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Brokerage that works: Balanced triads and the brokerage roles that matter for innovation

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Abstract

A key premise in innovation literature suggests that individuals enabling contact between pairs of otherwise disconnected others (i.e., holding open triads) are more innovative, as they benefit from more opportunities for knowledge recombination. Such benefits also come with a cost, as conducting innovative action from open triads requires finding common ground to coordinate and integrate disparate knowledge and efforts from unconnected others. However, it is yet unclear which specific open triadic structures offer the greatest net value to facilitate individual innovativeness. We contribute to this debate by going beyond a homogeneous conceptualization of open triads, examining the relation between different brokerage roles and individual innovativeness. We theorize that some roles are more balanced than others in terms of access to knowledge novelty and integration costs. Specifically, we find that balanced open triads (gatekeepers and itinerant roles) are crucial to facilitate individual innovativeness, as compared to unbalanced open triads (coordinator and liaison roles). We also propose that brokers obtain the greatest innovation benefits from balanced open triads when they are embedded in institutional settings that are distant from knowledge applicability. We test our ideas through a large-scale study of 1,010 biomedical scientists.

KEYWORDS

brokerage roles, innovation involvement, institutional theory, medical innovation, open triads

1 | INTRODUCTION

It is well established that exposure to diverse sources of information increases the opportunities for knowledge recombination by offering the "requisite variety" of ideas and knowledge needed for innovation (Dahlander et al., 2016). One of the main ways that individuals access this knowledge required for innovation is through social relationships. This makes the brokerage structures "in which one actor mediates the flow of resources or information between two other actors who are not directly linked" (Fernandez & Gould, 1994, p. 1457) crucial. Much of the network research stresses that open triads, which are the simplest structural form of brokerage (Simmel, 1950; Wynstra et al., 2015), facilitate brokers' innovation activities at the individual (Tortoriello, 2015; Wong & Boh, 2014), team (Balkundi et al., 2007) and organizational (Owen-Smith & Powell, 2004) levels. However, it has been shown also that brokers find it difficult to integrate and leverage the knowledge accessed by open triads (Tortoriello & Krackhardt, 2010; Zou & Ingram, 2013). Innovative activities based on triads requires identification of common ground to coordinate and integrate the knowledge and efforts of unconnected others (Obstfeld, 2017), and this can represent a significant cost for the broker (Dahlander et al., 2016; Salter et al., 2015).

In seeking to understand the sources of the variability in the relationship between open triads and innovation (Ozer & Zhang, 2019), we build on two network research streams. The first relies on the notion that not all open triads are structurally homogeneous (Gould & Fernandez, 1989); the individuals involved in a triad might belong to different communities, and depending on their different group affiliations they may play different structural roles. This implies that structure and composition capture non-overlapping properties of open triads (Balachandran & Hernandez, 2018; Ter Wal et al., 2016), and suggests that not all open triads offer similar net value to the broker. For instance, intermediating between two disconnected individuals in the same community limits the scope of the knowledge available to the broker (Maggitti et al., 2013). At the firm level, prior studies show that certain roles are more strongly correlated than others with innovation performance (Balachandran & Hernandez, 2018; Belso-Martínez et al., 2015). At the individual level, we know that not all brokerage roles are equally frequent among inventors (Lissoni, 2010) but it remains unclear which roles are more strongly associated with individual innovativeness. The second stream of work addresses the universal or contextual value of open triads for innovation (Borgatti et al., 2014; Kraft & Bausch, 2018). Ahuja (2000) suggests that structural holes are useful in settings where speedy access to information is essential but may be less efficient in minimizing opportunistic behaviors. Spanning structural holes can have different outcomes depending on whether the context is competitive or cooperative (Kilduff & Brass, 2010; Vasudeva, Zaheer, et al., 2013), or whether the national culture is collectivistic or individualistic (Xiao & Tsui, 2007). However, how the relationship between open triads and individuals' innovation involvement is shaped by the context when brokerage structures are decoupled into brokerage roles remains unclear.

Both perspectives suggest we need a better understanding of the underlying mechanisms explaining why some triadic structures are more efficient than others for individual innovativeness. Given that individuals involved in innovation build social networks based on their expected value for knowledge recombination (Levin & Walter, 2019; Ozer & Zhang, 2019) and their time and attention to cultivating social networks is finite (Dahlander et al., 2016), the question of what type of open triads are more effective to facilitate individual innovativeness is particularly pertinent and timely. Advancing this debate is important since intermediating across unconnected individuals does not come without costs: brokers are subject to cognitive tensions (Jasny & Lubell, 2015; Leana & van Buren, 1999) and structural holes are fragile (Baum et al., 2012; Burt & Merluzzi, 2016).

Practitioner points

- This paper confirms that intermediating between otherwise disconnected individuals facilitates innovation. It also shows that not all intermediation positions are equal, since each open triad brings a unique combination of benefits and costs to the focal individual.
- Individuals seeking to build up a collaborative network for innovation must pay attention to the composition of the triads they form: neither too homogeneous nor too diverse triads in terms of professional diversity help to come up with innovative solutions.
- Our findings also show that, in settings that are more distant from the application context, holding balanced open triads is particularly crucial to overcome institutional rigidities that deter innovation activity.

To address the question about the type of open triads more effective for facilitating individual innovativeness, we apply a cost–benefit perspective (Dahlander et al., 2016) to theorize that some specific brokerage roles are comparatively better than others for facilitating innovation. The cost–benefit view suggests that the net value of brokerage for individual innovativeness is the result of two opposing forces: the non-redundant knowledge provided by network contacts, and the costs required to integrate that knowledge coming from the network (Balachandran & Hernandez, 2018; Dahlander et al., 2016). We adopt Gould and Fernandez's (1989) typology and borrow the terms "balanced triads" and "unbalanced triads" from structural balance theory (Heider, 1946; Rawlings & Friedkin, 2017) to theorize why the net value of certain triadic structures is superior to others for enabling individual innovativeness. We also examine whether this comparatively superior value of certain brokerage roles depends on the institutional setting in which the broker is embedded. We propose that in contexts that are distant from where the knowledge is applied, the importance of cultivating balanced triads for individual innovativeness is magnified compared to settings that are closer to knowledge applicability. This expectation aligns with previous results showing that managers make greater use of social networks to gather new knowledge if they are embedded in weaker institutional settings (Kraft & Bausch, 2018; Li et al., 2008), and that organizational factors can alter the net value of social networks for individual innovativeness (Salter et al., 2015).

We test our ideas in the biomedical context where several policy initiatives have increased interest in knowledge brokers (Currie & White, 2012; Waring et al., 2013). The translational research paradigm assumes that individuals connecting different medical research communities are crucial to bridge the gaps between basic knowledge, clinical practice, and medical innovation (Bornstein & Licinio, 2011). Therefore, the biomedical context offers an ideal setting to examine the role of brokers since they are crucial for ensuring communication between "bench and bedside" and facilitating the flow of resources between scientific discovery and clinical application (Bone et al., 2020). So far, most brokerage research in the biomedical context is prescriptive with only a few empirical studies on the direct effects of brokerage on medical innovation. This makes it an appropriate context to study the influence of the brokerage role on innovation. We test our hypotheses on a sample of 1010 Spanish biomedical scientists from two institutional settings characterized by distinct logics: a science logic and a care logic (Dunn & Jones, 2010; van den Broek et al., 2014).

2 | BROKERAGE AND INNOVATION

2.1 | The limits of the brokerage advantage for individual innovativeness

Prior research on the social structure of innovation highlights the key role of brokerage position which exposes focal actors to non-overlapping sources of knowledge. The core element of brokerage is the open triad (Simmel, 1950; Wynstra et al., 2015). That is, a focal individual connecting two other people (alters) who are not mutually connected. Since knowledge is shared imperfectly among individuals, brokers are expected to be able to identify original opportunities for knowledge recombination (Hargadon & Sutton, 1997; Soda et al., 2018). The value of open triads for innovation has been explored at different levels of analysis. Inventors bridging between otherwise disconnected partners produce more novel patents (Fleming et al., 2007; Lee, 2010), and employees in non-redundant network positions are more creative (Perry-Smith, 2006; Tang et al., 2017; Zhou et al., 2009) and innovative (Tortoriello, 2015). At the organizational level, firms at the intersection between industries benefit from technology brokering to create new products (Hargadon & Sutton, 1997), and a central network position facilitates firm innovativeness (Owen-Smith & Powell, 2004).

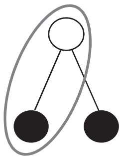
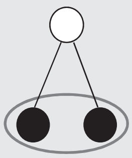
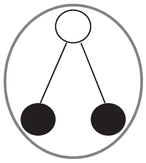
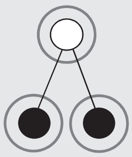
However, we know also that the value of open triads for innovation is limited and relative. Open triads are social structures which suffer from disruptive tensions and contradictions which mean brokers are obliged to deal with the inherent tensions between unconnected parties (Fleming & Waguespack, 2007; Jasny & Lubell, 2015; Podolny & Baron, 1997; Stovel & Shaw, 2012). To maintain and exploit their structural positions brokers need to invest time, attention, and other limited resources—described as the "maintenance costs" (Leana & van Buren, 1999), or the "integration costs" of brokerage (Salter et al., 2015). This idea was already suggested by Burt (2004), pointing that managers often lack incentives to span structural holes since filling these positions demands significant investments of time and effort. To develop a more fine-grained theoretical reasoning of the trade-off between the benefits and costs of brokerage, we suggest an explicit disaggregation of open triads into brokerage roles. We focus next on the notion of brokerage role and employ this framework to theorize that some roles have a better balance in the facilitation of individual innovativeness.

2.2 | Decoupling brokerage roles from brokerage structures

The idea that brokers play different roles in terms of "spheres of social action" goes back to Merton (1968) who proposed the distinction between local and cosmopolitan brokers. While local brokers are interested primarily in their direct social environment, cosmopolitan brokers are more oriented to the world outside their community. Gould and Fernandez (1989) proposed partitioning the individuals involved in a brokerage triad into non-overlapping groups, to allow different structural roles to be distinguished depending on the groups to which individuals belong. A key assumption in this model is that actors are organized according to different criteria (e.g., type of institution, professional affiliation or membership), and hence have different interests, aims, and goals (Jasny & Lubell, 2015).

Some innovation scholars have adopted this perspective to account explicitly for the fact that not all open triads are structurally similar. For instance, at the organizational level Jiang et al. (2019) show that among patenting firms certain roles are more strongly associated with knowledge transfer than others. Belso-Martínez et al. (2015) found that internally oriented brokerage is more efficient for increasing technical innovation, and Balachandran and Hernandez (2018) suggest that foreign triads are better at facilitating radical innovation. This stream of literature provides important insights which suggest that the value of open triads for innovation differs if roles are considered

TABLE 1 Definition of brokerage roles

Brokerage role	Definition
	**Gatekeeper**. The broker belongs to the same group as one of the contacts being brokered. The other actor belongs to a different group
	**Itinerant**. The broker is an outsider with respect to both of the contacts he/she is linked to. The intermediated actors belong to the same group
	**Coordinator**. Both the broker and the two intermediated actors belong to the same group
	**Liaison**. The broker is an outsider with respect to both contacts he/she is linked to. All three members of the brokerage triad belong to different groups

Note: Clear points represent the broker. Ellipses correspond to subgroup boundaries. Adapted from Gould and Fernandez (1989).

explicitly. However, most work adopting this perspective is at the organizational level. So far, at the individual level we know that some brokerage roles are more frequent than others (Lissoni, 2010) and that the broker's strategic goals determine the specific brokerage role adopted (Shi et al., 2009). Most of the evidence is based on secondary network data such as patents (e.g., Jiang et al., 2019; Lim & Park, 2010; Lissoni, 2010), academic publications (Ho & Liu, 2013), published reports (Spiro et al., 2013), or R&D alliances (Balachandran & Hernandez, 2018). Thus, our study aims to complement existing research by offering a conceptual and empirical investigation of the relationship between brokerage roles and individual innovativeness employing primary network data.

2.3 | Balanced open triads, unbalanced open triads and individual innovativeness

Building on the typology of brokerage roles suggested by Gould and Fernandez (1989) (see Table 1), we contend first that each brokerage role provides distinct opportunities for knowledge recombination but requires dissimilar efforts from brokers to coordinate and integrate this knowledge for innovation. For instance, an open triad which includes three contacts from different institutional domains (i.e., liaisons) will offer more knowledge recombination opportunities but will involve high knowledge integration costs.

To theorize about the net value of brokerage roles for individual innovativeness, we suggest that certain roles are more balanced than others in terms of access to novel knowledge and its integration costs. Structural balance theory distinguishes between "balanced" and "unbalanced" triadic structures (Heider, 1946; Sytch & Tatarynowicz, 2014). Balanced triadic structures are more stable, avoid relational tensions and are grounded on mutual cooperation and positive relationships among members. Unbalanced triads tend to be less stable, more polarized, and often involve stress and discomfort for their members (Marineau & Labianca, 2021). In our setting, we consider gatekeeper and itinerant roles as examples of more balanced triadic structures which are more efficient at sourcing and integrating new knowledge. In contrast, liaison and coordinator roles are related to more unbalanced triadic structures whose knowledge integration costs might exceed the potential information benefits for individual innovativeness, or which provide insufficient opportunities to access new knowledge. Below we develop our arguments for each type of brokerage role.[1]

2.3.1 | Balanced open triads: Gatekeeper and itinerant roles

The notion of gatekeeper was proposed by Allen (1977) to refer to R&D professionals with the ability to absorb external knowledge and transfer it internally. Gould and Fernandez (1989) define a gatekeeper as an actor who mediates between one member from his/her own domain and an external member. The fact that gatekeepers have one foot in and one foot out of their domain puts them in a pivotal position to access novel knowledge and apply it in their domain of interest (Patriotta et al., 2013). This capacity to scan and exploit external knowledge and promote it in their own context makes the gatekeeping role crucial for innovation at both the individual (Graf & Krüger, 2011; Le Gallo & Plunket, 2020; Ter Wal et al., 2017) and regional (Breschi & Lenzi, 2015; Giuliani & Bell, 2005; Guercini & Runfola, 2015) levels. In organizations, the concept of gatekeeper is linked closely to the notion of boundary spanner. Boundary spanners are employees who acquire, translate,

[1]Although the original typology of brokerage roles proposed by Gould and Fernandez (1989) considered 5 categories, it is not possible to distinguish between gatekeepers and representatives when working with undirected ties. Following previous work (e.g., Ho & Liu, 2013; Lissoni, 2010) we consider "gatekeepers" and "representatives" as equivalent roles, resulting in 4 different brokerage roles which is more appropriate when considering undirected ties or incoming ties only, as in our data and empirical design.

and disseminate external resources within the organization (Tortoriello & Krackhardt, 2010). For instance, in academic healthcare organizations, clinician-scientists often act as boundary-spanners between "bench and bedside", deal with the tensions between both spheres, and facilitate integration of scientific knowledge with clinical applications (Lander, 2016). To summarize, a gatekeeper position provides significant exposure to new knowledge and practices. At the same time, the knowledge integration costs tend to be relatively low since one of the actors belongs to the same domain as the gatekeeper. This balanced configuration between the knowledge sourcing benefits and the knowledge integration costs allows us to predict that the gatekeeper role facilitates individual innovativeness.

We hypothesize also that itinerant positions offer a balance compromise in terms of the capacity to source new knowledge and its knowledge integration costs. Itinerants[2] mediate between two alters from the same domain, which is different from the domain of the focal individual (Gould & Fernandez, 1989). For example, a basic scientist mediating between two medical practitioners is acting as an itinerant. Within organizations, an itinerant is likely to be a middle manager connecting two lower level managers or two top managers (Shi et al., 2009). Similar to a gatekeeper, the itinerant performs a boundary-spanning function which provides greater knowledge recombination possibilities for the focal actor. Itinerant roles also confer influence and legitimacy, which is crucial to implement new ideas into concrete innovations (Baer, 2012; Perry-Smith & Mannucci, 2017). For instance, itinerants in the organization obtain higher performance scores from their managers (Poleacovschi & Javernick-Will, 2016). With regard to knowledge integration costs, these mainly emerge from breaking boundaries between the broker's own domain and an external domain. The fact that two of the actors in the triad belong to the same domain keeps coordination and integration costs comparatively low. Thus, we expect that the balance between access to new knowledge and the knowledge integration costs provided by gatekeeper and itinerant roles will have a positive effect on individual innovativeness.

2.3.2 | Unbalanced open triads: Coordinator and liaison roles

Coordinator brokerage is the simplest form of brokering because it involves three actors from the same community. For instance, a triad of three basic scientists is formed where there is a focal actor involved who mediates between the other two. Coordinator roles help to communicate and diffuse knowledge within a given community e.g., teachers sharing new practices with peers (Coburn et al., 2013; Neal et al., 2019). However, in these types of triads the ability to gather new knowledge for innovation is limited. The coordinator mediates between individuals with similar interests, goals, and knowledge backgrounds which reduces the potential for knowledge recombination (Balachandran & Hernandez, 2018; Vasudeva, Zaheer, et al., 2013). While coordinator positions expose the broker to novel knowledge through his or her structural bridging activities, this might not be sufficient to promote individual innovativeness. Fernandez and Gould (1994, p. 1459) describe coordinators as a "null" form of brokerage. Although the knowledge integration costs associated with a coordinator role may be small the limited access to novel knowledge makes this role unbalanced for innovation.

Liaison roles refer to a situation where all the members of the triad belong to different domains. From a purely combinatorial perspective, liaison positions provide the greatest potential for new knowledge sourcing since the broker benefits from greater access to diverse knowledge stocks and practices. However, this comes at a high cost in terms of knowledge coordination and integration. The capacity of individuals to integrate disparate ideas from heterogeneous sources into a coherent whole is limited. Exposure to highly heterogeneous knowledge may be counterproductive by causing information overload (Paruchuri, 2010; Simon, 1955; Zhou et al., 2009), and brokers may simplify the knowledge inputs if they become too difficult to manage (Kilduff et al., 2006; Krackhardt & Kilduff, 1999). Liaison brokerage often involves tensions because the actors belong to different domains and each will respond to distinct institutional norms and interests, resulting in the absence of a common cognitive scheme and a common perspective (Currie & White, 2012; Ferlie et al., 2005). Although a liaison role offers greater exposure to novel knowledge, the coordination and integration costs maximize the "action problem" associated with open triadic structures (Fleming et al., 2007; Lingo & O'Mahony, 2010), resulting in an unbalanced position which is likely to hinder individual innovativeness.

In sum, we contend that open triads which are balanced in terms of access to novel knowledge and integration costs (namely, gatekeepers and itinerants), will be superior for facilitating individual innovativeness compared to unbalanced open triads (coordinator and liaison roles). Thus, we hypothesize that:

[2]The role of "itinerant" has been described also as "consultant" or "cosmopolitan" (e.g., Shi et al., 2009). In this paper, we decided to retain the term itinerant to be consistent with Gould and Fernandez's (1989) term.

Hypothesis 1 Balanced open triads are more strongly associated to individual innovativeness compared to unbalanced open triads.

2.4 | Brokerage roles in context: "Science-logics" and "care-logics"

The idea that the relationship between brokerage and innovation is influenced by the context in which the broker is embedded has been stressed in prior studies (e.g., Borgatti et al., 2014; Kilduff & Brass, 2010). Kilduff et al. (2006, p. 1042) point out that: "The meaning and relevance of network ties are likely to vary from one social context to another, even when the structural form is identical". For instance, open triads have a stronger impact on innovation if the brokering firm or its network partners are located in countries with higher levels of corporatism (Vasudeva, Spencer, et al., 2013). At the individual level, the advantages of open triads are magnified when skilled return migrants are strongly embedded in their host countries (Wang, 2015), and when brokers are embedded in a non-collaborative environment (Soda et al., 2019).

Drawing on these perspectives, we propose that the absolute and relative value of balanced open triads for individual innovativeness will be shaped by the institutional setting in which the broker is embedded. The literature on institutional logics provides a natural framework to characterize the contextual factors shaping the advantages of open triads for individual innovativeness (Adler & Kwon, 2002; Vasudeva, Spencer, et al., 2013). Institutional logics are defined as a coherent set of assumptions, values, beliefs, and rules which deeply permeate the individual's cognition and preferences (Singh & Jayanti, 2013; Thornton et al., 2012). We explore institutional differences in the context of publicly funded biomedical research. In this setting, scientists are rooted in one of two broad and often conflicting institutional logics: a "science logic" or a "care logic" (Dunn & Jones, 2010).

A science logic prioritizes understanding of the causes of diseases based on scientific advances. Scientists adhering to this logic respect the Mertonian norms of science (Merton, 1973) and the aim of contributing to the corpus of scientific knowledge. University departments and public research organizations are the natural loci of a science logic (Sauermann & Stephan, 2012). Cultivating balanced open triads is critical in this setting where social norms, rewards, and outputs are often distant from knowledge applicability and the priority is generating theory through scientific methods (Lander, 2016). Thus, the access to new knowledge and practices offered by balanced triadic structures may be critical to break down normative boundaries and thus, facilitate innovativeness. This argument aligns with the idea that interpersonal networks often are "important substitutes for weak and inefficient institutions to access information and resources" (Kraft & Bausch, 2018, p. 866).

In contrast, care logic institutions focus on practice both to apply and inform basic science advancements (Dunn & Jones, 2010; McDonald et al., 2013), and developing new diagnostics or better treatments is the priority (Nelson et al., 2011). This logic prevails in healthcare institutions such as hospitals (Consoli & Mina, 2009; Djellal & Gallouj, 2006). While there is frequent interaction between the scientists in both spheres, they operate within their own paradigms (Nelson et al., 2011). We contend that balanced open triads are likely to be less relevant for individual innovativeness if brokers are embedded in a care logic institution. Such institutions themselves act as "boundary-spanners" (Lander, 2016) by offering resources, means and incentives to engage in individual innovativeness. Prior research shows that "care logic institutions function as brokers among different domains and sources of knowledge, such as scientific, clinical, technical, and commercial knowledge" (Thune & Mina, 2016, p. 1546). Also, essential for the pursuit of medical innovation is direct exposure to insights from patients and medical practitioners which is relatively frequent among scientists located in care logic institutions. For instance, shared common spaces for patients and practitioners are the norm in research hospitals, and increase the possibilities for access to experiential knowledge, resources, and information about patients' preferences and needs (Caron-Flinterman et al., 2005; Llopis & D'Este, 2016). We hypothesize that in such settings, the salience of balanced open triads for individual innovativeness and their superior efficiency compared to unbalanced triads will be comparatively lower than in a science logic setting. These arguments suggest two related hypotheses:

Hypothesis 2a The relationship between balanced open triads and individual innovativeness is stronger in a "science" rather in a "care" logic institution.

Hypothesis 2b The superior value of balanced compared to unbalanced open triads for individual innovativeness is more pronounced in a "science" rather than a "care" logic institution.

3 | METHODS

3.1 | Research context and data collection

Biomedicine is an ideal context to explore the relationship between open triadic structures and innovation since it includes a range of epistemic communities ruled by heterogeneous norms and practices (Currie & White, 2012; Ferlie et al., 2005). The complexity inherent in producing biomedical innovations based on publicly funded science requires collaboration among individuals working on different biomedical areas. Dynamic exchanges and cooperation among actors from different institutions and professional domains are expected to increase the chances of achieving therapeutic targets, and reduce the time and costs in proposing safe and useful treatments (Shahzad et al., 2011). This is reflected in the several policy initiatives implemented to reduce the gaps among different biomedical institutional domains to promote medical innovation.[3]

Our research context is biomedicine in Spain where in 2006 the Ministry of Health launched an initiative to reorganize biomedical research. This led to the creation of the Spanish Biomedical Research Networking Centers (henceforth CIBERs), a series of decentralized research platforms. The primary goal of the CIBERs is to support collaborative and translational research in different pathologies.[4] Participant research groups may be physically located in a university, a hospital, a public research organization, or some other institution. The research groups were selected via several highly competitive open calls, focused on a specific range of pathologies of strategic interest to the Spanish National Health System. Our sample comprises all biomedical scientists affiliated to the research groups affiliated to the nine CIBERs. We contacted CIBER scientific directors to obtain support for our research and additional information on the research groups. We consulted administrative data and public databases to obtain the names, affiliations, and e-mail addresses of all the biomedical scientists in the CIBERs. This provided a total population of 4758 individuals.

To develop the questionnaire, during June 2012 to March 2013 we conducted fieldwork interviews with 15 individuals including scientific directors, research group principal investigators, and biomedical scientists. The interviews were instrumental to get a better understanding of the biomedical context and ensure that the survey questions were framed in a way that was meaningful to the biomedical research community. It allowed identification of relevant items and a higher level of granularity of the survey questions (particularly those in the innovation and network related sections of the questionnaire). It also allowed us to validate the survey instrument. Using an online survey platform, in April 2013 we sent a personalized invitation to each scientist explaining our objectives and encouraging them to participate in the survey which they were told would take around 30 minutes to complete.[5] We received completed questionnaire from 1309 scientists, a response rate of 27.5% which is in line with previous large-scale surveys distributed to individual scientists (Perkmann et al., 2013). Due to missing values, our working sample was reduced to 1010 responses (i.e., a final response rate of 21.2%).[6] We combined the survey data with data from secondary sources (administrative records, Web of Science, and PATSTAT) which allowed us to control for a range of additional factors and mitigate potential common method bias problems (Podsakoff et al., 2012).

3.2 | Measures

3.2.1 | Dependent variables: Individual innovativeness

We developed a variable for individual innovativeness which captures the frequency and variety of the activities and outputs related to medical innovation. In the biomedical context, innovation is defined broadly as a "process involving the creation and application of scientific and technological knowledge to improve the delivery of human healthcare and the treatment of disease" (Swan et al., 2007, p. 529). Medical innovation is multi-faceted, and is generally considered to be aimed at: development of new *treatments*, better *diagnostic* methods, and improved *prevention* protocols (Mogoutov et al., 2008; Omachonu & Einspruch, 2010). The innovation literature focuses predominantly on the discovery phase of new pharmaceutical products, and the multiple product development phases before commercialization. The discovery phase is generally measured based on the patenting of new active ingredients, and the product development states are captured by participation in clinical trials (Cockburn & Henderson, 1994; Lowman et al., 2012). Drug discovery

[3]Examples of such initiatives include the National Centre for Advancing Translational Sciences (NCATS) in the U.S. (Collins, 2011) and the European Infrastructure for Translational Medicine (EATRIS) in Europe (van Dongen et al., 2013).

[4]The different CIBER platforms are: Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN) (ref. category), Diabetes and Metabolic Associated Diseases (CIBER-DEM), Epidemiology and Public Health (CIBER-ESP), Hepatic and Digestive Diseases (CIBER-EHD), Obesity and Nutrition (CIBER-OBN), Mental Health (CIBER-SAM), Neurodegenerative Diseases (CIBER-NED), Rare Diseases (CIBER-ER) and Respiratory Diseases (CIBER-ES). See (http://www.ciberisciii.es/) for more detailed information of the composition of each platform.

[5]Survey participants were informed about the objectives of the research and given details of the research project funding the survey. Data protection requirements were adhered to ensure respondents' confidentiality.

[6]We found no evidence of non-response bias: we tested for: (i) differences between early and late respondents across our main variables, (ii) differences between respondents and non-respondents on several dimensions using secondary sources and archival data.

and drug development are important milestones in biomedical innovation, and epitomize an innovation pathway which potentially leads to the commercialization of a new pharmaceutical product, profits for the industry, and additional sources of income for its inventors (Gambardella, 1995; Pisano, 1997).

However, drug discovery and development may capture only a narrow, product-related perspective of a much more complex process. Biomedical scientists may be involved also in other activities related to how healthcare is delivered such as developing clinical guidelines (Berwick, 2003). Clinical guidelines involve a process of codification of tacit knowledge which produces specific protocols "to assist practitioners and patient decisions about appropriate health care for specific clinical circumstances" (Adler & Kwon, 2013, p. 932). The production of new medical devices and new equipment to enable new diagnostic methods is another area of innovation in healthcare and includes improved early-stage diagnosis and disease prevention (Hopkins, 2006; Poste, 2011). Therefore, we conjecture that innovativeness in this context will be reflected in a wide range of activities and outputs in which biomedical scientists might be involved.

The objective was to capture this array of activities and outputs in which our sample of biomedical scientists were involved, and which reflected an explicit effort to translate fundamental knowledge into more tangible healthcare improvements. Drawing on the medical innovation literature and insights from the interviews with biomedical scientists conducted in the pilot phase of the study, our survey asked respondents to report the extent of their involvement in an extensive list of activities related to medical innovation. A drop-down menu allowed them to indicate the frequency of their participation in each activity, ranging from 0 (never) to more than 10 times in a given year (we focused on 2012 which was the year before the questionnaire was administered).[7] We conducted principal component factor analysis with varimax rotation to explore whether the proposed items reflected the different dimensions related to medical innovation. We identified four dimensions (see Appendix Table A1 for details): (i) Product generation, (ii) Drug development, (iii) Clinical guidelines, (iv) Diagnostics and prevention. Based on these four dimensions, we computed our indicator of individual innovativeness. Specifically, we computed a Shannon index which combines innovation variety—range of distinct categories—with innovation frequency—frequency of participation in each activity (e.g., Connelly et al., 2017; Harrison & Klein, 2007). The main advantage of this variable is that it accounts jointly for two aspects of innovation involvement—variety and balance—within a single indicator. Formally, the indicator was computed as follows:

$$H = -\sum_{i=1}^{s} (p_i)\,(lnp_i)$$

where p_i denotes the relative frequency of participation in each of the four innovation dimensions and lnp_i accounts for the natural logarithm of this proportion.

3.2.2 | Independent variables: Balanced and unbalanced triads

The first part of the survey comprised the collection of individual network data, using the standard procedure for egocentric network surveys (e.g., Levin & Cross, 2004; Perry-Smith, 2006; Reiche, 2012). The survey began by asking individuals to respond to a name generator question to recall critical personal contacts located outside their research team. They were provided with ten blank spaces and invited to "*write down the names of those persons (up to 10) from outside your research group who are particularly important for the advancement of your research activities*". As for the dependent variable, we imposed a time-window of the previous 12 months (e.g., Baer, 2010; Perry-Smith, 2006). We asked them to list the relevant contacts outside their research group to prompt respondents to think beyond their immediate colleagues and to report ties in other fields and professional communities. The respondents were also presented with a set of name interpreter questions about the contacts listed which involved them indicating a professional community for each contact. They were provided with a drop-down menu which allowed them to choose one of the seven non-overlapping categories: (i) basic scientist; (ii) clinical scientist; (iii) healthcare professional; (iv) patient or patient representative; (v) private sector; (vi) public administration; (vii) other. These categories were defined based on the fieldwork interviews with biomedical scientists and confirmed that most relevant professional contacts outside their own research group fell into one of the proposed categories. Since some of the categories accounted for few cases, we further grouped them into four: (i) basic scientist, (ii) clinical scientist, (iii) healthcare professional or patient association representative, or (iv) other (e.g., an employee in a private firm or public administration). Finally, the respondents were asked to complete an alter-alter matrix showing all potential connections between each pair of previously named contacts.

[7]The rationale for this time frame is justified by the method used to build our network measures as explained in the construction of our independent variables.

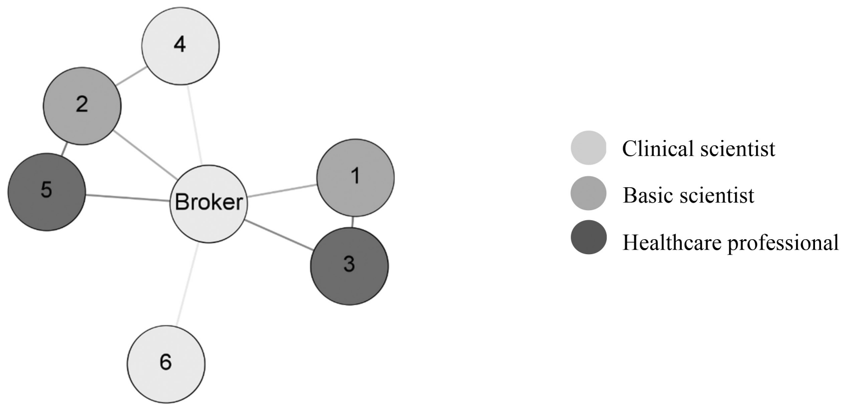


FIGURE 1 Brokerage roles for a sample respondent [Color figure can be viewed at wileyonlinelibrary.com]

These data were used to compute our variables for balanced and unbalanced open triads. We used group membership based on the four non-overlapping professional categories indicated, and built on Gould and Fernandez (1989) to count the number of open triads of each type within the respondent's ego network (e.g., Lissoni, 2010; Shi et al., 2009). This allowed us to assign a score to each brokerage role for every respondent. To create our variable of "balanced open triad", we counted the frequency each individual acted as a gatekeeper or an itinerant. Similarly, the variable "unbalanced open triad" is the count of the frequency of coordinator or liaison roles in each respondent's ego network. To demonstrate the diverse brokerage roles of a single individual, Figure 1 depicts a case from our sample. In this example, our focal individual is a clinical scientist reporting six relevant contacts. We observe that she holds one coordinator role (mediating between contacts 4 and 6), and simultaneously holds two itinerant (connecting 5–3 and 1–2), seven gatekeeper and two liaison roles. Thus, in this case, the focal scientist is involved in nine balanced open triads and three unbalanced open triads in her personal research network.

3.2.3 | Control variables

Each model controls for several factors which might provide alternative explanations for the hypothesized effects at both the individual and research group levels. All the controls were added to the multilevel regressions as fixed effects. At the individual level, we control for respondent age and academic position to control for the possibility that accumulated experience and resources might lead to higher levels of engagement in innovation activities among older compared to younger scientists (Abreu & Grinevich, 2013; Lawson et al., 2019). We control for gender to account for differences in engagement in knowledge transfer activities between men and women (Abreu & Grinevich, 2013; Tartari & Salter, 2015), and for psychological traits (Woods et al., 2018) and motivations for conducting research (Ryan & Deci, 2000). Moreover, as preceding network structures can influence current network positions (e.g., Milanov & Shepherd, 2013) it is important to control for a potential "network heritage" effect (Guercini & Milanesi, 2019). That is, the respondents' accumulated experience in setting up collaborative ties. To partially account for these effects, we downloaded from the ISI-Web of Science all the scientific publications authored by our respondents during the period 2010–2013. We then computed three bibliometric indicators for each respondent: average number of co-authors per article, average number of articles with industry co-authors, and average number of articles with international co-authors. All three indicators were included as control variables. Finally, we included two variables to control for ego-network size. At the research group level, we control for group size, internal network density, geographical location, and principal investigator's (PI) patenting experience (Aschhoff & Grimpe, 2014), as well as PI experience in co-publishing with hospital and firms. We controlled also for the CIBER scientific domain of each research group. Table 2 describes the control variables.

3.3 | Statistical method

We considered three features of our data when choosing a suitable statistical method for our analysis. First, our dependent variable (individual innovativeness) is a Shannon-index, and so by construction it is left-bounded to zero. The censored nature of the dependent variable must be accounted for in order to avoid biased results (Greene, 2003). Second, because a proportion of our respondents did not engage in any activity or output associated with individual innovativeness, we have several cases where the dependent variable takes the value zero. Tobit models provide robust estimates in the case of frequent zero values for the dependent variable (Wooldridge, 2010). Third, the data used for the analysis have a multilevel structure: individual respondents are affiliated to research groups (Level 1) which are embedded in a particular institutional logic (science or care) (Level 2). Accounting for the nested structure of data is important to avoid underestimation of the standard errors (Rabe-Hesketh & Skrondal, 2008). Taking account of all these features, we employed a random-intercept multilevel Tobit model using the *metobit* function in Stata v.15 (Lee et al., 2020; StataCorp., 2017).

4 | RESULTS

Table 3 presents the means, standard deviations, range (minimum and maximum), and correlations for the variables in our analysis. The results confirm that a large proportion of scientists do not perform any type of brokerage role, and that the frequency of balanced and unbalanced open triads is quite similar: 44.2% of the respondents were involved in at least one balanced open triad, and 49.2% were involved in at least one unbalanced open triad. The average number of balanced and unbalanced open triads related to our sample of biomedical scientists is 3.2 and 2.7, respectively.

Table 4 presents the results of the multilevel Tobit regression for the dependent variable individual innovativeness. Model 1 is the baseline model which includes only the control variables. Overall, the model confirms that senior scholars (i.e., PI's) show higher levels of individual innovativeness. At the research group level, we observe that respondents belonging to larger groups with PIs with patenting experience are more innovative. Model 2 includes the effect of balanced open triads and unbalanced open triads on individual innovativeness. The results of Model 2 show that the coefficient of balanced open triads is positive and statistically significant ($p < .001$), and the coefficient of unbalanced open triads is not significant. To confirm the difference between these coefficients statistically, we conducted a Wald test (e.g., Balachandran & Hernandez, 2018). The results support H1: balanced open triads are superior to unbalanced open triads since the former are more strongly associated than the latter with individual innovativeness (Wald χ^2 [1] = 6.22, $p = .012$).

Models 3–6 show the results of a split sample procedure (e.g., Laursen & Salter, 2014) to test H2a and H2b. The split between science logic and care logic institutions was based on archival data on the institutional setting of each research group. Scientists in research groups located in hospitals, clinics, and similar institutions are classified as embedded in care-logic institutions. Scientists in research groups in universities or public research organizations are classified as embedded in science-logic institutions. H2a suggested that the relationship between balanced open triad and individual innovativeness will be stronger if the broker is embedded in a science-logic institution. The coefficient of balanced open triads in the care-logic subsample is not significant, suggesting that involvement in balanced open triads does not translate into greater individual innovativeness if the broker is embedded in a care logic institution (Model 4). Model 6 shows that the coefficient of balanced open triads is positive and statistically significant for individual innovativeness if the broker is embedded in a science logic institution. To confirm that the difference between both coefficients is statistically significant, we ran a Wald test; the results show that the differences are not significant (Wald χ^2 [1] = 0.05, $p = .826$). Thus, H2a is not supported.

In H2b we suggested that the superior value of balanced open triads over unbalanced open triads for individual innovativeness will be accentuated if the broker is located in a science logic institution. A Wald test comparing the coefficients of balanced open triads and unbalanced open triads in model 4 indicates that the coefficients are not statistically different (Wald χ^2 [1] = 0.01, $p = .943$). Thus, the results suggest that in care logic institutions, there is no statistical difference between balanced open triads and unbalanced open triads. However, if we consider the coefficients of balanced open triads and unbalanced open triads in the science logic subsample (Model 6), the picture changes. In this case, the results of the Wald test confirm that both coefficients are statistically different (Wald χ^2 [1] = 6.59, $p = .011$). In sum, if the broker is embedded in a science logic institution, then holding balanced open triads is substantially more beneficial for individual innovativeness than holding unbalanced open triads, while differences between holding balanced and unbalanced open triads are not found for brokers who belong to a care logic institution. This supports H2b.[8]

[8]We conducted several robustness checks. Our initial dependent variable is a joint indicator of two dimensions: the range of different innovation activities in which respondents are involved, and their relative frequency. We re-estimated our models using two alternative dependent variables to account for each innovation dimension separately. First, instead of clustering innovation activities into 4 categories, we created a dependent variable that accounted for the frequency of participation in each of the 11 activities. Second, we built a categorical variable ranging from 0 (no involvement in any innovation activity), to 3 (involvement in activities that correspond to 3 or 4 different categories). This indicator allowed us to account explicitly for the variety of innovation activities in which the respondent was involved, irrespective of their frequency. Appendix Table A2 reports the results of a multilevel negative binomial (Model 1) and a multilevel ordered probit regression (Model 2). There are some small differences between the regressions, but the main findings hold.

TABLE 2 Description of variables and their data sources

Variable name	Description	Source
Balanced open triads	Frequency with which the respondent occupies gatekeeper or itinerant roles	Survey
Unbalanced open triads	Frequency with which the respondent occupies liaison or coordinator roles	
Age	Respondents' age	Survey
Academic position	Dummies for respondent's academic position (principal investigator, post-doc with projects as PI, post-doc w/o projects as PI, predoctoral researcher, technician, another position [ref. category])	Survey
Gender (Female = 1)	Dummy = 1 if respondent is Female	Survey
Conscientiousness	Mean value of 4-item construct to capture respondent's conscientiousness ($\alpha = .72$). e.g., I like order. Source: Donnellan et al. (2006)	Survey
Neuroticism	Mean value of 4-item construct ($\alpha = .63$). e.g., I have frequent mood swings. Source: Donnellan et al. (2006)	Survey
Openness to experience	Mean value of 4-item construct ($\alpha = .63$). e.g., I have a vivid imagination. Source: Donnellan et al. (2006)	Survey
Extraversion	Mean value of 4-item construct ($\alpha = .72$). e.g., I talk to a lot of different people at parties. Source: Donnellan et al. (2006)	Survey
Agreeableness	Mean value of 4-item construct ($\alpha = .64$). e.g., I feel others' emotions. Source: Donnellan et al. (2006)	Survey
Political skills	Mean value of 6-item construct ($\alpha = .73$). e.g., I spend a lot of time at work developing connections with others. Source: Ferris et al. (2005)	Survey
Intrinsic motivation	Mean value of 7-item construct ($\alpha = .83$). e.g., I perform research because I enjoy it). Source: Deci and Ryan (2000)	Survey
Extrinsic motivation	Mean value of 7-item construct ($\alpha = .80$). e.g., I perform research because I want to advance on my professional career. Source: Deci and Ryan (2000)	Survey
Avg. # co-authors	Average number of co-authors per article, for all articles where each respondent has participated (period 2010–2013)	ISI Web of Science
Avg. pubs. w/ industry	Average number of articles with at least one co-author affiliated to an industrial organization (period 2010–2013)	ISI Web of Science
Less than two contacts	Dummy = 1 if respondent has less than two contacts reported in his/her external network	Survey
Network size = large	Dummy = 1 if respondent's external network size (i.e., n° of contacts in his/her personal network) is in the highest quartile of the distribution	Survey
Avg. International pubs.	Average number of articles with coauthors from two or more countries of all authors (period 2010–2013)	ISI Web of Science
Ciber_contract	Dummies for type of contractual form linking respondent with the CIBER network (employed by the CIBER, affiliated to the CIBER, other contractual form [ref. category])	Archival data
Group size	Count of members belonging to the same research group as the respondent	Archival data
Internal network density	Number of contacts that each respondent reported from their own research group	Survey + Archival data
Region = Madrid or Barcelona	Dummy = 1 if the respondent's research group is in Madrid or Barcelona, since a substantial proportion of research. Groups are in these two metropolitan areas	Archival data
PI patents	Number of patent applications submitted by the PI of the CIBER research group to which respondent belongs, during the period 1998–2010 to control for group-level differences in technological performance	PATSTAT
PI co-authors	Average number of PI co-authors per article during the period 1998–2010	ISI Web of Science
PI Pubs with firms	Proportion of PI publications where at least one of the co-authors is affiliated to a firm	ISI Web of Science
PI Pubs with hospitals	Proportion of PI publications where at least one of the co-authors is affiliated to a hospital	ISI Web of Science
CIBER_dummies	Dummies for 9 different biomedical fields (see Footnote 4 for further details)	Archival data

5 | DISCUSSION AND CONCLUSIONS

Innovation processes are collective and social in nature. We set out to investigate the relationship between open triads and innovation by addressing two questions. Which brokerage roles provide the most advantageous positions to facilitate individual innovativeness? How does the institutional logic in which the broker is embedded influence these relationships? By separating the influence on innovation of distinct brokerage roles, we provide compelling evidence that balanced triadic structures are particularly beneficial for involvement in innovation. In turn, we found that unbalanced triadic structures do not favor individual innovativeness. Our findings suggest also that the superior value of balanced open triads over unbalanced open triads depends on the broker's institutional logic.

5.1 | Theoretical contributions

This study contributes to research on brokerage and innovation. Our research responds to recent calls for micro-founded conceptualizations of social networks (Casciaro et al., 2015; Fang et al., 2015; Kilduff & Brass, 2010) and contributes to an understanding of individual patterns in the search for knowledge related to innovation (Dahlander et al., 2016; Maggitti et al., 2013). Numerous studies show that individuals with networks rich in open triads have more opportunities for knowledge recombination (Tortoriello, 2015; Wong & Boh, 2014). However, this relationship varies significantly (Ozer & Zhang, 2019), suggesting that the magnitude of this association is subject to contingencies. Focusing on the trade-offs from brokerage, some studies report that forming and maintaining open triads is costly for the broker (Leana & van Buren, 1999). Relatedly, using knowledge from different sources demands coordination and integration efforts (Dahlander et al., 2016; Salter et al., 2015) which need to be taken into account when examining the brokerage-innovation relationship.

We contribute to a growing stream of work which suggests that the net value of open triads for innovation depends not only on the structural separation of the actors but also on their heterogeneity (Balachandran & Hernandez, 2018; Ter Wal et al., 2016). Building on these insights, adoption of Gould and Fernandez's (1989) model of mediation structures allowed us to decouple brokerage roles from brokerage structures, and to show that structurally equivalent positions are associated with different levels of individual innovativeness. We suggest that the net value of each brokerage role for innovation is subject to two opposing forces: exposure to different knowledge sources, and the cost of coordinating and integrating the knowledge for innovation. We argued that some brokerage roles offer a better-balanced trade-off between these forces, and thus, are more closely related to individual innovativeness. Decoupling triadic structures into brokerage roles is not novel in the innovation literature. However, work based on this perspective is limited and fragmented, with the focus mostly on gatekeepers (Giuliani, 2011; Graf & Krüger, 2011; Ter Wal et al., 2017), secondary data (Lissoni, 2010), and the organizational level (Balachandran & Hernandez, 2018; Belso-Martínez et al., 2015). We aim to extend this research by theorizing explicitly about the benefits and costs associated with each brokerage role and its consequences for individual innovativeness and using primary data for the empirical analysis.

Our study contrasts with previous work which focuses directly on the relationship between open triads and innovation (e.g., Balachandran & Hernandez, 2018; Belso-Martínez et al., 2015) in two fundamental aspects. First, while these authors found that only the "extreme" brokerage roles tended to be related to firm innovation, our results suggest that the best balance is achieved by intermediate roles (namely, gatekeeper and itinerant roles). There may be several explanations for these different results; one might be the unit of analysis used. Prior studies suggest that the diminishing returns from external ties are particularly relevant to individuals (Dahlander et al., 2016) who "cannot scale themselves as well as firms and face finite search time" (p. 283). Relatedly, the costs associated with knowledge coordination and integration of disparate knowledge sources might be more salient for individuals (Salter et al., 2015).

Another contribution of our research is that it highlights the contingent effect of the institutional logic on the relationship between open triads and innovation. Previous research on a contingency view of brokerage structures (Kilduff & Brass, 2010; Soda et al., 2019; Tortoriello & Krackhardt, 2010) added to our understanding of the importance of contextualizing brokerage structures. Consistent with this, we provide systematic evidence on how two contrasting institutional logics condition the relationship between brokerage roles and innovation. Although previous studies show that the informational benefits of brokerage depend on the institutional context, research dealing explicitly with brokerage roles and innovation tends not to examine this contingency effect empirically (Stovel & Shaw, 2012). Guided by institutional theory, we drew on prior developments of the science and care logics in biomedicine (Dunn & Jones, 2010). Taking account of these institutional-level differences, we found that the relationship between brokerage roles and individual innovativeness is sensitive to context, such that individuals derive greater benefits from balanced open triads compared to unbalanced open triads, in science logic rather than care logic institutions. We argue that purposeful brokerage actions aimed at forming balanced open triads in personal networks are particularly important for individuals in institutional settings where

TABLE 3 Summary statistics and correlation matrix

		Mean	*SD*	Min	Max	1	2	3	4	5	6
1	Individual innovativeness	0.14	0.21	0.00	1.22	1.00					
2	Balanced open triads	3.19	6.05	0.00	39.00	0.14*	1.00				
3	Unbalanced open triads	2.69	5.16	0.00	45.00	0.04	0.37*	1.00			
4	Age	41.50	10.47	23.00	74.00	0.26*	0.15*	0.11*	1.00		
5	Conscientiousness	5.63	1.00	1.25	7.00	−0.03	−0.06	−0.09*	−0.10*	1.00	
6	Neuroticism	3.38	1.09	1.00	7.00	0.00	−0.06*	−0.02	−0.01	−0.07*	1.00
7	Openness to experience	5.35	1.00	1.00	7.00	0.03	0.12*	0.09*	−0.03	0.00	−0.18*
8	Extraversion	3.96	1.18	1.00	7.00	0.05	0.07*	0.08*	−0.13*	−0.04	−0.08*
9	Agreeableness	5.71	0.91	2.00	7.00	0.02	0.05	0.01	−0.06	0.16*	−0.04
10	Political skills	5.57	0.77	2.67	7.00	0.04	0.11*	0.07*	−0.03	0.22*	−0.29*
11	Intrinsic motivation	6.18	0.80	1.00	7.00	−0.02	0.06	0.05	−0.05	0.13*	−0.10*
12	Extrinsic motivation	3.71	1.18	1.00	7.00	0.11*	−0.01	−0.04	0.10*	0.08*	0.01
13	Avg. # co-authors	5.84	4.70	0.00	21.00	0.15*	0.12*	0.10*	0.14*	−0.03	0.00
14	Avg. pubs. w/ industry	0.03	0.12	0.00	1.00	0.03	0.05	0.07*	0.03	0.01	−0.03
15	Avg. International pubs.	0.23	0.32	0.00	1.00	0.03	0.09*	0.09*	−0.02	−0.02	−0.07*
16	Group size	18.77	10.82	4.00	79.00	−0.03	−0.05	−0.05	−0.19*	−0.10*	−0.01
17	Internal network density	0.71	0.27	0.00	1.00	−0.04	−0.07*	−0.04	−0.06	0.09*	0.01
18	PI patents	1.05	2.38	0.00	21.00	−0.04	0.00	0.03	−0.09*	0.01	0.03
19	PI coauthors	5.39	0.77	2.40	7.27	0.07*	0.04	0.05	0.02	0.03	−0.05
20	Pubs with firms	0.05	0.07	0.00	0.40	0.05	−0.02	0.00	−0.04	0.01	0.02
21	Pubs with hospitals	0.51	0.33	0.00	1.00	0.25*	0.10*	0.03	0.12*	0.06*	−0.05

$^{*}p < .05$.

the opportunities for exposure to different communities are limited.

5.2 | Managerial implications

The practical implication for individuals willing to engage in innovation activities is that they need to be selective when mobilizing brokerage structures which combine contacts from different professional communities. Individuals' awareness of the knowledge recombination benefits, and knowledge integration costs associated with different open triadic structures may be critical to crafting an effective network for innovation. This applies particularly to biomedical scientists, where an effective intermediation between basic research scientists and clinical scientists is viewed by funding agencies and public policy initiatives as crucial for a faster and better translation of biomedical findings into specific health benefits (e.g., de Groot et al., 2021; Long et al., 2013). We confirmed that brokerage greatly matters, but also observed that not all brokerage forms matter equally for medical innovation: instead, our findings suggest that biomedical scientists who more frequently are involved in balanced open triads in their personal networks (i.e., in gatekeeper or itinerant roles) are particularly active in innovation activities.

This implies that, when forming open triads, individuals need to account also for the professional communities of the contacts. While an excessive diversity in the triad can cause knowledge integration problems, too much homogeneity may not provide enough opportunities for knowledge recombination. These findings are consistent with Ter Wal et al.'s (2016) argument that open structures coupled with a degree of actor homogeneity provide an appropriate balance to yield information advantages; while open structures with too diverse or too homogeneous network partners lead to under-embedded or over-embedded networks, respectively. Similarly, we found that balanced open triads expose the broker to new sources of knowledge and allows to perform information processing and information communication functions (Giuliani, 2011; Gould & Fernandez, 1989; Ter Wal et al., 2017) compared to unbalanced open triads.

In addition, our results suggest that balanced open triads explain also why all brokerage structures do not lead equally to individual innovativeness in the presence of different institutional contingencies. In general, we found

7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1.00														
0.19*	1.00													
0.25*	0.23*	1.00												
0.29*	0.32*	0.51*	1.00											
0.26*	0.11*	0.16*	0.25*	1.00										
−0.04	0.11*	−0.02	0.06*	0.25*	1.00									
0.04	0.04	0.03	−0.00	0.06	0.07*	1.00								
0.06	−0.00	−0.02	−0.00	0.09*	0.03	0.21*	1.00							
0.10*	0.06*	0.06	0.04	0.05	−0.02	0.51*	0.22*	1.00						
−0.03	−0.01	−0.06	−0.10*	−0.10*	−0.03	−0.08*	−0.01	0.04	1.00					
−0.00	−0.03	0.01	0.09*	0.06	0.01	0.00	0.02	−0.03	−0.21*	1.00				
0.01	−0.07*	−0.04	−0.04	0.03	0.02	−0.05	−0.01	0.01	0.14*	−0.03	1.00			
0.01	0.02	0.04	0.04	0.04	0.06	0.14*	−0.02	0.07*	0.13*	−0.10*	0.02	1.00		
−0.04	−0.01	−0.06	−0.03	−0.00	0.07*	0.01	0.11*	−0.03	0.13*	−0.08*	0.00	0.05	1.00	
−0.07*	0.04	−0.00	0.01	−0.04	0.00	0.15*	−0.04	−0.04	−0.12*	−0.03	−0.37*	0.08*	0.08*	1.00

that the full potential positive effects of brokerage structures emerge in institutional settings where innovation activities are less supported and where the professional environment involves lower levels of interaction with other professional communities. It seems that in settings dominated by a science logic where norms and incentives prioritize the contribution to fundamental understanding and are more distant from the context of application, individual efforts to build social capital could help to overcome institutional limitations and rigidities which deter innovation activity. Instead, in care logic institutions, the mission-oriented nature of research and the plurality of the professional and social communities involved in clinical research (e.g., direct contact with patients and medical practitioners), may compensate for limited individual capacity or unwillingness to perform a brokerage role. Thus, the type of brokerage role seems to matter less in settings where exposure to distinct epistemic communities is a core institutional issue. Overall, our results provide a more nuanced understanding of the role of brokerage structures in favoring or hindering individual innovativeness. Our findings might prompt some rethinking about the optimal combination of contact diversity to maximize innovation gains, and how institutional logics intensify or limit the effects of particular brokerage roles on innovation.

5.3 | Limitations and future research

Our contributions should be considered in the context of the limitations of our research. First, the limitations related to using survey data. We were careful to base our claims only on robust and systematic associations: endogeneity and reverse causality issues are only partially mitigated although we consider a range of individual-level covariates to control for differences in research experience, ability, knowledge, and previous patenting experience. However, the absence of a dynamic perspective is a weakness of the present work, and we suggest that examining the extent to which brokerage roles are formed, renewed, or concluded, and how this dynamic affects innovation performance would be a fruitful direction for future research. Second, our data refer to the context of biomedical research in Spain and it is possible that our findings were driven partially by the context. Our findings may be more applicable to settings with similar characteristics such as other scientific fields or highly creative industries, but more research

TABLE 4 Main results—Multilevel tobit regression

	Full sample		Care logic		Science logic	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	Coef. (*SE*)	**Coef. (*SE*)**	**Coef. (*SE*)**	**Coef. (*SE*)**	**Coef. (*SE*)**	**Coef. (*SE*)**
Balanced open triads		0.007*** (0.00)		0.007 (0.00)		0.007** (0.00)
Unbalanced open triads		−0.002 (0.00)		0.007* (0.00)		−0.006 (0.00)
Individual controls (FE)						
Age	0.004** (0.00)	0.004** (0.00)	0.001 (0.00)	0.001 (0.00)	0.005*** (0.00)	0.005** (0.00)
Principal investigator	0.083*** (0.01)	0.098*** (0.02)	0.098 (0.12)	0.118 (0.12)	0.118 (0.14)	0.139 (0.14)
Postdoc w/projects as PI	0.034 (0.05)	0.045 (0.06)	−0.016 (0.08)	−0.012 (0.08)	0.097 (0.12)	0.119 (0.12)
Postdoc w/o projects as PI	−0.045 (0.07)	−0.029 (0.07)	−0.116 (0.09)	−0.099 (0.08)	0.032 (0.13)	0.049 (0.13)
Predoc scientist	−0.020 (0.03)	−0.011 (0.03)	−0.067 (0.09)	−0.065 (0.09)	0.022 (0.13)	0.030 (0.13)
Technician	−0.093*** (0.03)	−0.085** (0.03)	−0.152 (0.11)	−0.145 (0.11)	−0.049 (0.15)	−0.040 (0.15)
Gender = Female	−0.108** (0.04)	−0.116*** (0.04)	−0.162*** (0.04)	−0.163*** (0.04)	−0.069** (0.03)	−0.080** (0.03)
Conscientiousness	0.001 (0.01)	0.002 (0.01)	−0.016 (0.02)	−0.020 (0.02)	0.012 (0.01)	0.013 (0.01)
Neuroticism	0.017 (0.02)	0.018 (0.01)	0.035** (0.02)	0.035** (0.02)	0.000 (0.02)	0.003 (0.02)
Openness to experience	0.013 (0.02)	0.011 (0.02)	−0.020 (0.02)	−0.026 (0.02)	0.026 (0.02)	0.026 (0.02)
Extraversion	0.013 (0.02)	0.013 (0.01)	−0.006 (0.02)	−0.008 (0.02)	0.027** (0.01)	0.026** (0.01)
Agreeableness	0.004 (0.00)	0.005 (0.01)	−0.001 (0.03)	0.007 (0.03)	−0.001 (0.02)	−0.000 (0.02)
Political skills	0.041*** (0.01)	0.040*** (0.01)	0.038 (0.03)	0.037 (0.03)	0.053** (0.02)	0.051** (0.02)
Intrinsic motivation	−0.019 (0.02)	−0.018 (0.03)	0.026 (0.03)	0.031 (0.03)	−0.036 (0.03)	−0.035 (0.03)
Extrinsic motivation	0.016** (0.01)	0.015** (0.01)	0.005 (0.02)	0.006 (0.01)	0.023* (0.01)	0.022 (0.01)
Avg. # co-authors	0.006* (0.00)	0.006* (0.00)	0.013*** (0.00)	0.013*** (0.00)	0.003 (0.00)	0.004 (0.00)
Avg. pubs. w/ industry	0.035 (0.12)	0.032 (0.13)	−0.130 (0.16)	−0.158 (0.16)	0.123 (0.11)	0.124 (0.11)
Avg. International pubs.	−0.026 (0.04)	−0.030 (0.03)	−0.080 (0.07)	−0.069 (0.07)	0.008 (0.05)	0.005 (0.05)
Less than two contacts	0.000 (0.02)	0.005 (0.02)	−0.013 (0.05)	0.004 (0.05)	0.024 (0.04)	0.024 (0.04)
Network size = large	0.035* (0.02)	−0.015 (0.05)	0.016 (0.05)	−0.076 (0.06)	0.054 (0.03)	0.031 (0.04)
Group-level controls (FE)						
Group size	0.002*** (0.00)	0.002*** (0.00)	−0.002 (0.00)	−0.002 (0.00)	0.002 (0.00)	0.002 (0.00)
Internal network density	−0.002 (0.04)	0.005 (0.05)	0.060 (0.07)	0.068 (0.06)	−0.040 (0.05)	−0.038 (0.05)
Region = Madrid or Bcn	0.032 (0.04)	0.034 (0.04)	0.055 (0.06)	0.048 (0.06)	−0.026 (0.04)	−0.020 (0.04)
PI patents	0.016** (0.01)	0.016* (0.01)	0.001 (0.01)	−0.001 (0.01)	0.022*** (0.01)	0.023*** (0.01)
PI coauthors	−0.005 (0.02)	−0.007 (0.02)	−0.032 (0.03)	−0.032 (0.03)	−0.003 (0.03)	−0.005 (0.03)
PI Pubs with firms	0.063 (0.38)	0.092 (0.36)	0.636* (0.37)	0.638* (0.36)	−0.171 (0.30)	−0.141 (0.30)
PI Pubs with hospitals	0.281** (0.14)	0.281** (0.14)	0.062 (0.13)	0.042 (0.13)	0.382*** (0.07)	0.377*** (0.08)
Constant	−0.733** (0.29)	−0.741*** (0.27)	−0.374 (0.35)	−0.397 (0.34)	−0.927*** (0.29)	−0.914*** (0.29)
Random intercepts						
Level 1 (Research group)	0.024*** (0.01)	(0.01) 0.024***	0.006 (0.01)	0.007 (0.01)	0.024*** (0.01)	0.024*** (0.01)
Level 2 (Institution type)	0.001*** (0.00)	(0.00) 0.001*				
var(e.shannon_index)	0.088*** (0.00)	(0.00) 0.086***	0.086*** (0.01)	0.085*** (0.01)	0.084*** (0.01)	0.082*** (0.01)
N	1010	1010	364	364	646	646
Obs.(uncensored)	463	463	215	215	248	248
Obs.(left-censored)	547	547	149	149	398	398
Log likelihood	−448.1	−443.3	−149.8	−146.9	−263.9	−260.3
Number of Level 1 clusters	309	309	111	111	198	198
Number of Level 2 clusters	2	2				

TABLE 4 (Continued)

	Full sample		Care logic		Science logic	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Coef. (*SE*)	Coef. (*SE*)	Coef. (*SE*)	Coef. (*SE*)	Coef. (*SE*)	Coef. (*SE*)
ICC (Level 1)	0.212	0.225	0.068 (0.06)	0.071 (0.06)	0.220 (0.04)	0.229 (0.04)
ICC (Level 2)	0.008	0.007				

Notes: ICC displays Residual intraclass correlations. All models were computed with robust standard errors. All models include dummy variables to control for CIBER scientific domain (9 dummies) and the contract type linking each respondent with her research group (3 dummies).

*$p < .1$; **$p < .05$; ***$p < .01$.

is needed in different contexts. Third, our conceptualization of non-overlapping groups to compute brokerage roles was based on the professional communities of the individuals forming the open triads. Future work could use additional or complementary definitions to capture brokerage roles which might increase the generalization and validity of our findings. For instance, the geographical location of alters and their hierarchical positions in the organization could be considered. Fourth, the phenomenon we addressed is complex. Participation in innovation and the formation of roles depend on a multitude of factors, many of which are not captured in this study. We would encourage more qualitative analyses to refine our findings. For example, case studies focused on individuals who perform distinct brokerage roles might provide fundamental insights. Fifth, the data used to construct our dependent variable are from primary sources. Secondary data (e.g., clinical trial records or licenses) could be included to corroborate our findings and check whether our results hold for other forms of innovative outputs. Finally, we focused on the relationships between brokerage and innovation at the individual level and it would be useful to analyze these relationships at the group level. Adopting a project or team-level perspective would allow examination of brokerage roles at the team or organizational level based on departments or hierarchical units.

6 | CONCLUDING REMARKS

Our study offers a new way to understand how structural holes facilitate individual innovativeness. By applying the notion of role to the brokerage-innovation relationship, we showed that brokerage roles based on balanced open triads are crucial for facilitating innovation, whereas brokerage roles based on unbalanced open triads make no significant difference. Our work confirms that the importance of roles is also context dependent. In institutional settings more distant from where the knowledge is applied, forming networks rich in balanced open triads becomes central for innovation. We hope our study will trigger further research from a brokerage role perspective to advance our understanding about how social interaction shapes innovation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

The authors have read and agreed to the Committee on Publication Ethics (COPE) international standards for authors.

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APPENDIX A

TABLE A1 Factor analysis of individual innovativeness dimensions

	Product generation	Drug development	Clinical guidelines	Diagnostics/ prevention
Patent applications for new drugs of therapeutic substances	**0.763**	0.055	−0.035	0.059
Licenses granted from patents	**0.729**	0.090	0.003	−0.053
Participation in spin-off companies	**0.733**	−0.001	−0.012	0.088
Clinical trials phases I, II, III, new drugs or therapeutic substances	0.188	**0.620**	0.363	−0.079
Clinical trials phase IV, new drugs or therapeutic substances	0.155	**0.818**	0.204	−0.046
Clinical trials phase IV, new diagnostic techniques	−0.120	**0.730**	−0.222	0.219
Development of guidelines for healthcare professionals	−0.048	0.204	**0.772**	0.237
Development of guidelines for patients	−0.025	0.018	**0.811**	0.067
Patent applications for new diagnostic techniques	0.216	−0.051	0.128	**0.764**
Clinical trials phases I, II, III, new diagnostic techniques	−0.062	0.276	−0.026	**0.693**
Development of guidelines for the general population	−0.041	−0.166	0.395	**0.632**

Notes: Extraction method: PCA. Rotation method: Varimax with Kaiser Normalization. Factor 1 (Product generation) explains 21.8% of the variance. Factor 2 (Drug development) explains 16.2% of the variance, Factor 3 (Clinical guidelines) explains 13.6% of the variance, and Factor 4 (Diagnostics/Prevention) explains 10.2% of the variance. Bold values indicate high loadings (>0.60) between items and dimensions.

TABLE A2 Robustness checks

	Multilevel negative binomial regression						Multilevel ordered probit regression					
	Full sample		Care logic		Science logic		Full sample		Care logic		Science logic	
	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*
Balanced triads	0.033***	(0.00)	0.024	(0.02)	0.034**	(0.02)	0.024***	(0.00)	0.021	(0.02)	0.023**	(0.01)
Unbalanced triads	−0.015	(0.01)	0.012	(0.02)	−0.024	(0.02)	−0.009	(0.02)	0.030**	(0.01)	−0.027**	(0.01)
Individual controls (FE)												
Age	0.021**	(0.01)	0.008	(0.01)	0.028***	(0.01)	0.012	(0.01)	−0.000	(0.01)	0.018**	(0.01)
Principal investigator	0.414***	(0.14)	0.416	(0.36)	0.616	(0.78)	0.234	(0.19)	0.132	(0.45)	0.541	(0.48)
Postdoc w/projects as PI	0.077	(0.26)	−0.144	(0.29)	0.364	(0.71)	0.097	(0.26)	−0.158	(0.31)	0.441	(0.43)
Postdoc w/o projects as PI	−0.291	(0.20)	−0.493	(0.32)	−0.053	(0.72)	−0.166	(0.28)	−0.457	(0.31)	0.191	(0.43)
Predoc scientist	−0.125***	(0.01)	−0.186	(0.37)	−0.082	(0.73)	−0.063	(0.17)	−0.292	(0.35)	0.168	(0.44)
Technician	0.015	(0.02)	−0.054	(0.40)	0.001	(0.82)	−0.293*	(0.15)	−0.554	(0.39)	−0.087	(0.50)
Gender = Female	−0.480***	(0.04)	−0.506***	(0.17)	−0.461***	(0.17)	−0.430**	(0.19)	−0.692***	(0.13)	−0.272**	(0.13)
Conscientiousness	0.053	(0.08)	−0.061	(0.08)	0.142**	(0.07)	−0.018	(0.05)	−0.116	(0.07)	0.024	(0.05)
Neuroticism	0.056	(0.08)	0.134**	(0.06)	−0.030	(0.07)	0.072**	(0.03)	0.106**	(0.05)	0.034	(0.05)
Openness to experience	0.041	(0.07)	−0.087	(0.07)	0.087	(0.08)	0.043	(0.08)	−0.096	(0.06)	0.105*	(0.06)
Extraversion	0.085	(0.10)	−0.037	(0.07)	0.180**	(0.07)	0.029	(0.03)	−0.022	(0.06)	0.057	(0.04)
Agreeableness	0.077***	(0.02)	0.057	(0.11)	0.105	(0.11)	−0.002	(0.02)	0.016	(0.09)	−0.024	(0.07)
Political skills	0.131***	(0.01)	0.178	(0.12)	0.124	(0.14)	0.166**	(0.08)	0.120	(0.11)	0.247***	(0.09)
Intrinsic motivation	−0.058	(0.08)	0.085	(0.09)	−0.125	(0.12)	−0.052	(0.12)	0.168*	(0.10)	−0.135	(0.09)
Extrinsic motivation	0.076***	(0.01)	0.089	(0.06)	0.063	(0.07)	0.068*	(0.04)	0.018	(0.05)	0.103*	(0.05)
Avg. # co-authors	0.027***	(0.01)	0.049**	(0.02)	0.018	(0.03)	0.021**	(0.01)	0.042***	(0.02)	0.015	(0.01)
Avg. pubs. w/ industry	0.369	(0.81)	−1.056	(0.80)	0.979*	(0.58)	0.221	(0.54)	−0.736	(0.57)	0.630*	(0.33)
Avg. International pubs.	0.060	(0.14)	0.240	(0.30)	−0.031	(0.25)	−0.064	(0.11)	−0.167	(0.26)	0.051	(0.18)
Less than two contacts	0.114	(0.07)	0.071	(0.21)	0.205	(0.20)	−0.040	(0.05)	−0.018	(0.19)	0.021	(0.15)
Network size = large	−0.053	(0.11)	−0.263	(0.27)	0.073	(0.23)	−0.001	(0.20)	−0.270	(0.23)	0.185	(0.16)
Group-level controls (FE)												
Group size	0.019**	(0.01)	−0.010	(0.01)	0.025**	(0.01)	0.007***	(0.00)	−0.005	(0.01)	0.007	(0.01)
Internal network density	0.039***	(0.00)	0.081	(0.28)	0.084	(0.29)	0.021	(0.17)	0.215	(0.23)	−0.151	(0.20)
Region = Madrid or Bcn	0.274	(0.18)	0.183	(0.26)	−0.001	(0.21)	0.094	(0.13)	0.121	(0.20)	−0.092	(0.15)
PI patents	0.099*	(0.05)	0.003	(0.03)	0.147***	(0.04)	0.056	(0.03)	−0.012	(0.03)	0.085***	(0.03)
PI coauthors	−0.060***	(0.00)	−0.055	(0.13)	−0.086	(0.14)	0.007	(0.06)	−0.086	(0.11)	0.014	(0.10)

TABLE A2 (Continued)

	Multilevel negative binomial regression						Multilevel ordered probit regression					
	Full sample		Care logic		Science logic		Full sample		Care logic		Science logic	
	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*	Coef.	*SE*
PI Pubs with firms	1.084	(1.27)	3.790**	(1.52)	0.620	(1.44)	0.176	(1.29)	2.383*	(1.33)	−0.662	(1.13)
PI Pubs with hospitals	1.400***	(0.29)	0.241	(0.50)	1.765***	(0.41)	1.079***	(0.41)	0.139	(0.43)	1.359***	(0.29)
Constant	−4.230***	(0.88)	−2.520*	(1.41)	−5.088***	(1.41)						
cut1							2.754**	(1.09)	1.174	(1.27)	3.607***	(1.02)
cut2							3.714***	(1.15)	2.107*	(1.27)	4.645***	(1.03)
cut3							4.676***	(1.15)	3.092**	(1.29)	5.625***	(1.03)
Random intercepts												
Level 1 (Research group)	0.547***	(0.18)	0.161	(0.14)	0.595***	(0.16)	0.285***	(0.07)	0.103	(0.08)	0.300***	(0.08)
Level 2 (Institution type)	0.003	(0.02)					0.000	(0.00)				
lnalpha	0.184	(0.18)	−0.072	(0.22)	0.313	(0.21)						
N	1010		364		646		1010		364		646	
Log likelihood	−1532.0		−671.0		−827.0		−1007.3		−406.6		−562.0	
Number of Level 1 clusters	309		111		198		309		111		198	
Number of Level 2 clusters	2						2					

Notes: All models were computed with robust standard errors. All models include dummy variables to control for CIBER scientific domain (9 dummies) and the contract type linking each respondent with her research group (3 dummies).

*$p < .1$; **$p < .05$; ***$p < .01$.