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Organizing Collaboration in Inter-organizational Innovation Networks, from Orchestration to Choreography

Regular Paper

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Abstract

Innovation networks constitute a valid structure within which to foster members' abilities to interact and cooperate, in order to reduce environmental uncertainty and face the challenges that derive from economic change. Network members take advantage of their participation in the system by creating and extracting value when performing certain deliberate and purposeful activities. Traditionally, the interactions between network members are represented in a hierarchical structure with a prominent member performing a leadership role in managing the system. Recently, more complex organizations have emerged in which the power of the decisions is spread among all partners. In this paper, we overcome the single hub model and propose a new organizational framework called "choreography", which takes into account all network members, extending the roles of coordination and management throughout the entire network.

We consider a real inter-organizational innovation network as an eligible case study which supports the choreography model.

Keywords Inter-organizational Innovation Networks, Network Orchestration, Network Choreography, Complex Networks

1. Introduction

In recent times, innovation has evolved beyond the boundaries of single firms towards a network approach [1]. Communities of creation, open-market innovation and crowdsourcing are all indications of a connected world where innovation is spread among the members of several networks.

Innovation networks develop in response to changes within the economic environment. Thus, they go further than the simple relational ties that shape the diffusion of innovation, but rather "*constitute capabilities that augment the value of firms. These capabilities generate rents that are subject to private appropriation. It is through an understanding of networks as knowledge encoding coordination within and between specialised firms in specific cooperative and competitive structures that the missing sources of value can be found*" [2].

In this paper, we consider inter-organizational innovation networks, since they constitute an attractive environment in which to create innovation within different sectors. These networks are also characterized by the recurrent interactions between members who are able to retain residual control of their individual resources, yet periodically, and jointly, decide over their use [3].

Such networks exhibit the presence of members that act as hubs, i.e., members to which most of the others are linked, as well as semi-peripheral members that make a relevant contribution to tying the greater portions of the network together, and peripheral members that are connectors for local portions of the system.

The members of such systems could be firms, organizations or research centres, located in different regions and specialized in particular sectors, linked by common interests, technologies and skills, and networked by the decision to collaborate according to specific rules. Technological districts, business incubators and consortia created by international initiatives financed by the European Commission are some examples of this kind of network.

Members are formally linked by joint ventures, licensing arrangements, management contracts, sub-contracting, production sharing and R&D collaborations [4, 5, 6]. Traditionally, the interaction between network members is represented by a hierarchical structure, with a prominent member performing a leadership role in managing the system [7, 8, 9, 10].

In the literature, the management of such networks is described by the *orchestration* model, which considers the fundamental role of the hub (orchestrator) as one that holds particular importance and influence, due to its individual qualities and prominent position within the network [7].

The hub should have particular qualities in pulling together and leveraging the dispersed resources and skills of the network members, facilitating and coordinating their interactions to reach a favourable outcome for the system. It influences the network design and how the processes are established [11].

Recently, more complex organizations have emerged in which the sources of decisions are spread among all partners and the complexity of the activities performed in the network is raised [12]. Thus, the orchestration model is no longer suitable to describe such an environment.

Indeed, network members participate in a self-organizing process in which order emerges due to the interactions between partners [13]. All members are simultaneously involved in the ongoing management of the network, and the resulting structure and performance is co-produced by their actions [12].

From this perspective, some research questions arise: how are inter-organizational innovation networks organized and modelled? Is it possible to understand the network characteristic from an analytical representation? Does the network structure support the organizational processes?

This paper proposes a new model, defined in terms of *choreography*, which takes all members of a network into consideration without relying on one core actor. This model takes advantage of an analytical description of the underlying network organization and of some of its rules of membership in order to establish more efficient interactions.

Choreography benefits from many hints deriving from the orchestration model and adapts them to the new framework. Thus, we reserve a section of the paper for a description of the orchestration model.

The choreography model makes use of complex network theory [14, 15], a useful paradigm for delineating innovation networks, assessing organizational behaviours and mapping structural insights [16].

In particular, complex network theory allows us to study the correlation between the structure of an inter-organizational innovation network and its overall performance [17], as well as the relations between the structure of the connections between members and a given node's characteristic [18].

Complex networks form the structure of a wide range of organizations in nature and society [15] and offer a theoretical framework that permits a suitable abstract representation of inter-relations, whereby the network structure indicates the mapping of connections among elements [16]. Here, complex networks constitute a set of nodes that are associated by links, representing network elements and the interactions between them, respectively. One suitable model for representing the real innovation network topology among different network organizations is the scale-free model [19].

To attest the effectiveness of this approach, we consider as a case study the Enterprise Europe Network, with a description of its architecture along with its quantitative information.

The paper is organized into six sections: Section 2 surveys the most relevant contributions to the orchestration model; Section 3 presents the choreography model and compares the features of the two models; Section 4 shows the network properties that support choreography; Section 5 discusses the case study; and Section 6 presents the conclusion and highlights any other key issues that require further research.

2. The Orchestration Model

The orchestration model was originally defined by Dhanaraj and Parkhe as the set of deliberate, purposeful actions undertaken by a central actor to create and extract value from a network [7].

The hub utilizes its status to perform a leadership role in bringing together the resources and competences of network members and orchestrating network activities, ensuring the creation and utilization of value [8, 20]. The orchestration theory focuses on the activities of this pivotal actor in developing, managing and coordinating an innovation network. Furthermore, the hub leverages the resources and capabilities of the other network members [21].

We survey the two most significant scientific contributions to the orchestration theory: the framework presented by

Dhanaraj and Parkhe [7] and the model of Nambisan and Sawhney [22, 10]. For further details about these models, we refer to the original papers and the references therein.

2.1 The Model of Dhanaraj and Parkhe

Dhanaraj and Parkhe chose to analyse innovation networks, since " *they present a framework for understanding the processes through which hub firms perform their prime mover functions in network operations and because of the growing importance of innovation toward competitive success* [...] ". Therefore, "*a hub firm is one that possesses prominence and power gained through individual attributes and a central position in the network structure, and that uses its prominence and power to perform a leadership role in pulling together the dispersed resources and capabilities of network members*".

This model assumes that network members will pursue their own self-interests and that they are not inert towards the hub's initiatives. Thus, the hub influences the outcome by affecting the system design, as well as through the establishment and development of processes within the network.

2.1.1 Network Design

The hub controls its central position through network recruitment activities, specifically with regard to network membership, structure and position.

Network *membership* involves the size and diversity of the system. The hub attracts new potential participants and involves current members by showing them the opportunities offered within the organization.

Network *structure* is defined by density and autonomy. In particular, density refers to the degree of the connections between members. The hub can alter the network density by affecting the strength of the existing relations and establishing new promising links. Autonomy refers to the possibility for members to take action without the permission or control of another member within the system. It influences the possibility for each member to affect the network structure. The central actor can impact the network autonomy by changing the recruitment rules and designing the structure of the collaboration among members.

Network *position* concerns the centrality and the status ascribed to the hub by the network members. These qualities reveal the hub's role as network designer and orchestrator. Thus, it is crucial for the hub to demonstrate to the other members the relevance and added value of its role in generating common benefits.

2.1.2 Network Orchestration Process

The orchestration process entails certain network management activities, such as knowledge mobility, innovation appropriability and network stability, to achieve the network innovation outcome.

Knowledge mobility can be considered in terms of the knowledge shared, acquired and deployed within the network. Indeed, the network innovation outcomes would be minimal if the knowledge of each member were protected within its organizational boundaries. The hub assesses the value of knowledge in the network and organizes its transfer where it is required. It learns from partners and exploits the resources available through network relationships. Knowledge mobility is improved through knowledge absorption, network identification and inter-organizational socialization, i.e., connections among members. The hub enhances and improves knowledge mobility, developing the capacity of the other members to identify, integrate and exploit knowledge within the network, and even supporting new combinations of existing capabilities and strengthening a common identity to enable knowledge sharing. It promotes and increases knowledge mobility by encouraging the socialization among members through exchange forums and communication channels to create a suitable environment for knowledge flow.

The hub manages *innovation appropriability* to ensure that the value created within the network is impartially shared and perceived as such by members; this, in turn, prevents free riding and opportunistic behaviours. The hub guarantees innovation appropriability through trust and appropriate procedural justice. The joint asset ownership between the hub and the other members improves appropriability, providing mutual hostage positions that reduce incentives to behave in conflict with fiduciary responsibility. Innovation appropriability is also promoted through problem-solving negotiation arrangements and by increasing members' commitment to reaching common goals, which consequently provides incentives.

A critical task of the hub is to ensure *network stability*. The hub strengthens network reputation by managing expectations, promoting reliability and anticipating the future benefits for the members. It encourages participants to join the organization so as to benefit from the interactions between members. Network instability can occur in cases of isolation, migration, attrition or the creation of cliques that impact on the creation of value. The hub increases the dynamic stability of the network by enhancing its reputation as a market leader, discouraging members to cut links with it, encouraging the creation of ties with new members and building a vision of the network's future benefits. The hub maintains strong relationships, even increasing network multiplicity by expanding existing relationships to broadly improve members' interactions.

Figure 1 summarizes the framework proposed by Dhanaraj and Parkhe, highlighting the network design, the orchestration processes and their outcomes.

2.2 The Model of Nambisan and Sawhney

Nambisan and Sawhney focus their attention on the orchestration processes in the network-centric innovation framework. According to them, the orchestration model

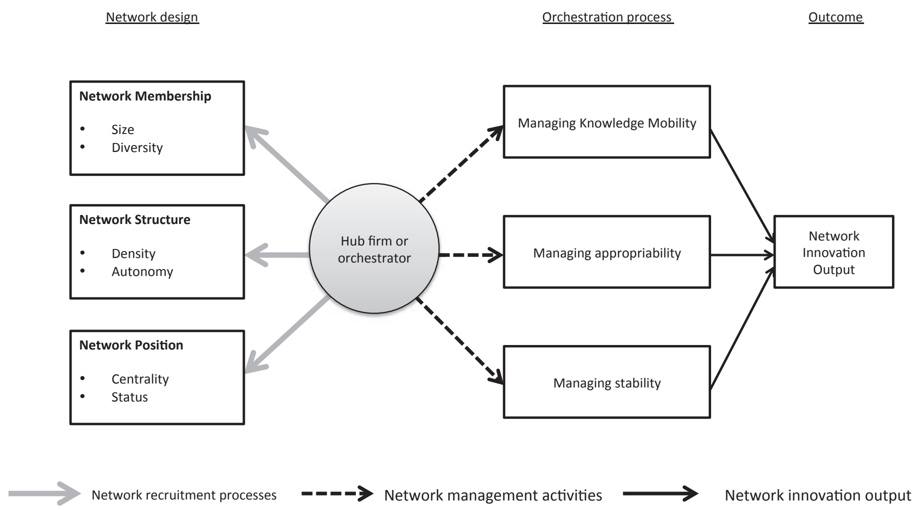

Figure 1. Network orchestration framework [7]

involves members interested in exploiting the market's opportunities as a consequence of a particular innovation framework that is defined and designed by the hub. They consider the orchestration activities performed by the hub from two different perspectives: the innovation integrator model and the platform leader model [10].

The hub, as an *innovation integrator*, defines the essential framework for innovation, while the other members develop the various components that will be integrated and coordinated by the main actor.

An example of this model is represented by the development of the Dreamliner 787, for which Boeing were joined by several partners who produced different parts of the plane. Boeing requested that all members be directly involved in the project, investing in both the design and the development. They remained the central decision-makers in the network, but each partner maintained a considerable degree of autonomy with respect to the design of the different components. Thus, Boeing, as integrator in the system, defined the innovation architecture, enabling and managing the partners' innovation activities, as well as integrating the components and ultimately bringing the finished product onto the market. In this way, the hub allowed the other partners to benefit from the value generated by their innovative contributions.

As a *platform leader*, the hub defines the innovation framework, developing the groundwork for the other network members to realize complementary innovations that extend the range of the basic platform.

This model is also implemented by Salesforce.com: the leading on-demand enterprise software solution provider. The company offers sales force automation, marketing, partner relationship management, customer service and support automation. It has created a network of partners, and was able to control the innovation and capabilities of external developers by changing the company into a versatile computing infrastructure provider. The company has also developed the AppExchange platform, which allows external developers to produce applications that complement and extend its core offerings, as well as the AppExchange forum, a marketplace for partners' complementary solutions.

2.2.1 Network Design

Nambisan and Sawhney recognize a number of elements of innovation design, including modularity, choice of technology standards, development process frameworks, technological novelty and risk, and product complexity and identity, in addition to network design elements, such as embeddedness, openness, cohesion, density, and centralization.

They consider the impact of innovation design and network design on orchestration processes and focus their attention on three design elements: modularity, openness, and embeddedness.

Figure 2 depicts the orchestration model proposed by Nambisan and Sawhney.

Modularity indicates the degree to which the network's innovation structure has been divided into independent or loosely coupled elements.

Openness concerns the extent to which an innovation network is open or closed. It is related to the facility with which members can join or leave the network. Innovation networks can range from closed organizations, in which the access of new members is strictly controlled, to open systems with free entrance. Openness also regards the modalities in which innovation is shared among network members, and how innovation decision-making is spread throughout the network.

Embeddedness refers to members' activities and their relations within the innovation network. Structural

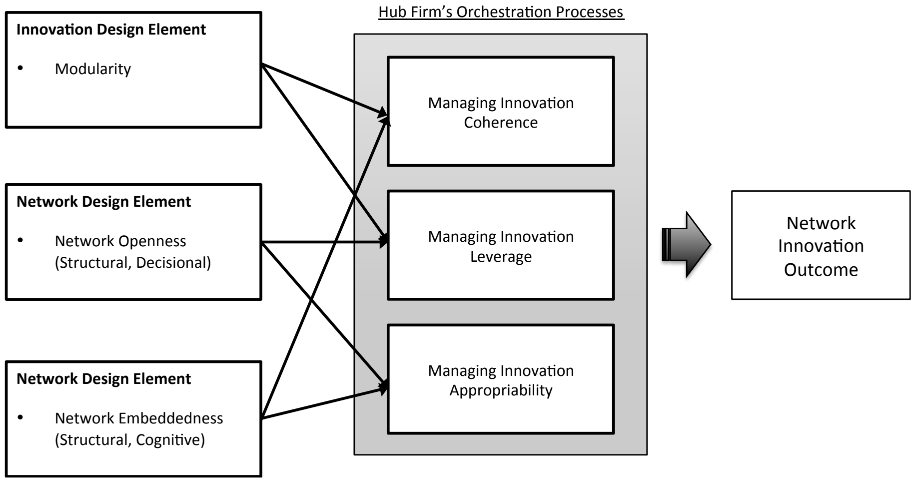

Figure 2. Orchestration processes, innovation design and network design [10]

embeddedness concerns the direct or indirect linkages among network partners. Cognitive embeddedness concerns the degree of joint awareness among members, which is represented by the extent to which partners are connected through a common vocabulary, mutual representation, interpretation systems and knowledge overlapping.

2.2.2 Network Orchestration Processes

Nambisan and Sawhney highlight three orchestration processes: managing innovation leverage, managing innovation coherence and managing innovation appropriability.

Regarding *innovation leverage*, network members can control, reuse or redistribute the technologies, processes and other innovation assets of fellow members in order to support and enable their own innovation. Innovation leverage creates additional value for asset owners and for the firms controlling the assets. The hub manages and strengthens the innovation leverage opportunities within the network by considering the structure of the assets and the connections between the members involved in the process (network design).

Innovation coherence refers to the internal and external coherence of the innovation activities and the network outcome. Internal innovation coherence organizes and configures the processes and outputs of the partners in the network, whereas external innovation coherence concerns the alignment of network goals and outputs with respect to the market. The hub foresees possible changes in the system regarding innovation objectives and arranges the network framework (innovation design), paying attention to roles and relations among members (network design).

Innovation appropriability concerns the instruments available to partners to create value from their innovative ideas. The hub guarantees the impartial distribution of value among partners, taking into consideration their different contributions towards innovation, and even reducing members' concerns regarding the appropriability regime. Managing innovation appropriability requires a deep knowledge of partners' contributions (innovation design), and of the relationships and dealings among members (network design), on the part of the hub.

3. The Choreography Model

Recently, several innovation systems have emerged with more than one hub. Although such networks must deal with similar issues to the orchestrated systems, such as interactions, processes and value creation, they require leadership that is more likely to be spread throughout all partners.

Herein, we introduce the *choreography model*, which takes all members of the network into consideration without relying on one core actor. We argue that choreography governs behaviours by shaping the level of connectivity and cohesion among network members. It represents a valid organizational system able to sustain certain activities and to achieve effects that generate innovation outcomes.

The word "choreography" is derived from the Greek words for "dance" *χορεια* and "write" *γραφια*, reflecting the sequence of steps and movements in dance, and the art or the practice of designing choreographic sequences. The emergence of choreography in a network leads to the establishment of coordinated activities among all members, which allow the creation and extraction of innovation through the final outcomes [12]. This last piece of evidence suggests the development of a new framework, which we have called "choreography", defined as *the network's capacity to address collaboration among multiple members*.

The presence of choreography results in the establishment of coordinated activities among all members, which, as a consequence, produces heightened innovation.

Interactions in choreography are concrete instances of activities carried out by members, which comply with the network's rules and purposes. Activities can be between members – for example, in the case of the knowledge flow when two or more agents share information – or they can be within agents (such internal activities are often not visible to the rest of the network).

In orchestrated networks, activities are implemented according to the members' role in the network and constrained through the corresponding patterns of network composition. Such activities are undertaken through instances of the orchestration processes undertaken by the hub [20]. The orchestrator – i.e., the hub in the network – acts as a controller and executer in the network and functions as a leader with the possibility of invoking process execution by network members.

Choreography governs behaviours by shaping the level of connectivity and cohesion among different partners. It focuses on inter-organizational coordination from external perspectives and represents a valid system, able to sustain certain activities and contribute in generating innovation outcomes.

Choreography represents a more realistic situation, in which network's members share certain assets, capabilities and production capacities while maintaining their individuality. The network's leadership and control is peer-distributed among partners and collaboration patterns are more relevant than individual roles.

The management of network processes in choreography is considered to align with asynchronous information flows, in contrast to orchestration, in which the processes are directly requested by the central actor.

3.1 From Orchestration to Choreography

Once a firm is aware of its networking needs, it should decide which kind of network organization is more suitable according to its particular requirements. Some behavioural features of the two different models have been presented in the previous sections.

The *orchestrated* network is characterized by a hub leading the innovation activities. The innovation goals are well defined and the market opportunities are clearly specified. The other members implement, complete or extend the innovation framework proposed by the central actor that defined the mechanisms for value appropriation [7].

In such a system, a relevant issue is the dyadic relation between the hub and the other members. The tighter the collaboration, the more likely the member is to be considered a valuable network partner, and this can help realize greater returns from its contributions. On the other hand, this also increases the constraints that the network places on the firm's ability to achieve its goals.

Achieving a balance between these two forces is important and a firm has to consider these issues before committing to a particular innovation network [22].

In choreography, the leadership is diffused and the different members are organized in an absence of hierarchy. They spontaneously combine their resources and capabilities to extract the value added to the network. The benefits are spread among members according to their efforts. Network assets and best practices are shared and disseminated broadly, as opposed to in an orchestrated model, where the hub has full control over its members. In choreography, firms play an active role to safeguard the knowledge flow, but they are also able to manage the risks associated with the sharing of ideas.

Table 1 describes the main differences between the orchestrated and choreographed models.

Orchestration	Choreography
Individual leadership	Diffused leadership
Hierarchical organization	Heterarchical organization
Clearly defined outcome	Broad innovation outcome
Managing innovation leverage	Ontology-driven leverage
Managing innovation coherence	Network membership-driven coherence
Clearly defined market opportunities	Less-defined market opportunities
Hub controls assets	Broad sharing of assets
Asymmetry of benefits for hub and members in creating and adding value	Benefits for all members in creating and adding value

Table 1. Main characteristics of the orchestration and choreography models

In orchestrated networks, activities are performed according to the members' role in the network and constrained through the corresponding patterns of network composition. Such activities function through instances of orchestration processes performed by the hub. The orchestrator acts as a controller and executer in the network and performs the function of a leader, with the possibility of delegating specific tasks to other members.

Choreography, on the other hand, is focused on inter-organizational coordination from external perspectives; collaboration is achieved by self-organizing interactions. Choreography entails a set of complex interactions among roles that are performed in a peer-to-peer approach and carried out according to network organization.

Table 2 outlines the main differences between orchestration and choreography in terms of network processes.

4. Network Properties

The emergence of choreography requires a particular structural hypothesis regarding network topology and

Orchestration	Choreography
Specification of the role patterns	Specification of the collaboration patterns
Process model	Interaction model
Processes explicitly invoked	Processes information-driven
Inter-organization processes	Inter- and intra-organization processes
Within a single participant	Among participants
Centralized control	Distributed control
Centralized executer	Peer-to-peer
Node-focused	Network-focused

Table 2. Orchestration vs. choreography with regard to network processes

membership characteristics, and involves the accomplishment of certain activities among members to reach the innovation outcome.

4.1 Network Topology

To the best of our knowledge, the literature of orchestration theory considers the *network* in a qualitative way; indeed, any analytical representation is proposed.

In contrast, the choreography model relies on an analytical description of the relations among a network's members given by means of complex networks, a systemic prospective in which heterogeneous agents interact without a formal hierarchy [23].

Complex networks offer a theoretical framework that permits a suitable abstract representation of inter-relations, where the network characterization indicates the mapping of connections among elements. Although networks may appear very different from each other with respect to their functions and attributes, the analysis of their structure denotes the ubiquity of several asymptotic features and reveals the emergence of general and common self-organizing rules [24].

The classical mathematical abstraction of a complex network is a graph $G=(V,E)$, containing a set of vertices V (called "nodes") that are associated by edges E (called "links"), defining the interactions between nodes. In [17], we show that a suitable model to represent innovation networks topology, among the various complex network organizations, is the Barabási-Albert (BA) scale-free model [19]. Scale-free networks are open and dynamically formed by the continuous addition of new nodes that represent members, while the links between members mimic collaborative agreements.

Scale-free networks emerge in real situations characterized by the kind of inhomogeneity in degree distribution in which a few nodes have many links while the majority have only a few connections. Figure 3 depicts a power law trend for such a degree distribution. Thus, this organization matches the degree of members' involvement in the network and the differences among hubs, semi-peripheral and peripheral members.

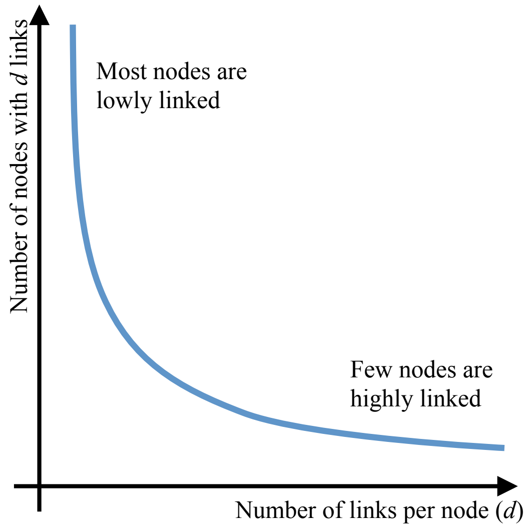

Figure 3. Power law degree distribution trend

Hence, a single node or hub cannot be considered representative since these networks are held together by a different, although limited, number of highly connected nodes.

In the literature [15], scale-free networks are mainly identifiable by three characteristics: the average path length, the average clustering coefficient and the degree distribution.

All nodes are linked with rather short paths, due to the *small world* characteristic [15, 25]. This property implies that two nodes, even in large graphs, will be connected via a relatively short path. As a consequence, in innovation networks under choreography, members benefit from tighter communication.

The clustering coefficient of a given node is the number of links in its neighbourhood expressed as a fraction of the maximum possible links in that neighbourhood; it ranges from 0 to 1. The clustering coefficient of the network is averaged on all nodes, and in scale-free networks, it assumes values close to 1 and reveals the existence of stable groups.

In BA models, the connectivity distribution follows a power law function, i.e., the probability $P(k)$ that a node in the network interacts with k other vertices decays with the law $P(k) \sim k^{-\gamma}$ with slope γ as the scaling exponent, while the likelihood of a node having a degree k is proportional to $k^{-\gamma}$. This property is the reason behind the name "scale-free", since the graph is invariant to scaling, i.e., a small portion of the graph maintains the same connectivity distribution. In scale-free networks, γ assumes value between 2 and 3.

The BA model asserts that growth and preferential attachments determine the self-organization of networks with a scale-free structure. Indeed, real networks constantly grow by adding new nodes that, at each time-step, join the network and link to other nodes already present in the system. New nodes tie preferentially to those that are more highly connected, following a *rich get richer* phenomenon [19]. The probability that a new node will be connected to an already existing node depends on its degree for the property of the *preferential attachments*.

4.2 Network Membership

Choreography requires some particular membership characteristics from potential members that are attracted to join networks to gain benefits. Network membership features are expressed by means of *ontology* and *homophily* properties.

4.2.1 Ontology

The term ontology became relevant in knowledge engineering and in artificial intelligence fields after a definition was given in [27]. There, it was viewed as a designed artefact formulated to support knowledge-sharing activities. Many other definitions followed and a wide range of applications have been considered in different topics (e.g., see [28] and references therein).

Here, we use the definition provided in [29]: "*An ontology is a formal explicit specification of a shared conceptualization*". Thus, ontology is the following:

- *Formal*: since it should communicate the intended meaning of defined terms, definitions should be independent of social or computational context; formalism implies a complete set of definitions stated as logical axioms and documented in a natural language.
- *Explicit*: it explicitly defines the design of decisions, concepts and constraints.
- *Shared*: it considers knowledge accepted by a group, in which the members agree on the objects and the relations of such knowledge.
- *Conceptualized*: it considers an abstract, simplified view of the world that we wish to represent for some purpose; every knowledge-based system is committed to some conceptualization.

By definition, ontology allows network members to conceptualize what exists within the network. The conceptualization is completed with the domain of knowledge, characterized formally by the set of objects that can be represented and referred to as a *universe of discourse*. The set of objects and their relationships are reflected using a specific vocabulary that represents knowledge. In this context, ontology is described by defining the names of entities in the universe of discourse (i.e., members, relations, processes, etc.) with a semantic description of each term.

Ontology extends the concept of embeddedness introduced in Section 2.2.1. In orchestration, the hub leverages embeddedness to facilitate information dissemination, interpretation and persuasion. On the other hand, in choreography, members recognize a certain rate of consensus to the knowledge domain of ontology and are committed to it as long as their actions are consistent with its set of definitions. Indeed, members act respecting the ontology and behave rationally to achieve the final outcome of the network.

4.2.2 Homophily

Homophily is the tendency of nodes to link with others that are similar to themselves, as well as members' attitudes towards associating and connecting with other like-minded members [30]. Individuals in homophilic relationships share certain common characteristics that make communication and relationships easier.

In terms of the BA model, it's possible to say that homophily approaches a topological network in terms of preferential attachment and node similitude [31]. Indeed, homophily tends to create tighter links between members, enhancing network cohesiveness. Homophily can be related to the openness introduced in Section 2.2.1, with the difference being that, in orchestration, openness is leveraged by the hub, which allows new members to join the network, while choreographed networks presume similar interests among members that share certain attitudes, goals and beliefs.

Thus, homophily affects the dyadic similarities between nodes and creates correlated outcome patterns among neighbours. In particular, regarding the spread of behaviours in networks, homophily determines a more perceived contagion. In fact, homophily-driven diffusion processes are extremely effective since they are governed by the distribution of characteristics over nodes [26].

In [18], we analyse homophily by detecting the structure of the connections among the partners and observing the interactions between the nodes' characteristics and the topology of the system, as well as their influence on the innovation attitude of the network. In particular, we investigate how the innovation performance, as a feature of the nodes, affects the structure of the network in avoiding the emergence of random behaviour.

4.3 Choreography Activities

The emergence of choreography involves the accomplishment of certain activities among network members: namely, management of knowledge flow, innovation appropriability, management of stability, and management of vitality and health.

These activities are similar to those requested by the hub in the orchestrated network, with the difference that, in

Choreography activities	Processes
Managing knowledge flow	Exchange, share and use information among network members
	Diffuse good practices
	Create an environment of trust and commitment in which to share information among members
Managing appropriability	Enhance trust among members for sharing assets
	Involve members in devising norms and policies relating to IP rights management
	Implement systems that enhance transparency in relation to the sharing and usage of IP rights
	Offer instruments to members to help them create value from their innovative ideas
	Provide contractual agreements that protect IP and guarantee knowledge transfer, equity and impartiality among members
	Remain aware of the reliability among members
Managing stability	Enhance collaboration and reinforce relationships among members
	Reduce isolation, exit movements, free riding and opportunistic behaviours
Managing vitality and health	Attract new members that will bring new resources, innovation perspectives and practices
	Maintain the existing members so that they renew their contributions to the network, and avoid their withdrawal

Table 3. Network choreography activities

choreography, these are self-organized within the system and information-driven.

Knowledge flow consists of exchanging, sharing and using information among network members. In the proposed framework, the distribution and combination of knowledge is permitted by an ontology that allows the overcoming of its members' boundaries.

Innovation appropriability, as in orchestration, concerns the instruments offered to members to create value from their innovative ideas. Networks strengthen innovation appropriability by contractual agreements that protect intellectual property and guarantee knowledge transfer, equity and impartiality among members. Choreography allows an equitable distribution of value in consideration of members' diversity and their different contributions to innovation. It mitigates the partners' concerns by embedding them within ontology and legal procedures.

Stability enhances collaboration and reinforces relationships among members, reducing isolation, exit movements, free riding and opportunistic behaviours. Choreography supports stability through scale-free organizations, in terms of the small-world property and a clustering attitude among members [17].

Vitality and health relate to the introduction of new members to the network, bringing new resources, innovative perspectives and practices, as well as to existing members renewing their contributions to the system [9].

Throughout all activities, interactions are intended as processes, i.e., concrete instances of actions performed by members. Indeed, through the ontology, members are committed to acting rationally in order to achieve the final network outcome, with the scale-free organization permitting robust relationships among members as a result of its characteristics.

Innovation appropriability impacts positively on knowledge flow, since it is strictly related to the awareness of reliability among members and to the strength of the ties between them. Partners hesitate to share knowledge when innovation appropriability concerns are relevant, whereas in an environment of trust and commitment, they are willing to share their information.

Innovation appropriability and stability have a mutual positive influence, due to the equity that decreases the competitive dynamics and opportunistic behaviours. If a network member feels that it is being exploited by another member, it will remove its support from the network and end all relationships with those it perceives as a threat. Network vitality and health also affect the stability and vice versa. Stability reinforces relationships among members, increasing their capacity to regenerate their resources. Vitality and health attract new members whilst discouraging their withdrawal.

Figure 4 presents the layers of interaction among network structure, processes and activities. The processes can be distinguished in two categories: inter-member processes, which govern the correct performance of the activities in the choreographed network; and intra-member processes, which are performed within a single member. These processes are summarized in Table 3.

4.3.1 Effects

In choreography, the activities that lead to innovation leverage and innovation coherence help the final innovation outcome of the network to be attained. Such observed

Choreography effects	Emergent processes
Coherence	Use of common and shared tools based on network ontology
	Attendance of network members to organized workshops and training sections
	Alignment of processes and outcomes
Leverage	Enhancement of the network identity
	Identification of opportunities for asset leveraging among network members
	Involvement of partners in the design and development of leverageable assets
	Control, reuse and sharing of innovation assets

Table 4. Network choreography effects

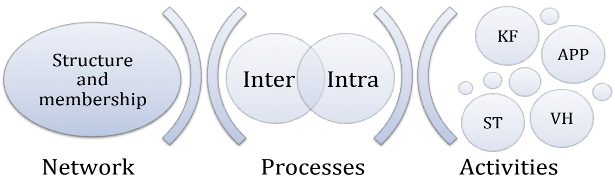

Figure 4. Choreography interaction layers framework (Legend: KF = knowledge flow; APP = appropriability; ST = network stability; VH = network vitality and health)

effects differ from those of orchestration theory, in which they are considered processes performed by the hub.

We refer to innovation leverage and coherence as internal effects of the network since they represent the value added to the system for the members. They ensure the impartial distribution of value, reducing the threat of members' opportunism and strengthening equitable divisions.

Innovation coherence deals with the consistency of the network's activities regarding the coordination and alignment of processes and outcomes. Within choreography, we can distinguish internal and external coherence. The internal coherence is the alignment of innovation activities with the interactions of members within the network. The external coherence is related to the technological environment and the market structure in which the network is positioned.

Innovation leverage is related to the control, reusing and sharing of technologies, processes and other innovation assets in order to support and enhance innovation, thus creating additional value for asset owners and for the actors controlling the assets.

The network is able to manage and strengthen the opportunities through choreography, for leverage among members, generating surplus value, whilst taking into consideration the structure of the assets that can be shared and deployed. This effect can be improved by allowing new members to join the network, thereby increasing the degree to which current innovation assets can be leveraged. Furthermore, members are expected to be more willing to leverage other members' innovation assets if they recognize similar characteristics.

With regard to the relationship between the two effects, we agree with Nambisan and Sawhney [10], who state that coherence creates the setting for leverage. Higher levels of coherence increase the partners' trust with regard to how their innovation assets relate to other relevant components and processes in the network. Thus, coherence increases members' ability to assess the potential and value of leveraging assets. In addition, the mutual understanding and coordination between members, which arises from higher internal coherence, may enable the network to manage the expectations of partners regarding the leveraging of the opportunities of assets.

Table 4 presents the emergent processes under choreography's effects.

4.4 Choreography and Innovation Outcome

To summarize, Figure 5 presents the choreography model, depicting all the characteristics required for the network structure (i.e., scale-free organization) and for the network membership (i.e., ontology and homophily). Network properties enable the accomplishment of certain activities: namely, the management of knowledge flow, appropriability, stability, and vitality and health. Activities generate certain effects, such as coherence and leverage, to attain innovation as the final network outcome.

Regarding the final network outcome, in the literature, innovation refers to an outcome of an innovative process or to the innovative process itself [32]. Usually, innovation is considered the result of the process, while innovation management refers to the managerial activities regarding its control. In this paper, we consider innovation as the final outcome of the network. Hence, we are interested in the innovation activities of the system as performed by its members, and we focus on their abilities to foster innovation, rather than on specific issues relating to products, services, markets and processes innovation.

5. Evidence from a Case Study

An example of a real innovation network that exhibits choreography is the Enterprise Europe Network (EEN),

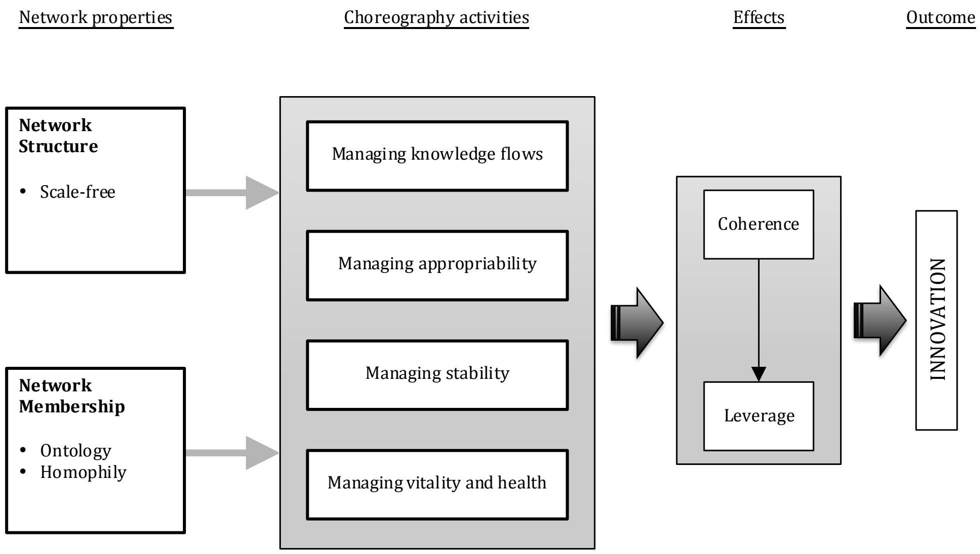

Figure 5. Network properties, choreography activities, effects and outcome

which was launched in 2008 by the European Commission's Directorate-General for Enterprise and Industry. The EEN is often considered instrumental in the European Union's strategy to boost growth and jobs. Its mission is to help companies make the most of the opportunities offered by the European marketplace by offering a one-stop shop for all the services and information they need to reach new markets, find business and technology partners, improve innovation management capacities, and access EU finance and funding.

Network members support companies in finding partners for business cooperation, technology transfer and collaborative research, which match their needs and expectations in terms of innovation. Once the cross-border partner search has been finalized, the parties involved sign a partnership agreement (PA).

The aim of the partnership process is to establish a transnational PA, i.e., a long-term collaboration between SMEs or between SMEs and large companies, research institutes or other possible clients.

Providing partnering services to clients represents a significant part of the EEN's roster of activities. Indeed, developing a PA requires a lot of effort in terms of time, skills and follow-up, since it embraces a variety of network services.

The PA signature process has the characteristic of being measurable, thus it can be an important performance indicator for assessing the effectiveness and efficiency of the activities undertaken by the EEN to fulfil its goals.

The network brings together, as members, more than 600 different and independent organizations from 52 countries, including chambers of commerce, technology centres, universities, research institutes and development agencies, all organized in consortia at country level.

The available data set received from the Executive Agency for Small and Medium-sized Enterprises (EASME) concerns 4940 PAs signed during the period from 1st January 2011 to 31st December 2012 among the 52 EEN countries. The data of the PAs relating to the individual organization members are confidential (hence we aggregate them at country level). Therefore, the PAs signed by network clients, assisted by the EEN members, represent the connections between countries.

The granularity of the available data is at country level, so the network is composed as follows: each node is a centroid that represents a country inside which there are independent organizations as network partners, while links exist if two countries share at least one PA. The network is illustrated in Figure 6, in which the node labels are the official country codes.

From the analysis of the network properties, we can compute an average path length equal to $L = 1.82$ and an average clustering coefficient of $C = 0.66$.

To evaluate the value of γ, we use the goodness-of-fit approach for fitting the power law distribution to data using a maximum likelihood estimator, resulting in a value of $\gamma = 2.79$.

The values of the average path length, the average cluster coefficient and γ meet the three scale-free properties required, and are comparable with the values of other real networks as reported in [15].

The analysis of the case study reveals that EEN displays a scale-free structure represented by the BA model as outlined in the choreography framework.

We remand to [17] for a complete analysis of the network and an in-depth study of the whole set of data as integrated within a social network analysis. Therein, we show that the EEN exhibits scale-free properties and that the BA model is a suitable representation of the system.

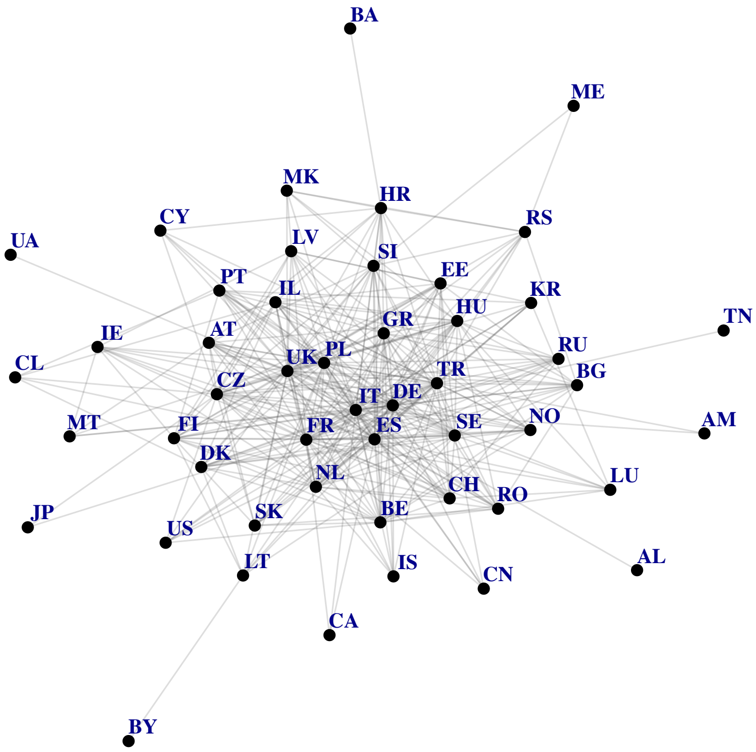

Figure 6. The EEN network

Ontology features	EEN
Formal	Network members are grouped into consortia and legally bound with the network executive agency by Framework Partnership Agreements.
Explicit	The operational manual and guidelines contain all the key information regarding working practices. These documents outline the obligations and formalities that members should follow.
Shared	All rules and procedures are shared. A common language is accepted and used among members. The exchange of good practices is encouraged in order to spread knowledge and enhance excellence and professionalism across the network.
Conceptualized	Rules and guidelines are conceptualized. Members sign a "code of conduct".

Table 5. EEN ontology

With respect to ontology as a membership characteristic, we present some basic features regarding the EEN in Table 5. The set of rules and guidelines that govern the EEN, and the common language, are formalized, explicit, shared and conceptualized among network members.

Regarding homophily, which is the tendency of nodes to link with others which are similar to themselves, in [18] we trace this characteristic in terms of dyadicity.

To summarize, the EEN complies with the network properties and membership required for the emergence of choreography. Network topology influences the connections among members; scale-free networks are able to spread and uphold interactions among nodes; ontology provides a shared common vision of the network; and homophily enables cohesive relationships among members.

Although further research will be devoted to an in-depth investigation of network activities and effects in the case study, we observe that, in EEN, each member is autonomous and acts independently. Network activities are not executed by a central actor but there is a specification of the interaction behaviour among a set of independent roles.

Network members exchange knowledge through a common web platform and share best practices to learn from each other. Contractual agreements guarantee the intellectual property protection and knowledge transfer among members. The clustering attitude among members enhances collaboration stability and strengthens relationships. The entrance of new members is encouraged, as well as the active participation in network activities on the part of existing partners.

Network activities lead to certain observed effects. In particular, innovation coherence deals with the consistency concerning the coordination and alignment of processes and outcomes; in contrast, innovation leverage refers to the control, reusing and sharing of technologies and processes generating additional value for the network participants.

6. Conclusions and Final Discussion

This study has been devoted mainly to the investigation of inter-organizational innovation networks, as these are systems that constitute an attractive environment in which to create innovation. The analysis of such networks in terms of a single and unified model is particularly difficult to perform. Nevertheless, some promising attempts have been made, with reference to the processes and activities within the networks.

We have surpassed the conventional literature by proposing a new model called "choreography", which benefits from many hints deriving from the orchestration model adapting them to the new framework. The model considers complex network theory, a useful paradigm for delineating innovation networks, assessing organization behaviours and mapping structural insights.

Choreography involves certain structural properties of network topology and peculiar membership characteristics that are expressed through ontology and homophily features. Network properties allow for the accomplishment of activities that, in turn, generate the specific effects necessary for achieving innovation as a final network outcome.

The choreography model aims to represent a realistic situation in which members share certain assets, capabilities and production capacities, whilst still maintaining their individuality. The network leadership and control are peer-distributed among partners and the collaboration patterns are more relevant than individual roles.

We have observed that scale-free networks can provide a substrate that enhances dynamical processes. Such a substrate can affect the performance of the system by strengthening the innovation diffusion. In particular, scale-free networks hold the small-world properties that can be assumed to be a causal mechanism linking the network structure to its performance.

Scale-free systems have certain interesting positive features, such as flexibility, autonomy and robustness, that other organizational systems lack. These qualities can all be seen as aspects of the process of self-organization that typifies scale-free networks: these systems spontaneously organize themselves so as to better cope with various internal and external dynamics. This allows them to evolve and adapt to a constantly changing environment.

The case study supports the network properties of the choreography model. In EEN, the inhomogeneity of the degree distribution means that few nodes have many links while the majority have only a few connections. Our analysis of the network shows its compliance with the network properties and membership required for the emergence of choreography.

Further research should be devoted to the subjects of decision efficiency and policy-making effectiveness in the network. The need for an integrated vision in all these aspects, i.e., an analytical approach and a new management practice, should change the way we approach innovation networks, whereby their complexity is taken into consideration.

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