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Guidance in the Network Jungle - A Typology of Inter-Company Innovation Networks

(Full Paper)

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ABSTRACT

Inter-organizational networks are recognized as a collaborative means of enabling small and medium-sized enterprises to compete and innovate in a dynamic environment. Previous studies have analyzed network types and their characteristics, yet there is no empirically grounded network typology combining and integrating these lone-standing attributes from either an academic or a practitioner-oriented point of view. By applying an explorative, sequential, mixed methodology approach, we provide the first typology of innovation networks based on both previous theories and newly generated empirical data. We conduct a directed content analysis to compile a comprehensive data set and apply a hierarchical, agglomerative clustering approach using the Ward linking method. We contribute to existing academic network research by providing the first compelling, generic typology of inter-organizational innovation networks and thereby offer guidance to practitioners and policy makers in the jungle of word creations around innovation networks. We identify and describe 11 types of formal inter-organizational innovation networks: Avid Persuaders, Value Chain Drivers, Collective Facilitators, Niche Specialists, Lateral Thinkers, Transnational Opportunity Seekers, Financially Resilient Connectors, Local Trend Sponsors, Regional Activists, Associated Industry Supporters, and Dynamic Research Groups.

Keywords: Inter-organizational networks; innovation networks; SME; cluster analysis

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INTRODUCTION

Digitalization and fast-paced company environments are increasing the competitive pressure on companies (BMWi, 2018). In order to succeed, companies aim to include collaborative activities in their innovation strategies, thereby executing a change in paradigms as companies and organizations transform their innovation processes from privately conducted research to collaborative behavior, from closed to open innovation (Chesbrough, 2003). Within this change, engagement in innovation networks increases, which plays a crucial role in innovation strategies for almost all kinds of companies. The firms seek collaboration through networks to overcome limited resources as well as to share risks incorporated in research and development (R&D) activities (Sydow, 2001).

Networks are of particular relevance to small and medium-sized enterprises (SMEs). SMEs are bound by limited financial as well as human resources in seeking innovation (Mieke, 2008). Other than large enterprises, SMEs do not have a regular exchange with partners from science or engage in common R&D partnerships (Rammer, Gottschalk, Peters, Bersch, & Erdsiek, 2016). Therefore, networks and collaborative activities are recognized as playing a crucial role in enabling SMEs to compete and innovate in a dynamic environment (Valkokari & Helander, 2007). Nevertheless, the participation of SMEs in innovation networks is still significantly lower than for large companies (BMWi, 2018; Buhl, Sedlmayr, & Meier, 2019; Mieke, 2008; Rammer *et al.*, 2016). In order to support SMEs in their collaboration efforts, policy makers aim to further promote the engagement of SMEs in innovation networks. Therefore, it is of interest which innovation networks are available for SMEs to promote these networks in a directed manner and to offer companies guidance when defining an innovation strategy.

Previous literature has identified a variety of network types based on different, non-consistent sets of characteristics, including direction of collaboration (e.g. Hagenhoff, 2008; Killich, 2011; Morschett, 2003; Payer, 2008), geographical orientation (e.g. Killich, 2011; Morschett, 2003; Payer, 2008), the intensity of collaboration (Killich, 2011), the commitment of the involved parties (Hagenhoff, 2008; Killich, 2011), duration (e.g. Hagenhoff, 2008; Killich, 2011; Morschett, 2003), goal identity among actors (Killich, 2011), and departments or functions involved (e.g. Hagenhoff, 2008; Killich, 2011). Thus, existing studies are either bound to common limitations of qualitative studies, especially the lack of generalizability, or suffer from a limited range of network characteristics they take into account. This has led to the emergence of various network typologies (see, e.g., Provan & Kenis (2008), Inkpen & Tsang (2005), Cooke *et al.* (1997), Bau *et al.* (2014)), which are especially lacking in their underlying empirical database. To address this gap in the literature, we combine previously identified, lone-standing characteristics and attributes of networks to create a comprehensive typology for formal inter-organizational innovation networks. We ask: What are the predominant types of formal inter-organizational innovation networks and how can they be characterized?

To address this question, we apply an exploratory, sequential, mixed method approach. We conduct a directed content analysis using a framework of network characteristics and attributes derived from previous research to compile a comprehensive data set of innovation networks. Subsequently, we apply hierarchical agglomerative clustering (HAC), building on similarities and differences across the identified network attributes. As a result, we observe 11 general types of networks with distinctive characteristics that constitute our typology of formal inter-organizational innovation networks. We compare our typology with previously existing literature and identify potential research directions for further analysis.

The remainder of this study is structured as follows. In section 2, we give an overview of the research background, deriving the study's relevance from potential benefits that SMEs can realize from collaboration within network integration, and give an overview on formal networks and related typologies. Section 3 shows our sample and data construction and introduces our sequential use of qualitative content analysis and quantitative clustering. Section 4 introduces and describes our 11 network types, which we discuss in section 5. Section 6 concludes the study, explicates implications as well as limitations, and sheds light on avenues for further research.

BACKGROUND

The theoretical background sheds light on the broad area of networks and educates the reader on previous research. We outline the need for collaboration for SMEs and their motivation to join network solutions. We provide an overview of the variety of existing studies targeting network typologies and characteristics and identify the need for an empirically grounded network model. We further define our research focus by giving a definition of formal inter-organizational innovation networks and formulate our research question.

SMEs' benefits from collaboration and network integration

SMEs show great innovation capabilities and quality, as they strive to gain competitive advantages through innovative products, manufacturing technologies, and services. The development of such innovations ties up considerable resources and requires special know-how, both being limited factors especially in SMEs (Mieke, 2008). Furthermore, SMEs have significant limitations in terms of their ability to internationalize, innovate, and cope with competitive and environmental pressures (Agostini & Nosella, 2019). At the same time, the competitive pressure on SMEs is increasing nowadays, boosted by the development of digital technologies. As an example, the share of implemented digital processes is comparatively lower for SMEs than for large companies (BMWi, 2018). The era of digitization forces companies more than ever to develop and implement new processes and products or to adapt their business models to changing market environments.

In order to meet future challenges, a high degree of innovation orientation of SMEs in Germany is reflected in their business strategies. A large proportion of German SMEs, however, carry out technological innovation activities without internal R&D activities, particularly because of barriers that have recently arisen in terms of high economic risks, innovation costs, and lack of financial resources (Rammer *et al.*, 2016). This can be regarded as an indicator of a great need to access external know-how (Mieke, 2008). Barriers can be overcome by collaborative activities and networks, as they can reduce the need for capital as well as the strategic risk (Sydow, 2001). Collaborative activities and networks are suitable for SMEs to compete and innovate in dynamic business environments (Valkokari & Helander, 2007). Policy makers are already taking the need for collaboration into account by offering public funding and various support programs to promote engagement in networks (Rammer *et al.*, 2016). The promotions target the technology transfer at the interface of industry and research with a special focus on the integration of SMEs into initiative programs (BMWi, 2020). Technology-open promotions and support programs are intended to strengthen and expand competitiveness, networking, innovative strength, and employment among SMEs (Buhl, Sedlmayr, & Meier, 2019).

Formal inter-organizational innovation networks

In contrast to simple forms of dyadic collaboration, a network is generally characterized by complex relationships between several entities involved. Owing to the broad, cross-disciplinary use of terms referring to networks, such as collaboration, network, and cluster, various definitions exist for networks. Within the heterogeneous spectrum of definitions, many terms are used differently depending on the individual definition of the author (Friese, 1998). Therefore, it is crucial to first define the scope of networks under analysis in this study.

Participation in a network reflects a strategic decision by organizations seeking to exchange resources and gain a competitive advantage that they could not obtain alone (Child, Faulkner, & Tallman, 2005; Sydow, 2001; Wissema & Euser, 1991). Previous research discusses different approaches and theories dealing with the motivation, emergence, and processes of networks, resulting in two commonly accepted approaches (Casals, 2011). The Transaction Cost approach explains collaboration with the aim of minimizing costs, whereas the Resource Based View explains collaboration as the bundling of resources (Williamson, 1981). As internal resources are limited, the Resource Based View approach suggests that, in order to exploit all existing resources and to develop a long-term competitive advantage, firms need to access external knowledge (e.g. Williamson, 1981). To reduce the uncertainty of resource availability, organizations can either acquire them or access them through collaboration (Sydow, 1992). Access through collaborative activities and networks offers the opportunity to increase strategic flexibility and, furthermore, to reduce capital requirements. In contrast, the resulting risks include a loss of strategic autonomy and a potential increase in coordination costs (Sydow, 2001).

Different types of collaboration and networks are hybrid forms of coordinating economic activities between the two established paradigms of market and hierarchy. Networks combine market and hierarchical, competitive and collaborative elements (Sydow, 1992). In contrast, Powell (1990) claimed that networks have to be seen as an independent form of coordination besides the forms of market and hierarchy. As this assumption would imply that only one general form of networks exists, other studies disprove this view and suggest network typologies to differentiate forms of collaboration accounted for as networks (Provan, Fish, & Sydow, 2007; Provan & Kenis, 2008). As all forms of collaboration and networks share different market- and hierarchical-oriented characteristics, we consider that different types of networks can be positioned within the spectrum of market and hierarchy, influencing, e.g., network governance (Friese, 1998; Sydow, 1992). This, furthermore, implies that networks can "produce positive outcomes that would not be possible in a market or a hierarchy" (Provan & Kenis, 2008, p. 5), fostering beneficial expectations for network engagement among SMEs.

Networks are an organizational form of economic activity aimed at realizing competitive advantages that are characterized by complex reciprocal, collaborative rather than competitive and relatively stable relationships, whereas involved entities are legally independent, but economically mostly dependent enterprises and organizations (Sydow, 1992). Reciprocal behavior suggests that social exchange always leads to an immediate or later counter-exchange; however, the motivation is based on a social norm rather than on a contract (Gouldner, 1960). As collaboration can exist between two entities, networks consist of multiple organizations linked through multilateral ties that result in a group of three or more organizations. The connections are created in order to facilitate the achievement of a common goal (Provan *et al.*, 2007) that can vary, e.g., from access to new or complementary knowledge, marketing, the increase in economies of scale, and risk sharing (Mariti & Smiley, 1983). Members of a network usually aim for a combination of different objectives (Morschett, 2003). Provan, Fish, & Sydow, 2007, distinguish inter-organizational and intra-organizational networks. For this study, we only consider inter-organizational networks of at least three organizations interacting across their organizational boundaries (Provan *et al.*, 2007). Networks can emerge between organizations resulting from business transactions without being created by any kind of authority. These networks are described as informal networks, but lack visibility and publicly available data (Cross, Nohria, & Parker, 2002). On the other hand, networks can be created and managed by either a hierarchical or a heterarchical structure (Sydow, 2001). Networks are established by collaborative actions and fixed by an explicit collaboration agreement (Van Aken & Weggeman, 2000). In order to ensure consistent data availability, we limit our study to formalized networks.

Especially in R&D, which is assumed to play a crucial role in the value creation process and can determine the competitiveness of companies, collaborations can lever product innovation and market success of new products (Hottenrott & Lopes-Bento, 2016). Collaboration is therefore usually determined by a combination of the different skills and knowledge bases of the partners involved. Collaborative networks are the most significant source of innovation that leverage resources and capabilities across multiple organizations (Schilling, 2013). Networks offer vast opportunities, e.g., to enhance the use of tacit specialist knowledge, overall competence exchange, and dynamic technological innovation (Powell, 1990). Innovation networks are characterized by organizations that are engaged in product, process, or service innovation (Van Aken & Weggeman, 2000). For this study, we include networks in which organizations or departments of companies are involved that focus on R&D projects. We do not limit our focus to inter-firm R&D partnerships (Hagedoorn, 2002), but rather regard networks consisting of different organizations that share research or development activities toward their common objectives.

In order to narrow our research focus, we determine a working definition of formal inter-organizational innovation networks based on the previously presented literature and research: *Formal inter-organizational innovation networks are multiple legally independent organizations linked through multilateral ties in order to achieve common process, product, or service innovation. The linkages and activities between the organizations are aligned and coordinated by a management, organization, or authority.*

Particularly occurring in high-technology sectors, collaboration is often facilitated by geographical proximity, which can lead to regional technology clusters (Schilling, 2013). The interaction between firms tends to be more intense when they share some type of similarity, such as geographical or technological proximity (Schilling & Phelps, 2007). Regional knowledge networks of related organizations are often referred to as "clusters" (Vieregge, 2011). This term was coined by Porter (1998, p.78), who defined clusters as "(…) geographic concentrations of interconnected companies and institutions in a particular field." Clusters can consist of competitors, suppliers, customers, and other entities such as governmental organizations, research institutes, universities, and trade associations (Porter, 1998). In contrast to clusters as local agglomerations, formal networks are not necessarily linked to specific locations and are actively controlled by an authority or management. However, for the purpose of this study, our definition includes clusters that also share the characteristics of formal inter-organizational networks with strong regional ties.

Typologies of networks

Even though some preliminary literature on inter-organizational networks exists, yet no consistent typology of networks grounded in empirical data is established. Existing analyses based on qualitative methodologies such as case studies and semi-structured interviews from company perspectives are limited in their ability for generalization (see, e.g., Bau, Bentivegna, & Forster, 2014). Still, academic predecessors provide a number of network typologies and give a broad selection of distinctive network characteristics, able to distinguish between networks (Payer, 2008). As definitions of network types are often based on their characteristics, previously identified network types can differ significantly and lack comparability. Some are defined

based on one specific key characteristic, and others refer to a set of selected characteristics. A proposed morphological box of collaboration characteristics by Killich (2011) summarizes common characteristics in Figure 1, independent of the type of collaborative activities. Within the morphological box, a variety of different features of the respective characteristics are suggested.

Characteristic	**Features**					
Direction	Horizontal		Vertical		Lateral	
Geographical extension	Local	Regional		National		Global
Intensity	Low		Moderate		High	
Commitment	Agreement		Contract		Capital commitment	
Duration	Temporary				Unlimited	
Goal identity	Redistributive				Reciprocal	
Collaborative departments	R&D	Sales	Procurement	Marketing	Production	Other

Figure 1: Morphological box of collaboration characteristics, based on Killich (2011, p. 18).

The direction indicates the value creation stage at which collaboration partners operate. Horizontal collaboration is conducted between partners at the same stage, whereas vertical collaboration includes partners from different stages in the value chain. Lateral collaboration can include partners from different value chains as well (e.g., Hagenhoff, 2008; Killich, 2011; Morschett, 2003; Payer, 2008). Geographical activities of collaboration can be distinguished between very locally concentrated up to global spanning collaboration (e.g. Killich, 2011; Morschett, 2003; Payer, 2008). The intensity of collaboration describes the degree to which activities need to be coordinated with partners (Killich, 2011). Another key characteristic is the commitment, which can extend from loose agreements up to signed contracts or monetary investments (e.g. Hagenhoff, 2008; Killich, 2011). Therefore, the duration is also often regarded, but is only distinguished between temporary and unlimited time horizons (e.g. Hagenhoff, 2008; Killich, 2011; Morschett, 2003). A crucial characteristic for collaboration is the goal identity, which describes the benefit the actors aim to achieve. A distinction is made between the pooling of resources with the same intention, a redistributive goal identity, and an exchange of services to achieve individual but complementary goals, namely reciprocal goal identity (Killich, 2011). Additionally, collaboration can be characterized by the departments or functions actively involved (e.g. Hagenhoff, 2008; Killich, 2011).

Academically identified characteristics are complemented by additional network characteristics and typologies. Although typologies should ideally be free of overlaps, previous research indicates that transitions between network types are often fluent and not precisely determinable (Schuh *et al.*, 2011). Sydow (2001) has already described the opportunities for creating typologies of inter-organizational networks as infinite and provides a list of 26 different possibilities to distinguish network types based on their characteristics. A review of empirical research about inter-organizational networks by Provan, Fish, & Sydow (2007) has already identified a general focus on network governance and network structure. Following on from this, Provan & Kenis (2008) differentiate networks according to their form of governance, resulting in three types of networks: Participant-Governed Networks, Lead Organization-Governed Networks, and Network Administrative Organization. Network types are further determined based on their structure, as some are dominated by a focal organization and others have polycentric structures (e.g. Child *et al.*, 2005; Sydow, 2001). Sydow (2001) suggests a typology of networks based on the type of control (hierarchical—heterarchical) and the stability of relationships (stable—dynamic) and derives four types: Strategic Networks, Regional Networks, Project Networks, and Virtual Undertakings. Networks are also observed regarding the positioning of the actors in the value chain. A commonly identified network type is the collaboration of partners with a vertical relationship in the value chain, referred to as vertical integration or vertical partnerships (e.g. Bau *et al.*, 2014; Dussauge & Garrette, 1999; Sydow, 2001). As local agglomerations are associated with networks, previous studies also described networks by their local and regional focus (e.g. Inkpen & Tsang, 2005; Payer, 2008; Porter, 1998; Sydow, 2001, 2010). Cooke, Gomez Uranga, & Etxebarria (1997) established the theory of Regional Innovation Systems. Regarding innovation, networks have been observed in terms of their purpose and the common objectives of their actors. A series of previous studies identified several different network types that aim to foster innovation among their actors (e.g. Bau *et al.*, 2014; Lyytinen *et al.*, 2016; Priestley & Samaddar, 2007; Wissema & Euser, 1991). To mention one example that is directing our analysis, Bau, Bentivegna, & Forster (2014) conducted a quantitative analysis of network characteristics to identify types of informal innovation networks. However, as they collected secondary data from semi-structured interviews with company representatives, their typology solely reflects the company perspective. Based on a consecutive cluster analysis, a typology of five innovation network types with their corresponding characteristics is suggested: Knowledge and Learning, Financial Procurement, Vertical Integration, International Scope, and Isolate Islands.

To summarize, the existing literature provides a large selection of network characteristics to describe and differentiate possible network types. This results in a wide variety of independent network typologies. Provan *et al.* (2007) have already proposed the combination of previously gained insights with an analysis at a network level. They formulated the need to study inter-organizational networks using a qualitative and quantitative approach. Yet a considerable number of qualitative studies contribute to the area of network types and characteristics, whereas only a few conducted a mixed method approach to structure previous insights and provide a framework. In an attempt to build a comprehensive framework based on a mixed method approach, e.g., Bau *et al.* (2014) used secondary data from a multiple case study and conducted a quantitative cluster analysis in order to generate their typology. Comparably, existing typologies are based on the derivation of individually

conceptualized matrices that consist only of selected network features from theory. Thus, existing typologies are difficult to compare and are not comprehensively grounded in empirical data. As reflected by Provan *et al.*, (2007), this represents only individual perspectives on networks, yet the existing literature does not provide a comprehensive generalizable classification.

Therefore, we recognize a need to combine previously identified, lone-standing network types and attributes into a comprehensive typology with a solid empirical foundation. Taking into account network characteristics and attributes from existing literature, we aim to identify and analyze types of formal inter-organizational innovation networks in order to derive a comprehensible, generally applicable typology, thereby answering the question: *What are the predominant types of formal inter-organizational innovation networks and how can they be characterized?*

RESEARCH DESIGN, SAMPLE, AND METHODS

Research design

We conduct a qualitative content analysis followed by a quantitative cluster analysis, inspired by previous research about innovation networks by Bau *et al.* (2014), the applied clustering approach of Delgado, Porter, & Stern (2016), and the applied mixed method approach of Täuscher & Laudien (2018). Our methodology represents an exploratory sequential mixed method approach (Creswell, 2014). We first use directed content analysis to compile a comprehensive data set (Hsieh & Shannon, 2005). Subsequently, we apply a hierarchical clustering approach using Ward's linkage method to cluster the results from our content analysis (Ward, 1963). In the following section, we describe our sampling procedure and applied methods.

Sample

In order to identify networks in a structured manner, we use a large online listing of networks provided by "Clusterplattform Deutschland" (BMWi, 2020). This guarantees a structured sampling procedure as well as networks of sufficient quality. The term cluster can be misleading, as the focus of the platform is not limited to clusters in a narrow sense. The listed networks on the platform, so-called cluster initiatives, are supported by funding programs to foster the development of cluster and network structures. The networks are subject to the assumption that the actors involved are key players in the innovation process and thus make a decisive contribution to innovation and value creation (Buhl *et al.*, 2019).

As we generate our sample data, all entries from the online listing of "Clusterplattform Deutschland" are retrieved, resulting in a list of 463 networks. Within a first screening process, the entries are tested in terms of consistency with our previously formulated definition of formal inter-organizational innovation networks. Following this, some identified networks do not match our definition and are excluded from the sample. Furthermore, several entries are removed, as they either do not provide sufficient information to fulfill the purpose of a content analysis or represent duplicates. After this process, our sample consists of 300 formal inter-organizational innovation networks.

The resulting sample of networks shows the following characteristics. As we retrieve the networks from a German online listing, the sample is geographically limited. Besides, no further limitations are made regarding the networks' locations across Germany as well as the age or size of the networks. A distribution across the 16 federal states of Germany can be observed, as presented in Figure 2. A few states, namely Baden-Wuerttemberg and Lower Saxony ("Niedersachsen") are represented with more networks in our sample, but we did not include aspects of representativeness in our analysis. This issue is not solely present in our final sample, but also reflects the initial distribution of networks on "Clusterplattform Deutschland" (BMWi, 2020) before our exclusions.

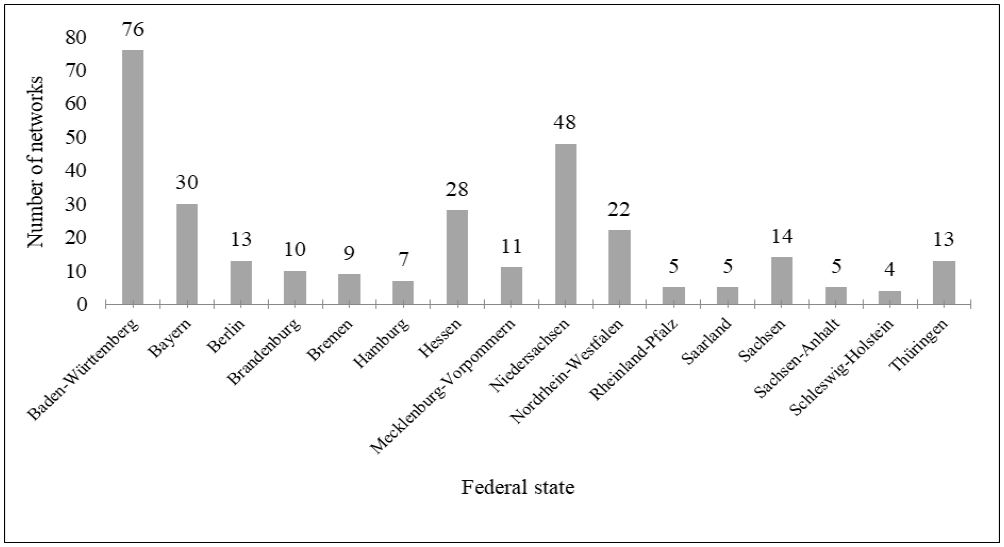

Figure 2: Distribution of analyzed networks by federal state.

We use the number of actors involved in a network to describe the size of the networks. No information or an exact number of actors could be found for 26 networks, marked as N/A in Figure 3. As illustrated, most of the networks range between 10 and 100 actors. Only very few networks consist of less than 10 or more than 500 actors.

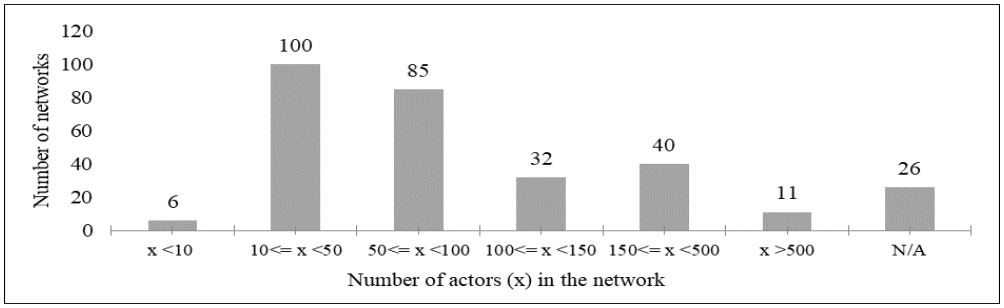

Figure 3: Distribution of analyzed networks by size (number of actors).

Qualitative content analysis

In order to generate a comprehensive data set, we conduct a qualitative content analysis using a directed approach. The purpose of this content analysis is to translate qualitative information into numerical data, which can be analyzed consecutively using a quantitative method (Potter & Levine-Donnerstein, 1999).

For a directed content analysis, codes are first derived from theory and relevant research findings and are adapted during the analysis (Hsieh & Shannon, 2005). We first consider a selection of network and collaboration characteristics based on previous literature as initial coding categories (Potter & Levine-Donnerstein, 1999). The coding process is conducted based on publicly available information on the websites of the identified networks, complemented by information provided by "Clusterplattform Deutschland" (BMWi, 2020). The set of characteristics and features is continuously adapted during this process (Hsieh & Shannon, 2005). An overview of our initial set of characteristics is given in Appendix 4 1. Characteristics that appear to be less appropriate, difficult to interpret, or that can only be determined based on highly subjective assessments are removed from the data set. Furthermore, characteristics must be removed if sufficient information cannot be retrieved from publicly available sources.

The final set of characteristics we take into account for the quantitative cluster analysis covers a wide range of potential factors, able to explain differentiated types of networks. Origin explains whether the network is created top-down by one or more entities or emerged through the relationships of several organizations. Control captures the expected weighting of management influence among the partners in the network, i.e., whether a network is managed via a focal company or controlled by several entities. Governance, in contrast, describes the stringency of administration throughout the network and in relation to the partners involved. Network identity evaluates the objectives of the network and its members. Geographical extent covers the geographical range of the network. The positioning of actors in the value chain describes the relationship of the network partners with regard to their process of value creation. Commitment depicts the binding nature by which network partners enter to become network members, i.e., an agreement, a contract, or even an equity contribution. Initiators of the network include a range of organizations that kick-off and thereby initiate networks. Actors in the network, on the other hand, can be companies, scientific institutions, and others at an appropriate level of explanation depth. Further single features target special foci such as a special industry, start-ups, physical premises, lobbying, and technology. The final characteristics and features of the sample are presented in Table 1 together with the corresponding description.

Table 1: Definition of network characteristics for survey during the directed content analysis.

Characteristic	Feature	Description
Origin	Top-down Bottom-up	The network is either created top-down by one or more entities or emerged through the relationships of several organizations.
Control	Hierarchical Heterarchical	Hierarchically managed networks are characterized by the existence of a focal company. Heterarchical networks are controlled by several entities.
Governance	Lead organization	A focal organization is leading the network or is determining the management.
	Network administration	An independent management is set up to manage and control the network.
	Shared	Decentralized and joint coordination by many or all members.
Network identity	Reciprocal	Equalization of one's own weaknesses through the strengths of complementary capabilities from partners.
	Redistributive	Equalization of common weaknesses through the bundling of resources.
Geographical extent	Local	The network activities are concentrated in one city.
	Regional	The network focus is set on one region.
	State	The network activities concentrate within a federal state.
	National	The network activities are nationwide.
	International	The network activities are across national borders.
Positioning of actors in the value chain	Horizontal	The actors are positioned at the same stage within the same value chain.
	Vertical	The network includes actors in upstream and downstream stages of the value chain.
	Lateral	Actors from different value chains and stages are involved.
Commitment	Arrangement	Loose collaboration based on verbal agreements.
	Contract	The membership of a network requires the signing of a contract.
	Equity	The membership of a network requires a monetary investment.
Initiators of the network	University/R&D institutes	Research institutes or universities are among the initiators.
	Association	Associations are among the initiators.
	Company	Companies are among the initiators.
	Chamber	Chambers are among the initiators.
	Network	Another (established) network is among the initiators.
	Local development organization	A local development organization is among the initiators.
	Public institution	A public institution is among the initiators.
Actors in the network	Companies	Companies are active in the network.
	Universities/R&D institutes	Universities or research institutes are active in the network.
	Other	Other organizations, not further specified, are active in the network.
Single features	Industry focus	The common objectives of the network target an industry.
	Start-up support	The network interacts with start-ups.
	Common premises	The network offers common premises, such as co-working spaces or think labs.
	Lobbying	The network actively engages in lobbying activities for its actors.
	Technology focus	The network focuses on the development of a specific technology.

The preselected characteristics are transferred into binary variables to assess whether a network fulfills a feature or not. During the coding process, a "1" is assigned for each existing feature and a "0" for every feature that is not fulfilled by an observed network. In order to reduce elements of subjective interpretations during the coding process, the coding of qualitative information is partially counter-tested vice versa by the authors.

Quantitative cluster analysis

We apply a quantitative cluster analysis to identify groups of networks with similar features in the previously generated binary data set (Backhaus, Erichson, Plinke, & Weiber, 2018). Before conducting a cluster analysis, crucial decisions regarding the measure of proximity, clustering method, and number of clusters are made. Before all this, the sample variables must be prepared to guarantee interpretable results (Everitt, Landau, Leese, & Stahl, 2011).

First, each feature is assigned to a cluster variable for the cluster analysis. As the cluster variables represent the network characteristics and features, we ensure that the variables are of sufficient quality. We conduct a frequency analysis to identify characteristics that occur rarely. They are considered less appropriate for the cluster analysis and are removed. Not all variables within the same characteristic sum up to 100% as multiple feature selection is considered for certain characteristics. Moreover, variables indicating a doubled characteristic are omitted. Variables representing a feature of a hybrid characteristic are merged. Thus, for a hybrid characteristic, a "1" can represent the first feature and a "0" represents the second. The merged variables are listed in Table 2. This modification reduces the number of variables from 35 to 32.

Table 2: Merged cluster variables

Characteristic	**Original variable**	**Original feature**	**Merged variable**	**Merged feature**
Origin	C_orig_topdown	Top-down	C_origin	1 = Top-down
	C_orig_bottomup	Bottom-up		0 = Bottom-up
Control	C_control_hier	Hierarchical	C_control	1 = Hierarchical
	C_control_heter	Heterarchical		0 = Heterarchical
Network identity	C_ident_reciproc	Reciprocal	C_identity	1 = Reciprocal
	C_ident_redistr	Redistributive		0 = Redistributive

Highly correlated cluster variables lead to an overrepresentation of the underlying aspects as they provide redundant information. In order to guarantee a high quality of cluster variables, we conduct a correlation analysis of the 32 remaining variables, where we classify a correlation coefficient above 0.9 as critical. No critical correlation was observed between the sample variables; therefore, our final set of characteristics for analysis consists of 32 variables, which are shown in Table 3.

We apply hierarchical agglomerative clustering (HAC) methods, as they appear to be most suitable for our research purpose (Bau *et al.*, 2014; Delgado *et al.*, 2016; Täuscher & Laudien, 2018). HAC offers the advantage that it provides cluster solutions, but can also be used to determine the optimal number of clusters (Kassambara, 2017). In order to conduct a structured cluster analysis, we follow the approach suggested by Backhaus *et al.* (2016), which contains three steps. At first, a proximity measure is chosen, which is required for the selection of the cluster method that represents the clustering algorithm. Finally, the optimal number of clusters is determined to conduct the cluster analysis.

Therefore, we first select a distance measure and linkage method that determines how the algorithm combines the objects in our data set into clusters. The selection of a suitable method is of the utmost importance as the results can vary on the same data (Everitt *et al.*, 2011). For the comparison of absolute data, it is suggested to use a distance measure instead of similarity measures as a proximity measure (Backhaus *et al.*, 2018). We apply Ward.D2 as a linkage method in combination with the Euclidean distance as both aim to maximize the homogeneity within the clusters and generate clusters that are as different as possible from one another (Backhaus *et al.*, 2018; Ward, 1963). This is a crucial characteristic of the underlying algorithm, as we aim to achieve more easily interpretable results. Network types are generally assumed to have fluent transitions and are therefore difficult to distinguish (Schuh *et al.*, 2011). The third step in the cluster analysis represents the determination of the optimal number of clusters, referred to as k. As the determination of k has a great impact on the final cluster solution, we apply various methods to indicate an optimal k; as yet there is no optimal method suggested in the literature. We apply an indicator method by Han, Kamber, & Pei (2012), and compare this number with the Elbow Method, Silhouette Method, and Gap Statistic Method (e.g. Everitt *et al.*, 2011; Kassambara, 2017). Based on the results of the conducted methods, we consider k=11 as an optimal number of clusters for the following analysis. After determining the optimal number of clusters, we conduct a hierarchical agglomerative clustering analysis. The cluster analysis is performed using the Ward.D2 method as the algorithm to combine objects into clusters based on the generated Euclidean distance matrix (Ward, 1963). We use the programming language R to perform the cluster analysis. Following the cluster analysis, we review each group of networks in terms of their characteristics and features in order to identify distinctive characteristics for each cluster. Therefore, the frequencies of the cluster variables are calculated within each cluster. Through an iterative process, followed by a profound discussion between the authors, we define network types by choosing concise and appropriate names to reflect the networks in the respective clusters.

Table 1: Final set of cluster variables

Characteristic	Variable	Feature
Origin	C_origin	1 = Top-down 0 = Bottom-up
Control	C_control	1 = Hierarchical 0 = Heterarchical
Governance	C_gov_lead C_gov_admin C_gov_shared	Lead organization Network administration Shared
Network identity	C_identity	1 = Reciprocal 0 = Redistributive
Geographical extent	C_geo_local C_geo_regio C_geo_state C_geo_natio C_geo_intern	Local Regional State National International
Positioning of actors in the value chain	C_vchain_horiz C_vchain_vertic C_vchain_lat	Horizontal Vertical Lateral
Commitment	C_commit_arrange C_commit_contract C_commit_equity	Arrangement Contract Equity
Initiators of the network	C_init_uni C_init_assoc C_init_comp C_init_chamber C_init_netw C_init_devorga C_init_pub	University/research institutes Association Company Chamber Network Local development organization Public institution
Actors in the network	C_act_comp C_act_uni C_act_other	Companies Universities/R&D institutes Other
Industry focus	C_industryspecific	1 = existent 0 = non-existent
Start-up support	C_founders	1 = existent 0 = non-existent
Common premises	C_premises	1 = existent 0 = non-existent
Lobbying	C_lobbying	1 = existent 0 = non-existent
Technology focus	C_technologyfocus	1 = existent 0 = non-existent

RESULTS: TYPES OF NETWORKS

In the following section, we present the results of our HAC analysis. We describe common results and characteristics of the clusters and identify distinctive characteristics that we define as key characteristics for each group of networks. In order to create a comprehensive typology, we name every group of networks after their specific characteristics and provide a concise description.

As the optimal number of clusters is determined within our method, we observe 11 groups of networks. The number of networks defines the cluster size and is illustrated in Figure 4. The average cluster size is 27.27 networks per cluster, whereas the median is 17. Only three clusters are above the average size, of which cluster #3 represents the largest with 86 networks. The other eight clusters range from seven to 26 networks. The smallest cluster is represented by cluster #8 with seven networks.

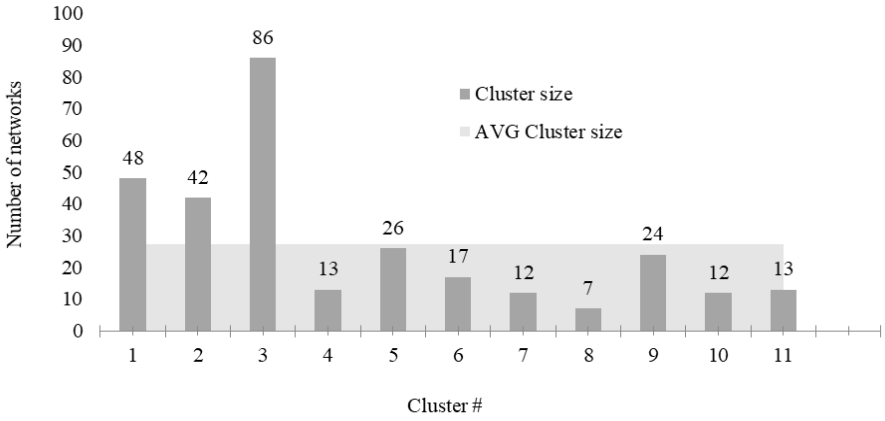

Figure 1: Cluster size: distribution of networks by cluster size (number of member networks).

Avid Persuaders

The first cluster represents 48 networks. The networks in the cluster show a diverse set of actors that are committed via either arrangements (54.17%) or contracts (43.75%). The networks are mostly controlled via hierarchical structures (95.83%). Complementarily, the governance of the network is determined by a leading organization (85.42%). Distinctive from other clusters, the networks in cluster #1 are partially initiated by chambers of commerce (27.08%). This is complemented by a comparably high frequency of engagement in lobbying activities (43.75%). However, the networks are not solely positioned in one value chain but are rather distributed across different stages in several value chains (70.83%) with a strong focus on a certain technology (91.67%).

Based on the previously described characteristics and features, we identify the following key characteristics for the networks in cluster #1:

- Engagement in lobbying activities
- Managed by a lead organization
- Hierarchical control structures

According to their key characteristics, we call the networks in cluster #1 the Avid Persuaders. The networks are focally initiated and managed and engage in start-up support and lobbying activities. The network is generally initiated by large focal organizations that seek to identify or develop new technologies. The objective of the network is clearly determined and tailored to the individual needs of the focal organization. The interactions and activities of the network are geared toward access to external resources that represent complementary capabilities not only for the leading organization, but also for the other network actors. However, other actors are not necessarily fully committed to the network via contracts.

Value Chain Drivers

The second cluster comprises 42 networks. The networks in cluster #2 are determined by shared governance forms (73.81%), which enable members to engage on equal participation rights within the network. This is also reflected by the high commitment of the members in the networks by contracts (92.86%). With a feature frequency of 73.81%, most of the network activities are concentrated within a single federal state. The actors in the networks are solely active across different stages within the same value chain (83.33%). Different from other clusters, the networks in cluster #2 also have redistributive (42.86%) goal identities as they aim for resource bundling to overcome common weaknesses. The networks are initiated either top-down (45.24%) or bottom-up (54.76%). Mostly, companies (64.29%) are involved in the initiation process; other actors are universities and public institutions (38.10%) as well as R&D institutes (26.19%).

Following the above-mentioned characteristics and features, we define the following key characteristics for the networks in cluster #2:

- Vertical positioning of actors within the same value chain
- Shared governance forms
- Geographical concentration in federal states

We call this group of networks the Value Chain Drivers that are characterized by joint decision makers who foster the development of value chains, concentrated within federal states. The organizations in a network are positioned within the same value chain. The networks follow objectives that target structural challenges and key technological changes for the value chain in order to stay competitive.

Collective Facilitators
With 86 networks, the third cluster represents the largest identified group of networks. Most of the networks in cluster #3 are emergent networks that are formed bottom-up by several organizations (79.09%). Complementary distinct characteristics of the networks are heterarchical (81.40%) structures and shared governance forms (94.19%). In most initiations of the networks, companies are engaged (77.91%) that are also present in every network (100%). A comparable high share of universities and R&D institutes (41.86%) is engaged in the initiation process as well. They also represent actors in the network in 93.02% of the networks. The actors in the network are positioned across different value chains as well as value chain stages (95.35%). All actors in the networks are committed by a binding contract (100%). The strong reciprocal network identity (90.70%) as well as the technology focus (74.42%) is consistent with the common characteristics of all clusters. Additionally, networks within this cluster partially engage in lobbying (37.21%) and start-up support activities (38.37%). The activities of the networks are often focused on a specific industry (59.30%).

With the above-described characteristics and features, we recognize the following key characteristics for the networks in cluster #3:

- Emergent formation (bottom-up)
- Heterarchical control structure
- Shared governance
- Lateral positioning of actors in the value chains

We call this group of networks the Collective Facilitators that are characterized by emergent formations with equal participation rights to increase the scope of action beyond value chain boundaries. The networks on the one hand aim to actively support companies, R&D facilities, and other institutions in order to facilitate connections and partnerships. Innovations, projects, and solutions are jointly developed and implemented. On the other hand, they promote general trends and technology developments. For example, the establishment of standards for new technologies

Niche Specialists
The fourth cluster represents 13 networks from our sample. Most networks in this cluster are top-down (92.31%) initiated by already established networks (100%). Complementary to the origin of the networks, the control structure is hierarchically organized (84.62%). However, a governance structure that is determined by a leading organization occurs in only 53.85% of the networks in this cluster. We further observe a geographical concentration of network activities within federal states (84.62%). The objectives of the networks are mainly reciprocal (84.62%). The actors in the networks are mostly committed with contracts (84.62%) and are rather positioned across different value chains and value chain stages (69.23%). The networks share a common technology focus (76.92%) and a comparably weak industry focus (30.77%).

Based on the previously described characteristics and features, the following key characteristics for the represented networks in cluster #4 are defined:

- Top-down initiated by established networks
- Tight technology focus
- Geographical concentration on federal states

We call this group of networks Niche Specialists that are described as network-initiated formations to foster specialized technologies within federal states. The integration of leading technology experts into the management of the networks ensures the achievement of long-term objectives. Target-oriented structures are established to achieve generally valid regulations and standardizations that are required for new technologies. The networks aim to develop and establish new key technologies.

Lateral Thinkers
The fifth cluster consists of 26 networks from our sample. In every network in cluster #5, companies (100%) as well as universities and research institutes are involved (100%). Both companies (73.08%) and universities and R&D institutes (34.62%) are engaged in the initiation process, complemented by public institutions (30.77%). The actors are positioned across different stages and value chains (92.31%) and share a reciprocal goal identity (92.31%). The networks are mostly managed very independently and are characterized by a network administration (80.77%). The initiation was conducted either top-down (46.15%) or bottom-up (53.85%). Control structures are slightly more hierarchical (65.38%). The cluster represents the highest specific technology focus (96.15%) as well as industry focus (92.31%) of all clusters. The networks in the cluster can be distinguished further as they provide support for their members to connect with start-ups or support start-ups directly (80.77%).

Regarding the previously described characteristics and features, we distinguish the following key characteristics for the networks in cluster #5:

- Network administration
- Positioning of actors across value chains and value chain stages (lateral)
- Strong industry and technology focus

- Interaction with start-ups

We call this group of networks the Lateral Thinkers that are characterized by independent industry centers seeking to identify innovative solutions through interaction with start-ups. Publicly funded non-profit associations foster the exchange of experience, knowledge, contacts, and ideas within a regional scope. The networks build an interface for entrepreneurs, scientists, technology seekers, as well as business angels to promote new technologies, which are of great relevance for the specialized companies that were already engaged in the establishment of the network. High-tech companies and start-ups in fast-growing industries represent the members. Companies are supported across all maturity phases of company development.

Transnational Opportunity Seekers

The sixth cluster comprises 17 networks. The networks in this cluster are rather initiated bottom-up (64.71%) and described by heterarchical structures (76.47%). Shared governance (52.94%) represents the preferred form of control by the networks and their actors. The networks within the cluster share common characteristics with other clusters such as a reciprocal network identity (94.12%) and actors committed by contracts (88.34%). The actors within the networks are rather positioned across stages on different value chains (64.71%) and are represented by companies (100%) as well as universities and R&D institutes (94.12%). Companies (82.35%), universities and R&D institutes (41.18%), as well as public institutions (47.06%) are engaged in the initiation process of the networks. A significant feature is observed within this cluster as all networks are engaged in international activities (100%) or relate to international partners. The networks are further characterized by a high technology (88.24%) and industry focus (58.82%).

Based on the previously described characteristics and features, the following key characteristics for the networks in cluster #6 are recognized:

- International scope
- Initiated by companies
- Strong reciprocal network identity

We call this group of networks the Transnational Opportunity Seekers that are jointly initiated by companies to achieve complementary capabilities across national borders. Registered non-profit associations aim to foster technology and market-oriented collaboration in science, research, and economics within an international scope. The actors intensify joint R&D activities with the possibility of opening new business fields. The network further represents its actors to the public and supports them in identifying experts as well as acquiring funds from the European Union.

Financially Resilient Connectors

The seventh cluster contains 12 networks, which are described by hierarchical structures (83.33%) and top-down (66.67%) initiation. All members are committed to the networks by monetary equity investments (100%). This enables the network to enhance innovation partnerships driven by connections with start-ups (50%). The cluster shares the characteristics of a strong technology focus (91.67%) and a reciprocal network identity (83.33%). Furthermore, companies (66.67%), public institutions (50%), as well as universities and R&D institutes (33.33%) are involved in the initiation of the networks. The positioning of the actors is a rather lateral (66.67%) distribution of the actors across value chains. The networks are primarily concentrated in regions (41.67%) or within a single federal state (33.33%). We also observe that especially small networks are represented within cluster #7.

Based on the above-described characteristics and features, we identify the following key characteristics for the networks represented in cluster #7:

- Actors are committed through equity
- Interaction with start-ups
- Strong technology focus

We call this group of networks Financially Resilient Connectors that we describe as purpose-driven enablers of financially sustainable innovation partnerships. The networks are initiated as limited liability companies and funded by public institutions and the European Union, together with partners from industry and science. They serve as a regional competence center to strengthen the region and entire industry. The networks reveal regional R&D capacities to promote and strengthen innovations and start-ups on behalf of the public sector. The partners from industry, research, and universities develop supra-regionally oriented forums, workshops, and working groups on current development trends in various fields of technology.

Local Trend Sponsors

With seven networks, the eighth cluster represents the smallest identified group of networks. Most networks within this cluster are initiated top-down (85.71%) by public institutions (71.43%). The networks are locally (100%) concentrated as many of them offer common premises (42.86%) for their members and partners. The clusters share common cluster characteristics of reciprocal goal identities (71.43%) as well as commitments based on contracts (71.43%). The actors within the networks are mainly based within the same value chain at different stages (71.43%), but also share common connections to start-ups

(57.14%). The networks seem generic as they have a comparably low technology focus (28.57) and are not specialized on specific industries (14.29%).
Based on their characteristics and features, we identify the following distinctive key characteristics for the networks in cluster #8:

- Local concentration
- Common premises
- Initiated by public institutions
- Vertical positioning of actors within the same value chain

We call this group of networks Local Trend Sponsors that are described as concentrated, publicly initiated, local interfaces for companies of all sizes. Public institutions that aim to shape and promote local industry districts or science parks determine the networks. The networks offer a meaningful point of contact for companies from different industries and sizes and act as a mediator with municipal partners. The networks draw attention to strategic trends and current developments at an early stage in order to involve actors in the development. A close network is offered by providing common premises and interaction with start-ups.

Regional Activists
The ninth cluster represents 30 networks. The networks within this cluster are top-down (95.83%) initiated by local development organizations (95.83%). Consistently, they have a hierarchical structure (91.67%) and are led by an organization (62.50%). They focus on several industries (41.67%) across different value chains (75%). Furthermore, the networks within this cluster share a reciprocal network identity (87.50%). Companies (100%) and universities and R&D institutes (87.50%) are among the actors in the networks. The networks also represent the interests of their actors as they engage in lobbying activities (50%). The technology focus of the networks is rather low (45.83%) compared with other clusters.

Regarding the above-mentioned characteristics and features, the following distinctive key characteristics for the networks in cluster #9 are determined:

- Top-down initiated by local development organizations
- Lobbying activities
- Strong local concentration

We call this group of networks Regional Activists that we describe as regional platforms to promote and foster selected business sectors holistically. The networks are based on initiatives from the federal states founded as collaborations to strengthen economic sectors within a region. They support actors in networking and development as well as in innovation and settlement projects. The networks bundle and coordinate resources between the actors for the purpose of knowledge transfer, exchange of experience, and initiation of joint projects. Therefore, they act as a mediator between politics, administration, and practitioners from industry, trade, and the service sector.

Associated Industry Supporters
The tenth cluster comprises 12 networks. Even though all the networks are at least partly initiated by associations (100%), they are not necessarily created top-down (58.33%). They also rather have a shared governance form (58.33%). Consistently with the large share of initiations by associations, many networks are engaged in lobbying activities (83.33%). Within the cluster, a high share of networks has an industry focus (91.67%). The scope of network activities is rather concentrated within federal states (66.67%). The actors consist of companies (100%) as well as universities and R&D institutes (91.67%). The positioning of the actors within a value chain is not specified as they are either at different stages of the same value chain (50%) or across different value chains (50%). As in the other clusters, the networks share common characteristics of a reciprocal goal identity (91.67%) as well as contract-based commitments (91.67%). The networks interact with start-ups (41.67%).

Based on the previously described characteristics and features, we identify the following distinctive key characteristics for the networks in cluster #10:

- Initiated by associations
- Lobbying activities
- Industry focus within federal states

We call this group of networks the Associated Industry Supporters. We describe this network type as sector-specific associations, based on company engagement to promote relevant topics, strengthen networks, and foster companies. With contacts from business, science, and politics, the associations represent an industry and form the interface between industry and politics. Additionally, projects are developed and implemented together with companies, research institutes, and local authorities to increase regional value added and competitiveness.

Dynamic Research Groups

The 11th cluster consists of 13 networks. The networks within this cluster are mainly initiated top-down (69.23%) by universities and research institutes (69.23%) as well as public institutions (30.77%). The formations have either a lead (46.15%) or shared (46.15%) governance form. Contrary to the common characteristics of other clusters, the actors in the networks within this cluster are mostly represented by universities and R&D institutes (92.31%), but only a few companies are involved (7.69%). Consistently, many actors are positioned at the same stage within the same value chain (53.85%). Additionally, a high degree of industry specialization (61.54%) as well as technology focus (84.62%) is observed. The commitment, however, is rather loose, as it is mostly based on arrangements (69.23%). The networks are primarily concentrated within federal states (76.92%).

Following the above-mentioned characteristics and features, we distinguish the following key characteristics for the networks in cluster #11:

- Commitment of actors via arrangements
- Initiated by universities and R&D institutes
- Actors are represented by universities and R&D institutes

We call this group of networks the Dynamic Research Groups that are characterized by university-driven, topic-specific centers to engage in multi-disciplinary research primarily in academic fields, including companies as sparring partners. The networks provide a collaboration platform for joint basic as well as applied research at the interface between science and industry. Interdisciplinary research activities are bundled for future-oriented complex topics. Institutes of universities as well as other research institutes in the region combine resources as well as know-how.

DISCUSSION

We identify 11 differential types of formal, inter-organizational innovation networks along a selection of distinctive characteristics. By ascribing each type, a unique name, we propose a comprehensive typology of formal inter-organizational innovation networks. Our proposed typology is presented in Table 4, which lists each network type with its key characteristics and a concise description. Furthermore, examples of networks are provided from our sample. The following section serves as a comparison of our defined network types with typologies and networks from previous studies. Thus, we fill existing gaps from previous research and identify possible discrepancies for further research. We might exclude networks from previous research that are not relevant in our typology, as we limit our observations to formalized innovation networks that focus on inter-organizational interaction

Table 4: Typology of formal inter-organizational innovation networks

Network name	Key characteristics	Description	Example networks
Avid Persuaders	• Engagement in lobbying activities • Managed by a lead organization • Hierarchical control structures	Focally initiated and managed, engaged in start-up support and lobbying activities.	• Nutzfahrzeuge Schwaben • AQUANET Berlin Brandenburg • BIO.NRW
Value Chain Drivers	• Positioning of actors across value chain stages • Shared governance form • Geographical concentration on federal states	Joint decision makers who foster the development of value chains, concentrated within federal states.	• AVIASPACE BREMEN • Netzwerk Logistik Mitteldeutschland • SolarInput
Collective Facilitators	• Emergent formation (bottom-up) • Heterarchical control structure • Shared governance • Lateral positioning of the actors in value chains	Emergent formations with equal participation rights to increase the scope of action beyond value chain boundaries.	• Landesnetzwerk Mechatronik BW • Energieagentur Region Göttingen • PolymerMat
Niche Specialist	• Top-down initiated by established networks • Tight technology focus • Geographical concentration on federal states	Network-initiated formations to foster specialized technologies within federal states.	• Wasserstoff- und Brennstoffzellen-Initiative Hessen • ikt.saarland • Competence Center Aerospace Kassel-Calden

Table 4 continued from previous page

Network name	Key characteristics	Description	Example networks
Lateral Thinkers	• Network administration • Lateral positioning of the actors in value chains • Strong industry and technology focus • Interaction with start-ups	Independent industry centers seeking to identify innovative solutions through interaction with start-ups.	• IT-Forum Rhein-Neckar • Virtual Reality Berlin-Brandenburg • CyberForum
Transnational Opportunity Seekers	• International scope • Initiated by companies • Strong reciprocal network identity	Jointly initiated by companies to achieve complementary synergies across national borders.	• Innovationszentrum Bahntechnik Europa • BalticNet - PlasmaTec • BioLAGO
Financially Resilient Connectors	• Committed by equity • Interaction with start-ups • Strong technology focus	Purpose-driven enablers of financially sustainable innovation partnerships.	• Kompetenz-Netzwerk Mechatronik in Ostbayern • BIOPRO Baden-Württemberg • BioRegio STERN Management
Local Trend Sponsors	• Local concentration • Common premises • Initiated by public institutions • Vertical positioning of actors within the same value chain	Concentrated, publicly initiated, local interface for companies of all sizes.	• Cluster Green City Freiburg • Cluster Medizintechnologie • Hamburg Kreativ Gesellschaft
Regional Activists	• Top-down initiated by local development organizations • Lobbying activities • Strong local concentration	Regional platforms to promote and foster selected business sectors holistically.	• Forst und Holz Allgäu-Oberschwaben • Digitale Wirtschaft Schleswig-Holstein • Cluster Gesundheitswirtschaft Berlin-Brandenburg
Associated Industry Supporters	• Initiated by associations • Lobbying activities • Industry focus within federal states	Sector-specific associations, based on company engagement to promote relevant topics, strengthen networks, and foster companies.	• media:net berlinbrandenburg • deENet Kompetenznetzwerk dezentrale Energietechnologien • BTS – Rail Saxony
Dynamic Research Groups	• Commitment via arrangements • Initiated by universities and R&D institutes • Actors represented by universities and R&D institutes	University-driven, topic-specific centers to engage in multi-disciplinary research primarily in academic fields, including companies as sparring partners.	• Bremen Research Cluster for Dynamics in Logistics • COALA Kompetenzzentrum • Niedersächsisches Forschungszentrum Fahrzeugtechnik

As we focus on the identification of different types of innovation networks, it is not surprising that most networks within the sample indicate a strong technology focus. Consistently with the definition of networks by Sydow (1992), we observe a high frequency of reciprocal network identities among our networks. As all observed networks have a diverse actor structure, the prerequisite for inter-organizational interaction is well met. Table 5 summarizes network types from previous literature for which we assume overlapping characteristics with our identified networks.

Table 5: Assignment of the identified networks to previous literature

Networks identified within this study	Networks with similar characteristics from previous literature	Reference
Avid Persuaders	Dominated Networks	(Child *et al.*, 2005)
	Lead Organization-Governed Networks	(Provan & Kenis, 2008)
	Federated Innovation Networks	(Lyytinen *et al.*, 2016)
Value Chain Drivers	Vertical Partnerships	(Dussauge & Garrette, 1999)
	Clan Innovation Networks	(Bau *et al.*, 2014)
	Vertical Integrations	(Lyytinen *et al.*, 2016)
Collective Facilitators	Cross-Industry Agreements	(Dussauge & Garrette, 1999)
	Equal Partner Networks	(Child *et al.*, 2005)
	Participant-Governed Networks	(Provan & Kenis, 2008)
	Knowledge and Learning	(Bau *et al.*, 2014)
	Anarchic Innovation Network	(Lyytinen *et al.*, 2016)
Niche Specialist	N/A	N/A

Table 5 continued from previous page

Networks identified within this study	Networks with similar characteristics from previous literature	Reference
Lateral Thinkers	Structure-based Innovation Networks	(Wissema & Euser, 1991)
Transnational Opportunity Seekers	Clan Innovation Networks	(Dussauge & Garrette, 1999)
Financially Resilient Connectors	Strategic Alliances	(Child *et al.*, 2005)
	Financial Procurement	(Bau *et al.*, 2014)
Local Trend Sponsors	Regional Innovation Systems	(Cooke *et al.*, 1997)
	Clusters	(Porter, 1998)
	Industrial Districts	(Inkpen & Tsang, 2005)
Regional Activists	Regional Innovation Systems	(Cooke *et al.*, 1997)
	Regional Networks	(Sydow, 2001)
Associated Industry Supporters	Associations as Innovation Platforms	(Mieke, 2008)
Dynamic Research Groups	Dynamic Networks	(Snow, Miles, & Coleman, 1992)
	R&D Partnership	(Hagedoorn, 2002)
	R&D Network	(Priestley & Samaddar, 2007)

Avid Persuaders

We identify the Avid Persuaders as equivalent to the Dominated Network described by Child *et al.* (2005) as well as the Lead-Organization-Governed Network defined by Provan & Kenis (2008). The network is initiated, managed, and controlled by a focal organization. Additionally, we identify significant engagement in lobbying activities and interactions with start-ups. The focal organization is suspected to have high bargaining power; however, the other organizations are not necessarily committed by contracts. Thus, they are rather loose collaboration partners based on agreements. Lyytinen *et al.* (2016) describe this organizational form as the Federated Innovation Network, which consists of a heterogeneous set of actors, integrated into a hierarchical control structure.

Value Chain Drivers

Value Chain Drivers are characterized by collaboration of actors within the same value chain, which are concentrated in a single federal state. The focus within these networks is on innovation among the value chain and does not necessarily include usual business relations between actors in the value chain. Dussauge & Garrette (1999) describe Vertical Partnerships between non-competing firms as a form of strategic alliances. However, we do not generally exclude competitors from Value Chain Drivers. A crucial aspect is mentioned as vertical partnerships might create conflicts as a result of different bargaining powers of the partners (Dussauge & Garrette, 1999). This issue is possibly targeted within the Value Chain Drivers, as we observe a high frequency of shared governance forms. As Bau, Bentivegna, & Forster (2014) identify the informal innovation network of Vertical Integration, we observe a strong consistency with the Value Chain Drivers, as both act along the value chain and are geographically limited to national borders or federal states. We assume that the Value Chain Drivers represent a formalized pendant to Vertical Integration. Additionally, Lyytinen *et al.* (2016) define the Clan Innovation Network, which shares common characteristics with the Value Chain Drivers, such as a homogeneous set of actors that are driven by common interests while no hierarchical control structure is established.

Collective Facilitators

We regard the Collective Facilitators as the most common type of formal innovation networks occurring in Germany, as they represent the largest group in our sample. The network is an emergent formation with equal participation rights that enables its actors to increase their scope of action beyond their value chain boundaries. This network type indicates similarities to the Equal-Partner Network described by Child, Faulkner, & Tallman (2005) as well as the Participant-Governed Network defined by Provan & Kenis (2008). The network is set up and controlled by multiple actors. The power is shared among different actors, which does not necessarily imply that all network members have equal power (Child *et al.*, 2005). The actors within Collective Facilitators aim to leverage their complementary capabilities. Thus, actors from different industries build lateral connections, which corresponds to Cross-Industry Agreements from Dussauge & Garrette (1999). We further observe overlapping features with the informal innovation network Knowledge and Learning described by Bau, Bentivegna, & Forster (2014). Both are characterized by a very diverse and large set of actors who aim to access external knowledge and bridge internal knowledge gaps. We further indicate overlapping characteristics with the Anarchic Innovation Network described by Lyytinen *et al.* (2016). A high level of knowledge heterogeneity and the absence of hierarchical control structures characterize this network.

Niche Specialists

The Niche Specialists represent a group of networks that are initiated by established networks in order to occupy a niche for a specialized technology. A generalist network initiates a special purpose-focused network benefiting from its existing network

structures. Company-wide initiatives and networks also initiate subordinated networks that are targeted at certain regions or technologies (BMWi, 2020).

Lateral Thinkers
The Lateral Thinkers are independent industry centers seeking to identify innovative solutions primarily through interaction with start-ups. The governance form of this network is comparable with the network administrative organization of Provan & Kenis (2008). The strong industry and technology focus represents similarities to Strategic Alliances that aim to access and establish new technologies (Child *et al.*, 2005; Dussauge & Garrette, 1999). The Lateral Thinkers inhibit characteristics of Cross-Industry Agreements described as collaboration "(…) formed by companies from totally different industries which seek to diversify their activities by leveraging their complementary capabilities" (Dussauge & Garrette, 1999, p. 55). Different from this definition, the actors within our Lateral Thinkers have their origin within the same industry. This is also reflected by Structure-Based Innovation Networks defined by Wissema & Euser (1991), in which companies from a sector interact to achieve common innovation.

Transnational Opportunity Seekers
We identify the Transnational Opportunity Seekers as networks that are jointly initiated by companies in order to achieve complementary synergies across national borders. Similar to the informal innovation network type International Scope described by Bau *et al.* (2014), Transnational Opportunity Seekers can be represented by large projects that are promoted by the European Union. This is also assumed to be a motivational factor to participate in such networks to get access to public funding.

Financially Resilient Connectors
We identify networks that consist solely of equity-committed actors. We call these networks Financially Resilient Connectors that represent a purpose-driven enabler of financially sustainable innovation partnerships. Even though these networks represent Joint Ventures of different organizations, they do not necessarily share the common characteristics of described forms of Joint Ventures in previous research (e.g. Dussauge & Garrette, 1999; Killich, 2011). We observe similarities to the informal innovation network, called Financial Procurement, described by Bau *et al.* (2014). As the networks rather consist of a small number of actors, they share a strong common objective. This is represented by the strong technology focus of the Financially Resilient Connectors. To access and achieve new innovations, the networks seek connections with other innovators and start-ups. As access to financial resources for innovation projects is limited, the network management can access the equity committed by its actors to initiate projects.

Local Trend Sponsors
The Local Trend Sponsors are highly concentrated networks that are initiated by public institutions to offer a local interface for companies of all sizes. The networks can include local hubs or innovation and technology centers that also offer common premises for their members. The innovation centers are politically supported and therefore initiated by public institutions, but also involve local universities and R&D institutes. The benefits of local concentration of companies are widely accepted and seen as a driver for the direction and pace of innovation (Porter, 1998). We find Local Trend Sponsors related to Industrial Districts, described by Inkpen & Tsang (2005). Their Industrial Districts consist of independent firms that operate in the same or related market segments and benefit from agglomeration effects. Cooke *et al.* (1997) describe such local concentrations as Regional Innovation Systems that are also regarded as inter-organizational networks for SMEs (Kofler & Marcher, 2018).

Regional Activists
We identify a group of networks that we call the Regional Activists. These networks are focused regional platforms to promote and foster selected business sectors holistically. Contrary to Regional Networks defined by Sydow (2001), the Regional Activists are described by hierarchical control structures. We assume that this results from the engagement of local development organizations during the initiation process of the networks. We see these organizations as the determining actors within the network. They can also be highly influenced by political initiatives and programs. The Regional Activists correspond to Regional Innovation Systems (Cooke *et al.*, 1997). Owing to the strong local focus, we assume a high relevance for SMEs (Kofler & Marcher, 2018).

Associated Industry Supporters
We identify Associated Industry Supporters as sector-specific networks that promote relevant topics, strengthen networks, and foster interaction between companies. They also represent the common interests of the actors within the network. Mieke (2008) has already described industry associations as a platform for innovations, especially for SMEs. They form a forum for discussion and joint processing of innovation-oriented technological areas. According to Mieke (2008), industry associations can bring together companies with complementary information channels and assessment skills that are willing to provide early information and thus contribute to a more active involvement in future technological issues. Based on the insights given by Mieke (2008), we assume that the Associated Industry Supporters benefit from the involved skill set and connections of the engaged industry associations. We suppose that the Associated Industry Supporters can play a crucial role within the innovation process of SMEs.

Dynamic Research Groups

We describe rather loose forms of research collaborations between actors from the research and university environment as Dynamic Research Groups. Previous research has already identified several different collaboration forms for R&D. Priestley & Samaddar (2007) describe R&D Networks as having a decentralized governance structure and a low intensity of competition. Dynamic Research Groups consist mainly of relations between universities and research institutes that maintain only a few relations with single, selected industry partners. Therefore, we have to make a differentiation from common R&D Partnerships that consist of inter-firm relations (Hagedoorn, 2002). The rather loose form of collaboration of Dynamic Research Groups is mainly based on agreements. Such loose formations are also described as Dynamic Networks, which inhibit the possibility of continuous network adaptations (Snow *et al.*, 1992).

Based on the number of members, our typology includes three major network types, Collective Facilitators, Avid Persuaders, and the Value Chain Drivers. Each type follows a different approach to enhance the exchange of knowledge among its actors and to enable access to external resources. We find that most of these network types are open to include SMEs, which does not necessarily mean that they are also the most suitable approaches for SMEs. Large networks with a broad focus could offer opportunities to internationalize or to enter new markets. As the business activities of SMEs are often geographically concentrated, we assume that especially networks with a regional and local focus, such as Regional Activists, Associated Industry Supporters, and Local Trend Sponsors, could enhance interaction with partners from science and industry to foster innovation. The Financially Resilient Connectors require a monetary investment that could indicate a barrier for SMEs to enter these networks. Capital provided by state initiative programs could reduce this barrier. Thus, this network could also reflect a very interesting approach to foster innovation among SMEs.

CONCLUSION, CONTRIBUTION, AND LIMITATIONS

Our study serves as guidance for researchers, practitioners, and policy makers in the jungle of innovation networks. We address the lack of a comprehensive typology of innovation networks that combines the lone-standing attributes of previous studies into a holistic network typology. To our knowledge, we offer the first comprehensive typology of formal inter-organizational innovation networks that is grounded in theory as well as empirical data. As we find a clear answer to our formulated research question on the identification of different types of innovation networks, we can give several theoretical and practical implications. We believe that the mixed method approach including a cluster analysis suits the purpose of this paper very well. However, there are various limitations resulting from our applied methods and sampling procedure.

We contribute to the literature by introducing the first comprehensive, empirically grounded network typology. Thereby, we confirm previously identified typologies and networks and reveal differences by comparing our findings with existing literature. Furthermore, we a find new network type—Niche Specialist—and refine and clarify existing types. Methodically, we contribute to the field of network research by applying a mixed method approach. We recommend this method as a very suitable approach to identify and verify network types based on their empirically identifiable characteristics. Previous studies analyze network types and their characteristics using qualitative data, yet there is no empirically grounded network model combining and integrating these lone-standing attributes from either an academic or a practitioner-oriented point of view. By applying an exploratory sequential mixed method approach, we provide a typology of innovation networks that takes into account previous theory as well as purposefully generated empirical data. Our typology of innovation networks is therefore well suited to serve as a basis for further research. It enables scholars to analyze networks and related topics like network performance or network benefits based on a precise model including clearly defined and delineated network types. So far existing typologies are not able to deliver a common basis for analysis and discussion, as they are not comprehensively depicting the empirical reality of networks.

The typology provides guidance for all actors already involved in innovation networks or striving to engage in networks in line with their innovation strategy. As every organization possesses a different set of resources, the need to access external resources is widely diverse across companies and sectors. Our typology can enable organizations to identify suitable networks regarding their individual needs, based on, e.g., geographical considerations, the ability and willingness to take individual influence or responsibility, or the aspired business support focus. Companies can choose network involvement targeting research and development and scientific partnerships, marketing, or a combination of motives. They can purposefully enter in networks that foster political contacting or that focus on business partnerships in privately administered associations. The typology can thereby be applied across industries as well as actor perspectives. The framework also serves as an orientation guide for the initiation of new networks or in formalizing existing informal innovation networks. As many networks are supported and funded by public institutions, federal administrations, or the German and European governments, this typology provides guidance for policy makers. The typology can be applied to better implement political and economic instruments to promote selected network types. We propose reducing barriers for SMEs to enter innovation networks by offering financial and organizational support.

Our study incorporates certain limitations resulting from the applied sampling procedure and methods. As all considered networks are identified from the online listing provided by “Clusterplattform Deutschland”, we are aware of possible exclusions of network types that might not meet the benchmark of the platform. The listing enables a structured sampling procedure to identify formalized networks at a comparable level of data and information quality. Still, we cannot ensure our typology to be complete. Nevertheless, we assume it is unlikely that other forms play a crucial role in undermining our results,

if they occur rarely. Furthermore, we cannot exclude the possibility that our sampled networks are more actively influenced by political interventions than networks not listed on the platform. Additionally, our data set is geographically limited to Germany. We do not include observations regarding location, founding year, and size in our analysis. Therefore, we do not control for correlations between these characteristics and the network types. Public funding programs as well as technological, economic, and environmental developments might influence the time of foundation. Furthermore, promotions of federal states could influence the location, size, and emergence of specific network types. Nevertheless, we do not regard these aspects as important in influencing our typology.

The selection of network characteristics and features as well as the coding process within the qualitative content analysis underlie critical subjective elements of interpretation. To reduce this, the coding process is partially counter-tested among the authors. Nevertheless, certain elements of subjective interpretation could remain. We excluded networks during the coding process, as insufficient data were accessible through publicly available resources at the time of the analysis. By excluding these networks, we possibly limit the outcome of the cluster analysis as well as the resulting typology. By only considering publicly available sources, we may lack information that would provide additional insights into the observed networks.

As networks play a crucial role in innovation strategies as well as economic developments, we suggest the analysis of the performance and effectiveness of different network types. The influence of specific characteristics on the performance of a network is of particular interest, as it could lead to contributions to steer the outcome of networks. Thus, it could support practitioners and policy makers during the initiation and promotion of certain network types.
By enriching the existing data set of identified formal, inter-organizational innovation networks, we expect to gain possible insights into the actor structure, the degree of involvement, geographical connections, as well as the temporal development of different network types. Additionally, private information from the networks could validate our findings and generate additional insights into the observed networks. We propose to analyze the identified networks in terms of their relevance and benefits for SMEs from both the network as well as the company perspectives. As our data set is geographically limited, we suggest enriching the data set by additional data from Germany as well as from other European countries. This could yield more insights regarding national or regional differences in network types.

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APPENDIX A: Initial network characteristics considered in the qualitative content analysis

Characteristic	Features
Origin	Top-down Bottom-up
Network positioning	Superior network Sub-network Independent
Network cooperations	1=existent 0=non-existent
Legal structure	Registered association (e.v.) GmbH GmbH & Co. KG GbR Foundation “Körperschaft des öffentlichen Rechts” Project or initiative by an organization
Legal representation (imprint)	Special purpose vehicle SPE by another organization/company Organization for local development Natural person from board Research facility or university Company Corporation under public law Chamber of commerce
Power distribution	Focal Polycentric
Control	Hierarchical Heterarchical
Governance	Lead organization Network administration Shared
Network management	Independent management University/research organization Local development organization Company representatives Chamber representatives Association representatives Public institution
Network identity	Reciprocal Redistributive
Structure	Simple Complex
Geographical extent	Local Regional State National International
Duration	Temporary No limit
Functional purpose	Procurement Production Marketing Customer R&D
Direction	Horizontal Vertical Lateral
Membership	Open Closed Partly open
Requirements for membership	Industry specific Branch location No requirements
Bond intensity	Low Medium High

Table continued from previous page.

Characteristic	**Features**
Commitment	Arrangement Contract Equity
Initiators of the network	University/research institute Association Company Chamber Cluster/network Local development organization Public institution
Actors in network	Companies Universities/R&D institutes Other
Supporting the search for skilled workers	1=existent 0=non-existent
Industry specific	1=existent 0=non-existent
Start-up support	1=existent 0=non-existent
Common premises	1=existent 0=non-existent
Lobbying	1=existent 0=non-existent
Technology focus	1=existent 0=non-existent