the partners' compatibility in an interorganizational R&D team and, consequently, the capacity to share knowledge, experiences, and ideas among partners. Despite the importance of these considerations regarding interorganizational teams, the impact of diversity in the institutional backgrounds comprising them seems to be still under investigated.

Hence, we formulate the following RQ: *what are the impacts of institutional team diversity on innovation outcomes in international R&D teams*?

Below, we develop these ideas more in detail to determine how institutional diversity and the duration of the collaboration affect innovation outcomes. We contribute to the debate about team diversity and innovation outcomes by arguing that institutional diversity hampers effective knowledge sharing and, thus, negatively affects innovation outcomes (Messeni Petruzzelli and Rotolo, 2015). Focusing on institutional diversity allows us to tackle the research gap from a specific perspective and to gain more insight regarding the foundation of the negative effect of team diversity on innovation outcomes. However, we also show that

this negative effect is mitigated by the duration of the R&D collaboration. The longer the diverse actors collaborate, the more likely they are to overcome the barriers of institutional diversity and find effective modes of collaboration for knowledge transfer and innovation. Thus, we additionally contribute to the literature by embracing a dynamic view of team diversity and introducing time as a moderating variable. This contribution also has very important managerial implications, as is shown below.

We investigate our research question in the context of clinical trials, a critical stage of the R&D process in pharmaceuticals and biotechnology. This setting has been analyzed in many studies of interorganizational collaboration (e.g., Powell et al., 1996, 2005; Xu, 2009, Greene et al., 2005; Huckman and Zinner, 2008; Ireland and Hine, 2007), given that, in this setting, research consortia are often seen as solutions to cope with increasing scientific and regulatory complexity. Moreover, in the light of the publication requirements on researchers and sponsors, the clinical-trial setting offers richness and accuracy of data, allowing for a thorough analysis of the dynamics of collaboration and the link to its outcomes. Through logistic regression, we investigate the impact of team institutional diversity on innovation outcomes and the potential moderation effects of the duration of collaboration. We analyze 3,658 completed clinical-trial projects performed globally between 2001 and 2015 by 457 companies that are registered on the ClinicalTrials.gov website, a comprehensive registry of privately and publicly funded studies created by the U.S. National Library of Medicine.

The paper proceeds as follows: we first present our hypotheses and the relevant literature, then describe our empirical model and, finally, discuss the results and implications.

2. Theory and Hypotheses

Diversity among members of interorganizational R&D networks may either improve or worsen innovation outcomes. On the positive side, having a number of diverse knowledge

sources guarantees a richer variety of ideas and, therefore, benefits exploration activities. This result is particularly evident in knowledge-intensive sectors, where R&D collaborations are sought at the international level and among highly diverse actors.

On the downside, diverse network members may differ in organizational routines, culture, and values, undermining their ability to collaborate effectively. This deep-level diversity (Milliken and Martins, 1996) might limit the capability to assess, assimilate and apply new knowledge (Batarseh et al., 2017). In terms of absorptive capacity, firms are more likely to assimilate external knowledge that relates closely to their own prior knowledge; thus, greater similarity among team members facilitates knowledge sharing and transfer (Cohen and Levinthal, 1989). In the context of R&D alliances, if partners have strongly diverse capabilities, the innovative benefits may indeed be reduced, since firms are better at assimilating capabilities that are similar to their own (Sampson, 2007). Moreover, individual and organizational ignorance, intended as the lack of awareness about something, may lead employees to underestimate the value of new knowledge to be acquired and to disengage from knowledge sharing activities (Israilidis et al., 2015). In teams with diverse knowledge bases, the negative impact of ignorance on knowledge sharing, and ultimately innovation, may be more intense.

In this vein, investigating network diversity in the context of R&D collaboration is an interesting way to highlight the impact of diversity on innovation outcomes. This type of collaboration requires a high level of coordination to allow for knowledge mobility, i.e., the sharing or transfer of knowledge across firms. In highly complex fields, characterized by tacit or complex knowledge, successful knowledge transfer is not straightforward. In fact, diverse knowledge, perspectives and experiences do not always translate into innovation, as the outcome depends on the type of ties between the network actors (Tortoriello and Krackhardt, 2010). The motivation to collaborate may be flawed in R&D teams that include members

from institutionally diverse organizations. In the context of clinical trials, teams are composed of members who may work either in for-profit firms or in not-for-profit organizations, or in public organizations or other institutions. These organizations are characterized by different institutional settings and may be very different in their approach to the trials. Hence, institutional diversity in those teams may hamper the effectiveness of the collaboration, resulting in lower rates of innovation outcomes, as explained in detail below.

2.1 Institutional diversity and innovation outcomes

Having a common and shared identity increases knowledge flows and innovation output via the positive impact on the motivation to interact and to share experiences and knowledge (Dhanaraj and Parkhe, 2006). Conversely, diversity in the institutional identities of the members will hinder knowledge transfer. Collaborations among organizations with different institutional cultures are particularly complex, since they must span differences at the political level (organizations and funding sources), at the ecosystem level and at the coopetitive learning level (practices in how to manage intellectual capital and outcomes) and often fail to mediate competing priorities and to bridge such cultural gaps (Carayannis et al., 2014).

In the clinical-trials setting, international R&D collaboration often brings for-profit pharmaceutical or biotech firms together with universities, research centers and institutes, nonprofit organizations that work in the healthcare sector, foundations, hospitals and other healthcare facilities, and certain specific actors, such as physicians. It could be argued that international R&D collaborations in clinical trials should unite the various researchers, who should share a common professional identity. However, R&D teams do not work in a vacuum but reflect and depend on their organizational context (Miner et al., 2001; Ambos and Schlegelmilch, 2004; Baker and Nelson, 2005; Joshi and Roh, 2009; Bechky and Okhuysen,

2011). Recent research shows that the impact of diversity on innovation and performance should be rated, distinguishing between job-unrelated diversity (such as geographic locations or demographics, van Dijk et al., 2012) and job-related diversity (such as organizational or functional diversity, Weiss et al., 2018). An extensive body of literature has shown that job-unrelated diversity, which is captured by cultural diversity, is detrimental to team performance. Conversely, the impact of job-related diversity, which can be captured by institutional diversity, remains unclear. In highly innovative settings, in particular, job-related diversity may improve the access to a wider spectrum of knowledge sources, while simultaneously hindering the collaboration process. These R&D networks may, thus, be characterized by considerable institutional diversity. Some authors maintain that the diversity inherent in R&D collaboration between universities and firms may benefit innovation outcomes (e.g., Lavie and Rosenkopf, 2006), as the partners bring different but complementary competencies and capabilities. However, it may also engender incompatibility, as the network partners differ in terms of the established practices, routines, habits, laws and rules governing their work (Zukin and DiMaggio, 1990; Messeni Petruzzelli and Rotolo, 2015).

One evident difference is that some actors are for-profit and others nonprofit. Thus, they may have different priorities, i.e., agendas with either scientific (research-driven) or business (market-driven) objectives (Ireland and Hine, 2007), which might be difficult to harmonize among partners. In fact, the pharmaceutical/biotech industry often has bipartite science and business designs, with specific strategies that must take into account both research and market imperatives. These differences can influence the behavior, routines and relationships with other firms (Child and Tsai, 2005; DiMaggio and Powell, 1983; DiMaggio and Powell, 1991). This orientation to the market marks the difference between a strategic search for innovation outcomes that are directly related to economic performance and the drive for

innovations more directly related to patient care and disease alleviation. Universities and other research centers and institutes are generally interested in exploration-oriented innovation activities (Saxenian, 1994; Del Giudice et al., 2017), as they are concerned with basic research and cutting-edge knowledge production (Messeni Petruzzelli and Rotolo, 2015), while firms tend to be more interested in refining existing knowledge and exploiting the innovation produced (Lavie and Drori, 2012). Moreover, previous studies have demonstrated differences in knowledge management and knowledge sharing between for-profit and nonprofit organizations (Bloice and Burnett, 2016), as the former tend to leverage knowledge sharing to increase financial gains, whereas the latter are more focused on "achieving organizational priorities and […] the betterment of society" (Bloice and Burnett, 2016, p. 126).

Our contention is, therefore, that even if the R&D team is composed entirely of researchers, insofar as they belong to different organizations, they may embed sharply diverse institutional backgrounds. If team members differ significantly in terms of their values, teamwork becomes more complicated (DiStefano and Maznevski, 2000). Researchers inevitably differ in their cultural characteristics (Hoppe, 1993), and the teams they comprise can either overcome or leverage their cultural differences to create – or destroy – value (DiStefano and Maznevski, 2000; Ambos and Schlegelmilch, 2004).

International R&D teams are certainly exposed to cultural differences. Team members interact on the basis of their own cultural values and norms, which are often tacit and difficult for people from a different culture to understand. Cultural differences inevitably hinder smooth interactions (DiStefano and Maznevski, 2000).

Hence, we formulate the following hypothesis:

H1: *The greater the institutional diversity, the lower the likelihood of successful innovation outcomes.*

2.2 The moderating role of duration on innovation outcomes

Interorganizational networks cross firm boundaries and connect independent organizations that become mutually dependent (McEvily et al. 2003). The intensity of the collaboration has effects both on the efficiency of the innovation process and on the ability to generate innovative outcomes, since it allows the development of complex and shared tasks and routines, as well as improving the effectiveness of knowledge transfer (Anzola-Román et al., 2019). Over time, the members develop mutual trust, which smooths out the cultural and institutional differences. Trust helps defuse the misunderstandings and conflicts that may arise from the complexities of different environments (Zaheer et al. 1998). Team members need to develop mutual trust in their colleagues' competence and in their nonopportunistic behavior (Newell and Swan 2000). Team members who trust each other are more likely to share knowledge (Evans, 2013). The longer an R&D team has been collaborating and the more cohesive it is, the greater the probability of knowledge sharing and new knowledge creation (Bakker et al., 2006; Sawng et al.,2006). In knowledge-sharing networks, all the members should perceive knowledge sharing as mutually beneficial in the long run (Khvatova et al., 2016). Thus, continuity and stability are pivotal for boundary-spanning collaborations (Linnarsson and Werr 2004; Tortoriello and Krackhardt, 2010). Moreover, an enduring collaboration exposes the team members to the others' cultures, norms, values, and behavior, generating a learning mechanism that makes the team more homogeneous. Over time, teams develop their own routines and coordination mechanisms (Nelson and Winter, 1982). The communication and coordination costs associated with team diversity (Dougherty, 1992) tend to decrease with time. In-group jargon that hinders sharing knowledge begins to

be abandoned in favor of shared-communication routines (Hoisl et al., 2017; Taylor and Greve, 2006). The intrateam trust and social integration associated with continuity in the collaboration have a positive impact on conflicts (Richard et al., 2007) and lead to better innovation outcomes.

Thus, we posit the following hypothesis:

H2: *The longer the duration of the R&D collaboration, the smaller the negative impact of institutional diversity on the likelihood of successful innovation outcomes.*

3. Empirical Setting and Methods

We test these hypotheses for the pharmaceutical industry and, in particular, for clinical-trial projects. These projects are backed by a sponsor, which may work with one or more collaborators. A sponsor is defined by the National Cancer Institute as a "person, company, institution or organization that oversees or pays for a clinical trial and collects and analyzes the data." Collaborators can be defined as other organizations, companies, institutions or actors that provide further support, such as reporting, data analysis, implementation, design or even funding (Califf et al., 2012). Sponsors and collaborators may be "for-profit" actors, such as pharmaceutical or biotech companies, but they may also be "nonprofit" institutions, such as foundations, national health institutes, universities, federal agencies, or even individual physicians.

A clinical trial may be designed to be carried out within one or multiple research centers (i.e., medical facilities, such as hospitals or medical clinics). In a trial, the centers follow the protocol designed by the sponsor, which defines the objectives, methodology and organization, ensuring the safety of the trial subjects and the integrity and homogeneity of the data collected. The centers, thus, proceed to enroll patients and test with the aim of speedy

protocol completion. Meetings between center representatives ("investigator meetings") are held periodically by sponsors (in person or by videoconference) to foster knowledge sharing on processes, technical issues, and the protocol, and possibly improvements (Edwards et al., 2011).

Clinical trials are carried out at every phase in the development of a new drug, each trial with its own characteristics and requirements (Smith and O'Donnell, 2006; Brunetta et al., 2015). Drug development traditionally starts within an in-lab discovery program, aimed at synthesizing and testing an active compound on cultured cells or animals to verify its efficacy and potential toxicity. This is the preclinical phase (so no clinical trial is yet required). If the compound is effective, it advances to the clinical-trial stage (testing on human subjects), which encompasses the following three phases: i) Phase I, in which it is tested on a few volunteers who do not have the disease targeted, to determine safe dosages and identify potential absorption, metabolic, distribution and side effects; ii) Phase II, testing on a group of volunteers who do have the disease, comprising random and double-blind studies to gather additional evidence on efficacy and safety; iii) Phase III, testing on a large group, sometimes thousands of subjects with the target disease, perhaps conducted by different centers, even in different countries (to ensure heterogeneity of gender, age and race); this phase serves to collect and confirm data on efficacy and safety. Only after the three phases have provided sufficient evidence can the sponsor file a New Drug Approval (NDA) application with the appropriate regulatory authority for authorization to market. After such licensing, there may also be a Phase IV of additional data collection, inquiring into side effects, when required, or possibly directed to authorization for extension to certain population groups (e.g., pediatric use).

The trial can be interrupted or prove unsuccessful at any stage of the process, which can last for as long as 10 or 12 years, increasing the cost and complexity of the R&D process.

Clearly, then, the clinical-trial stage is critical for any sponsor. A successful trial depends on the speedy recruitment of the trial subjects to meet the time and regulatory requirements (Fisher, 2009), and one way of speeding up the drug development process may be collaboration among the different actors. Previous research has in fact found that efficiency can improve when trials are conducted by research consortia (Greene et al., 2005; Sinackevich and Tassignon, 2004; Khwaja and Mendez-Duron, 2016).

Clinical trials are subject to publication requirements; therefore, several data sources are available, which allow for data collection and analyses studies focused on this setting. In the next section, we describe the dataset used for our analyses, how we have selected these data and their level. We also provide some illustrative examples of the data analyzed.

3.1 Data and Sample

We referred to data from ClinicalTrials.gov, a database of globally funded clinical studies, both public and private, provided by the U.S. National Library of Medicine. The ClinicalTrials.gov registry provides data on the characteristics of current, planned and past clinical studies, and has become the current referent registry for clinical trials conducted globally for several reasons. First, the registry complies with a requirement established in 1997 by the U.S. Food and Drug Administration Modernization Act, which mandated the registration and disclosure of private and public trials. Registration is compulsory for Phase II and Phase III trials (Khwaja and Mendez-Duron, 2016). Second, the registry comprises trials conducted in all countries, even if they do not involve U.S. centers or sponsors (Tse et al., 2009). Finally, in 2004, the International Committee of Medical Journal Editors (ICMJE) dictated that studies can be published only if they are registered in a public repository, and at that time, ClinicalTrials.gov was the only registry meeting the ICMJE's specific requirements for disclosure (Tse et al., 2009).

The extensive data available in the database were used to verify the impact of institutional diversity on innovation outcomes and the moderating effect of the duration of the collaboration.

ClinicalTrials.gov provides information about studies conducted on human volunteers, a vast majority of which are represented by clinical trials. They are more specifically defined as "interventional studies", since the subjects are assigned to a specific type of intervention (e.g., a medical product) in light of the plans and protocols dictating the rules for testing and verifying the efficacy of the intervention. Additionally, the site contains records of the so-called "observational studies," which are programs designed to provide expanded access to investigational drugs, even outside the clinical trial. The database contains record of trials conducted in approximately 208 countries (Clinicaltrias.gov, 2019). The data are initially submitted by the "responsible parties" (sponsor or principal investigator), who also provide updates throughout the study.

For each study record, the Clinicaltrials.gov website reports the main information about a study protocol, including the disease, or condition, which is the core focus of the analysis, and the related intervention(s). Together with the official title and protocol number of the study, the database specifies the description and design, including the sample description, requirements for enrollment and eligibility for participation, as well as the locations in which the study will be conducted. It also provides information on the study's start date and its status and, in some cases, the end date. The status includes the following specific definitions: (i) if the study is ongoing, it can be classified as "not yet recruiting" if the first participant has not yet been enrolled; "recruiting", if participants are currently being recruited; "enrolling by invitation", if participants have to be selected following the requirements for predetermined populations; "active, not recruiting", if the study is ongoing but no new participants are being

recruited; (ii) if the study has been completed, the database reports “completed”, meaning that the study has been concluded and participants are no longer being examined; finally, (iii) if the study has halted prematurely, the status might be expressed as “suspended” if there is the chance for it to be resumed, “terminated” if it will not be resumed, or “withdrawn” if it has been canceled before the enrollment of the first participant. The database also includes information on the responsible parties, such as the sponsors (the entity initiating the study), their collaborators (other entities providing support), and the principal investigator, which is the person responsible for the study, as designated by the sponsor. Additionally, the study record may include a demographic description of the study participants, results and outcomes, and reports of adverse events.

To provide an illustrative example, Study A was extracted from the database started in 2008 and was completed in 2012. It is a Phase III interventional study, with a focus on Preterm Delivery. The record shows the study details and a summary in a tabular view, providing descriptive information on the study, its design (investigative methods or strategies used in the clinical study), intervention, recruitment and administrative information on the sponsors and collaborators. More specifically, the record clearly indicates the names of the sponsors and a description of the 49 study locations.

Clinicaltrials.gov has made its data available since its inception, but it was only with the creation of the Aggregate Analysis of the ClinicalTrial.gov (AACT) database by the Clinical Trial Transformation Initiative that the data became easily usable for research. AACT is a publicly accessible relational database containing all information about every study registered in ClinicalTrials.gov. The content is downloaded from ClinicalTrials.gov and loaded into AACT daily.

We downloaded a static version of the AACT database in September 2018 to freeze the data collection and avoid bias due to dynamic updates. We extracted, using the software

pgAdmin 4 (version 3.2, 2018), 95,493 observations of clinical trials performed in collaborative sponsoring teams. Because registration is mandatory only for Phase II and Phase III, we excluded Phase I and Phase IV trials, reducing the sample to 24,823 observations. We decided to restrict the sample further, to Phase III trials only, because this premarketing phase is crucial for sponsors, and because limiting observations to the same phase permitted greater uniformity in the degrees of complexity, size and scope (which vary widely between Phase II and III), as well as preventing biases generated by the observation of innovative collaborations at different stages of the innovation funnel (Anzola-Román et al., 2019). This reduced the sample to 8,175 observations. Because Clinicaltrials.gov was established in 2000, we excluded trials from that year or earlier, which may have registration biases (incomplete or ex-post registration); we took 2015 as our cutoff year, as later trials may still be ongoing. The final sample consisted of 3,658 observations.

3.1.1 Variables and Measures

To test our hypotheses, we develop an empirical model where the dependent variable is innovation outcomes, team institutional diversity is the independent variable, and duration is the moderator. A set of control variables are also added to account for alternative explanations.

Dependent Variable. Our dependent variable is "***innovation outcomes***". We evaluate the performance of a clinical trial project by observing its completion status. Specifically, the AACT database indicates a study as "completed" when its subjects are no longer being examined or are no longer receiving the intervention; that is, the last visit has been made and the data are complete. This status refers to the clinical study as a whole, considering the status of each site (i.e., for a trial to be classed as "completed", *all* sites must have ended the trial). Our dependent variable is, thus, a dummy equal to 1 for "completed" trials, and 0 for any

other status (i.e., “not yet recruiting,” “recruiting,” “enrolling by invitation,” “active, not recruiting,” “suspended,” “terminated,” “withdrawn,” and “unknown”).

Independent Variables

Team Institutional Diversity. We have calculated the team institutional diversity (a measure of variety) according to the index of heterogeneity from Blau (1977), which is one of the most widely used indexes (Klein et al., 2001; Harrison and Klein, 2007). The index is calculated as $1 - \sum_{i=1}^{k} p_i^2$, where p_i = the proportion of team members per institutional category and varies from 0 (minimum variety, everybody in the group belongs to the same category) to 1 (maximum variety, membership spread equally across the different categories, with equal portions of the team part of each of X_k possible categories). The National Library of Medicine (NLM) classifies sponsors and collaborators into the following four categories: industry, National Institute of Health (NIH), non-NIH U.S. federal, and other). We have classified the actors in the same fashion.

Duration. The previous research has used measures of project duration as proxies for coordination efficiency, since partners need to adjust and coordinate their operative mechanisms (Gulati and Singh, 1998; Dyer and Singh, 1998; Khwaja and Mendez-Duron, 2016; Anzola-Román et al., 2019). We calculate the trial duration as the number of days between the start date – defined as the day of opening for recruitment or enrolment of the first participant – and the date when the status of the trial was updated to “completed” or any other status (i.e., “not yet recruiting,” “recruiting,” “enrolling by invitation,” “active, not recruiting,” “suspended,” “terminated,” “withdrawn,” and “unknown”), i.e., the date when data collection for that study was interrupted. For better approximation of a normal distribution, we used a log transformation.

Control Variables

We controlled for various trial project characteristics as follows: "***number of location countries*****"** in which the trial took place (an important measure of the geographic spread) and "***number of target conditions/diseases*****"** (these terms usually refer to the NLM's Medical Subject Heading - MeSH). We also controlled for the "***number of sponsors***" of the trial (ranging from 2 to 41), which might affect the collaboration dynamics. Finally, since industry players have a central role in financing new drug development and might have different approaches to the clinical-trial process with respect to nonprofit players, we included a variable for "***Percentage of industry members***" in the team of collaborators.

3.1.2 Data Analysis

Tables 1 and 2 report the means, standard deviations, and correlations for the studied variables. None of the correlation coefficients raised potential problems of multicollinearity, as the maximum value of the correlation coefficient is .4005 (see Table 2).

The hypotheses developed were tested by logistic regression since the dependent variable – innovation outcomes – is dichotomous. The data were analyzed using Stata 14 (StataCorp, 2015). The coefficients of each variable represent its effect on the likelihood of a completed clinical trial. Negative coefficients show that decreases in the independent variables are associated with a lower probability of negative innovation outcomes; vice versa for positive coefficients.

Because the sample comprised 3,658 clinical trials conducted by 457 companies during the period from 2001-2015, we accounted for year and firm effects. A Hausman test was applied to select the most appropriate specification between random and fixed effects. The test yields statistically significant results of $\chi^2 = 74.80$ ($p < 0.000$), indicating that firm-fixed effects control for the time-invariant firm-level variables and attenuate one important

source of endogeneity, namely, omitted variables. We added year dummies and firm-fixed effects in all the models reported in Table 3.

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INSERT TABLE 1 and 2 ABOUT HERE

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4. Results

Model 2 in Table 3 shows that "team institutional diversity" has a negative and significant effect on the probability of positive innovation outcomes (p <0.05). This finding accords with Hypothesis 1, implying that the barriers of institutional diversity do affect innovation outcomes. Since the logit function is not linear, additional analysis is needed to interpret the magnitude of the effects and the results (Hoetker, 2007). We used the *Margins* postestimation commands, holding all variables at their mean, to calculate the marginal effects of the models (e.g., Bergh and Sharp, 2015; Peruffo et al., 2018). The results are reported in Table 3 (Models 2A and 3A). This procedure increases the average marginal effect on the probability of critical trial success associated with an increase in "team institutional diversity" by 6.4 percentage points.

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INSERT TABLE 3 and 4 ABOUT HERE

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The findings for the mean-centered interaction involving "Duration" (ln) and "team institutional diversity" are reported in Model 3. As predicted by Hypothesis 2, the coefficient for the interaction of "Duration" (ln) and "team institutional diversity" shown in Model 3 of Table 3 is positive and statistically significant (p<.01).

To understand the effect on performance, in Figure 1, we analyze the moderation effect graphically. These graphical analyses show that in clinical trials whose duration is one standard deviation longer than the mean, the probability of a successful clinical trial is higher for low levels of team institutional diversity. By contrast, for trials whose duration is one standard deviation shorter than the mean, for low levels of institutional diversity, the probability of a successful clinical trial is lower. The significant interaction suggests that the "duration" attenuates the negative impact of "team institutional diversity on innovation outcomes;" that is, there is support for the theory that the longer a trial lasts, the less negative the relationship is between "team institutional diversity" and "innovation outcomes."

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INSERT FIGURE 1 ABOUT HERE

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Because the dependent variable is nonlinear, we have to test if the significance and the magnitude of this moderating effect varies with respect to the other variables. Thus, to better interpret the interaction between "team institutional diversity" and "innovation outcomes," we used a "continuous by continuous" interaction in which we fixed the moderator variable at given values while varying the independent variable. We show the marginal effect of "team institutional diversity" in Table 4. We consider three different levels of "duration" (mean, mean minus one standard deviation and mean plus one standard deviation), holding all other variables at their means. Observing clinical trials with shorter durations, "team institutional diversity" has a more severe negative impact on "innovation outcomes" (significant at $p<0.01$). By contrast, for trials of longer duration, the marginal effect of "team institutional diversity" becomes less negative ($p<0.05$). These findings support Hypothesis 2, i.e., the negative relation between "team institutional diversity" and "innovation outcomes" is less pronounced when the trial duration is longer and more pronounced when it is shorter.

5. Discussion and Conclusions

Our study offers a contribution to the flourishing debate on the impact of diversity in international interorganizational collaborations. The findings, counter to a widely held theory, indicate that greater diversity in networks is not always beneficial for innovation. The literature agrees that the diversity-performance relationship is influenced by different contingencies and that positive and negative moderation effects might emerge (van Knippenberg and Mell, 2016). We adopt a specific focus on institutional diversity. This allows us to link the team members' organizational contexts with the team's dynamics-of-collaboration level. Our results show that in a knowledge-intensive context, such as drug development in the pharmaceutical industry, institutional diversity may be negatively correlated with innovation outcomes. This is a context where collaboration networks are by nature international and can include organizations with very different institutional orientations and governance. In international R&D networks, firms are connected with and through individuals in a virtual environment, which can contribute to the creation of new knowledge in an open paradigm (Formica and Curley, 2018). At the same time, however, we show that the institutional background may also represent a severe liability for the members of the network. Thus, the flows of knowledge, which depend closely on the institutional context and organizational routines, may be impeded and knowledge sharing at the interorganizational team level may be hindered. This situation ultimately produces poorer innovation outcomes.

Additionally, because they are geographically dispersed, international R&D networks are more complex, imposing higher costs of coordination and communication and perhaps making knowledge integration more difficult (Singh, 2008). If colocating R&D units favor knowledge creation by leveraging knowledge sharing beyond organizational boundaries (Coradi, Heinzen, and Boutellier, 2015), our results show that, conversely, being

organizationally and geographically dispersed implies the fragmentation of knowledge and the need to actively manage knowledge sharing to overcome knowledge boundaries. We show that as the collaboration extends over time, opportunities to overcome such barriers emerge that lead to a smoother collaboration and mutual acknowledgment among the R&D team members. Thus, the social and institutional barriers between team members may be attenuated. Individuals who interact over time in an innovative project can establish their own collaboration routines. They overcome institutional barriers, developing a common language and shared understanding and meanings that mitigate the negative effects of diversity. Such results extend the research on knowledge creation in project teams, which shows how project teams utilize knowledge that has a common interpretation (Oluikpe, 2015).

Our contribution is in line with the recent dynamic view of networks (Chesbrough and Prencipe, 2008). Indeed, by adopting duration as a moderator, we expand the existing understanding of the innovation-network dynamics that unfold as the innovation evolves from the early stage – when alternative solutions are explored – to the mature stage of innovation-outcomes exploitation.

The previous studies on clinical trials (Brunetta et al., 2015) show that this context satisfies the conditions for shifting from the individual level of the network (the single individual as part of an interorganizational team) to the higher, organizational level (Zaheer and Usai, 2004). In particular, the R&D-collaboration performance in clinical trials improves where the network structure provides opportunities for resource sharing and learning. Our results delve further into this concept, as we show that over time, the collaborative network acquires its own legitimation in the face of the institutional diversity of the original organizations. In this vein, the extensive network acquires the features of a team, in which members collaborate closely and get to know each other better. From this perspective, our findings provide a link between the literature on networks and that on teams. As is shown in

Annosi et al. (2018), there is a persistent crucial tension, in terms of knowledge transfer and acquisition, between project-level goals and the higher (organizational and network) levels. We show that when there is sufficient time to allow the actors within the network to interact more closely and to share their routines, a sense of identity as a team can emerge (Annosi et al., 2017), overcoming the original institutional diversity. Our results are also consistent with the percolation-based approach to studying knowledge sharing (Khvatova et al., 2016), emphasizing the role of trust as a leverage to share and create new knowledge in diverse teams. Moreover, our results confirm the dynamics of team-level absorptive capacity (Lowik et al., 2016), in that we add evidence suggesting that collaborations that span over time allow team members to "develop similar dynamic capabilities" (Lowik et al., 2016, p.1096) and to enhance the team-level absorptive capacity.

Our study also presents some interesting managerial implications. Clinical trials constitute important means to evaluate the efficacy and safety of new drugs and devices and, eventually, deliver them to the market. In this light, a better understanding of the dynamics of collaborations in clinical research, among diverse institutional actors, is of pivotal importance for the improvement of the trial process and related policies. The literature has, so far, focused on addressing the benefits and bias of industry players (Chopra, 2003), highlighting the vital role of industry, in terms of contributions not only of funds but also of high-level competencies, which are complementary to those of nonprofit actors (Gelijins and Thier, 2002). A key implication of our study is that focusing merely on the pros and cons of industry participation, per se, might be misleading. Instead, the focus – when defining the members of the sponsoring teams – should be on their institutional diversity, rather than their belonging to specific categories.

At the same time, scholars have also underlined potential biases, such as conflicts related to the clash among business and science interests (Evans and Pocock, 2001; Chopra, 2003), methodological issues regarding the process or the registration of results (Montaner et al., 2001; Moses et al., 2002). In this light, the research (Del Giudice et al., 2017) has underlined the potential role of Principal Investigators as "explorative entrepreneurs", acting to strengthen the cooperation among diverse partners and environments and mediating their science and research agenda priorities. Principal Investigators, indeed, act as scientific leaders, guiding the scientific and innovative development of projects, but they also act as project managers, focusing on the fulfillment of requirements and goals. Thus, their ability to combine knowledge and business practice might be pivotal and deserves further research. Nonetheless, it is not only the institutional identity but also the role of country culture and context that might influence the orientation of Principal Investigators towards prioritizing research or business objectives (Del Giudice et al., 2017).

Another important managerial implication relates to a better understanding of the drug-development process and, more specifically, of the role of duration, which is considered a measure of the efficiency of the process, due to the importance of reducing the length of the development process to reduce the time-to-market of a new drug and the pressure to do so (Mattesich et al., 1992; Fisher, 2009). Nonetheless, an increase in duration, as demonstrated by this study, could also bear positive effects, by mitigating the potential tensions among institutionally diverse actors.

This study also suggests the need for project-management tools, which should include coordination mechanisms that help overcome institutional barriers. Indeed, among the main challenges facing the diverse actors collaborating in knowledge-intensive environments are those related to how to integrate collaborative practices and to cocreate shared values (Del Giudice et al., 2017), These mechanisms, focusing on the alignment and integration of

interdependent activities performed by distinct actors (Palmié et al., 2016; Martinez and Jarillo, 1991), are usually defined as threefold, including the need for the following: (i) centralization, focusing on establishing rules for distributing decision rights (Nobel and Birkinshaw, 1998); (ii) formalization designating ‘‘the extent to which rules, procedures, instructions, and communications are written’’ (Pugh et al. 1968, p. 75); and (iii) socialization, relating to “the level of interaction between, and communication of, various actors within and between the firms, which leads to the building of personal familiarity, improved communication, and problem solving” (Lawson et al., 2009, p. 159, on Gupta and Govindarajan, 2000). All these diverse mechanisms are important for coordination. However, in settings where formalization is very strong and rules for centralization are clearly defined, such as clinical trials, socialization among diverse members embedded in heterogeneous institutional backgrounds appears pivotal to facilitate the development of like-minded decision-making (Nobel and Birkinshaw 1998). Such a result is also suggested by the positive effects of an increase in the duration of a collaboration. Managers could, thus, focus on “soft” or informal socialization mechanisms, such as socialization tactics aimed at developing trust and communication by providing time, motivation and opportunities to facilitate coordination, or formal socialization mechanisms, such as structural formats, including, e.g., scheduled meetings or teams created following specific characteristics (e.g., Lawson et al., 2009).

Finally, our study has some limitations and offers grounds for further avenues of research. First, although the present study is built on data derived from the AACT database, which is a comprehensive source of every clinical study registered in ClinicalTrials.gov, we should account for some limitations of the data source. The AACT does not include data about the microlevel variables of the clinical trials. Thus, it was not possible to derive information

about the individual participants in the collaboration network. Microlevel analysis, which would include variables related to the individual organization or the individual human resources involved in the collaboration network, was not possible at this stage of the study. We would, therefore, suggest that further analysis could be made that includes diversity variables at the individual levels, by complementing the AACT database with additional data sources. Similarly, microlevel data could provide information on differences at the country level among participating actors, accounting for a different dimension of diversity. Finally, while this aspect was beyond the scope of our analysis, future research could focus on the diversity of experience among the participating actors. As experience has proven to be one of the key sources of knowledge (Argote and Miron-Spektor, 2011; Peruffo et al., 2018), computing the past experience of team members may account for disparity within the team, as one organization may be superior to other organizations in research expertise, which would have unknown effects on the knowledge-sharing process and the innovation outcomes.

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TABLES AND FIGURE

Table 1
Descriptive Statistics

	mean	***sd***	***min***	***max***
Innovation outcomes	0.66	0.47	0.0	1
Team Institutional Diversity	0.21	0.24	0.0	1
Duration (ln)	6.99	0.82	3.4	9
Number of sponsors	2.80	2.18	2.0	41
Number of countries	3.34	6.19	1.0	58
Number of conditions	1.56	1.27	1.0	27
Percentage of Industry members	0.35	0.40	0.0	1
Observations	5864			

Table 2
Correlations

	Innovation outcomes	***Team Institutional Diversity***	***Duration (ln)***	***Number of sponsors***	***Number of countries***	***Number of conditions***	***Percentage of industry members***
Innovation outcomes	1						
Team Institutional Diversity	-0.0241	1					
Duration (ln)	-0.230***	0.146***	1				
Number of sponsors	-0.111***	-0.0641***	0.120***	1			
Number of countries	-0.00416	-0.134***	0.127***	-0.0431**	1		
Number of conditions	-0.00389	0.0988***	0.0679***	-0.0107	-0.0321*	1	
Percentage of Industry members	0.141***	-0.110***	-0.262***	-0.209***	0.405***	-0.113***	1

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 3
Results of Logistic regression analyses (Dependent variable: Innovation outcomes)

	Model 1	**Model 2**	**Model 2A**	**Model 3**	**Model 3A**
	Coefficient	**Coefficient**	**Marginal effect at variable means**	**Coefficient**	**Marginal effect at variable means**
Duration (ln)	-0.64***	-0.64***	-0.063***	-0.68***	-0.069***
	(0.071)	(0.071)	(0.018)	(0.072)	(0.019)
Number of sponsors	-0.018	-0.022	-0.0021	-0.021	-0.002
	(0.025)	(0.025)	(0.002)	(0.025)	(0.002)
Number of countries	-0.025**	-0.023*	-0.0022*	-0.019*	-0.002^{+}
	(0.009)	(0.009)	(0.0010)	(0.009)	(0.001)
Number of conditions	0.0020	0.0034	0.000	-0.00085	-0.000
	(0.039)	(0.039)	(0.0034)	(0.039)	(0.004)
Percentage of Industry members	-0.66**	-0.36	-0.036	-0.29	-0.029
	(0.238)	(0.267)	(0.025)	(0.266)	(0.026)
Team Institutional Diversity		-0.65*	-0.064^{+}	-0.89**	-0.091*
		(0.269)	(0.033)	(0.275)	(0.039)
*Team Institutional Diversity * Duration (ln)*				1.04***	0.106**
				(0.265)	(0.039)
Observations	3658	3658		3658	
Year Dummies	YES	YES		YES	
Firm Fixed Effect	YES	YES		YES	
Log likelihood	-1282.61	-1279.69		-1272.02	
Number of companies	457	457		457	
Chi2	548.45	554.29		569.64	

Standard errors in parentheses

$+ p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001$

Table 4
Marginal effect of Team Institutional Diversity for a range of Duration (ln)

Value of Moderator Duration	Marginal effect of Team Institutional Diversity	z Statistic
Mean minus standard deviation	-0.14**	-2.84
Mean	-0.11**	-2.64
Mean plus standard deviation	-0.08*	-2.47

*+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Figure 1
Moderation effect

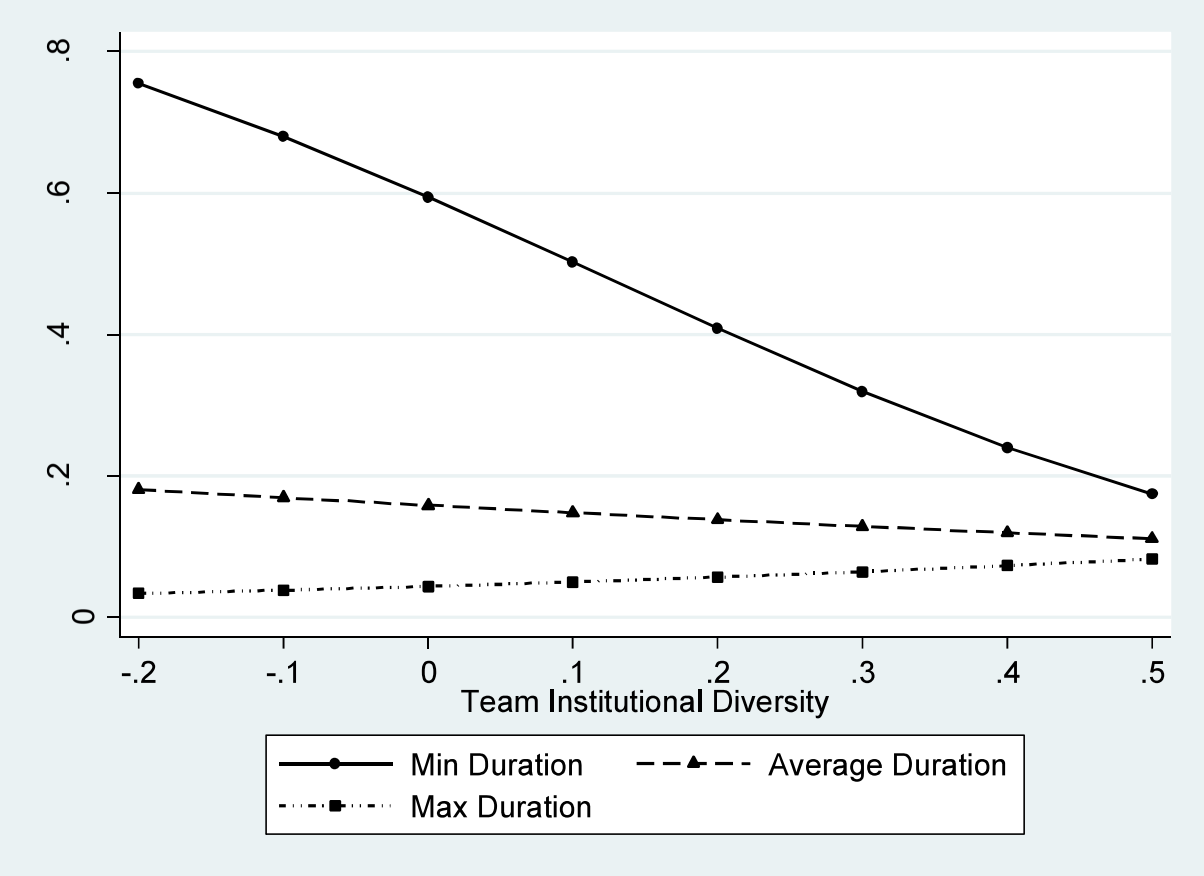

Figure 1

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