



From interregional knowledge networks to systems

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ABSTRACT

Whereas interregional networks of individual actors have recently received growing attention, networks in terms of collective regional groups of organisations interacting with their counterparts remain largely ignored. This is surprising given the Smart Specialisation agenda's 'outward looking' approach. This conceptual paper explores the rationales and dimensions underpinning interregional knowledge exchange, networks and systems including a definitional clarity, a typology of networks and the impacts of different types of proximity. The paper also introduces the concept of the interregional knowledge exchange system and sets a new agenda for studying their structure, formation and evolutionary path.

1. Introduction

The recent dramatic increase in knowledge exchange has brought the concepts of networks, interaction, spillovers and diffusion to the forefront of academic and political debates in general and the focus on the role of spatial and network in innovation and productivity performance in particular (Cortinovis and van Oort, 2019). The Regional Innovation System (RIS) concept, contextualising the place-based characteristics of innovation (Cooke et al., 1997), has proved popular with policy-makers in relation to the overarching EU agenda of Smart Specialization (S3) (Foray and Goenaga, 2013). However, interactive learning and inter-organisational relations are considered to be the building blocks of the RIS. They are rarely explored in terms of regional knowledge networks because such relational structures remain rather fuzzy and generic when using the term 'network'. Therefore, given the under-studied regional network dimension of the RIS, this study probes into the relationship between 'networks' and 'systems' (Stuck et al., 2016).

Research on networks has focused largely on descriptive aspects, drawing mostly on the relational and evolutionary perspectives. This includes inferences for individual actors or dyadic network ties with little work on discerning the underlying logics of connectivity for the

network as a whole, such as social and spatial divisions of labour in markets and the effects of network composition on the evolution, social meaning and performance of networks from a relational perspective (Glückler and Doreian, 2016; Glückler et al., 2017).

Interregional linkages are considered to give regions access to external knowledge that can tackle or avoid the tendency of regions to get locked-in and remain specialised (Balland and Boschma, 2020). A wealth of empirical evidence now exists confirming the positive association between interregional knowledge flows and spillovers, observed levels of innovation and growth (Basile et al., 2011; Frenken et al., 2009) and the influence of various proximity dimensions in facilitating them (Makkonen et al., 2018a). Moreover, related to these linkages are an emerging set of urban hierarchies, i.e. places, regions, which are better connected – and better performing – than others (Hoekman et al., 2009). Thus, while we can conceive of three broad fields within which such connections operate – trade, investment, and knowledge (Frenken et al., 2009) our focus here is on the latter aspect.

Thissen et al. (2013) show that knowledge externalities are not just 'in the air' but may also be channelled via networks of economic relations – labour mobility, supply chains and so on. These are not purely reliant internal upon urbanisation economies but can reach beyond the regional scale (Ponds et al., 2009); in this way small and/or peripheral

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regions may 'borrow size' from larger regions (Alonso, 1973). However, conceptual elaborations of this remain underdeveloped (Burger et al., 2014). This paper seeks to contribute here.

So far, the literature on interregional knowledge flows, spillovers and networks has mainly focused on the embeddedness and positioning of regions with networks of individual organisations rather than on the entire region as a group of organisations involved in interregional collaboration with similar groups in other regions. Moreover, little is known about policy mechanisms, networks and systems, which are aimed at enhancing knowledge exchange and joint innovation among regions (McCann and Ortega-Argilés, 2015). Thus, previously the focus has been on networks of *individual* organisations from different regions and intraregional networks, whereas this paper focuses on knowledge exchange in networks of regional *groups of organisations* from different regions, defined as Knowledge Networks of Regions (KNoRs).

However, whilst a key tenet of S3 policy is the facilitation of 'outward-looking' regions, this has proved less successful than might have been envisaged in terms of actual collaboration stimulated (Morgan and Marques, 2019). Given the predominance of what (Hoekman et al., 2009) term 'elite structures' between capital and/or excelling regions, this remains a key challenge for S3 policies in more peripheral regions. This paper suggests that regions as territorial groups of a wide range of stakeholders attempt to create knowledge exchange mechanisms including interregional networks and systems to overcome this predominance. Indeed, by extension, the very idea of S3 means that these processes require further conceptualisation. This paper will address this gap by exploring the multiple rationales and dimensions underpinning interregional collaboration, and the role of varying types of proximities and similarities for knowledge exchange in KNoRs. It also questions whether KNoRs emerge and develop into Inter-Regional Knowledge Exchange Systems (IRKESs). In doing so this paper will propose a novel innovation system concept, namely the IRKES, to theoretically discuss and empirically explore (with case study examples) whether KNoRs could further develop into systems.

2. Interregional knowledge exchange, innovation and networks

2.1. Interregional knowledge networks and regional innovation systems

For the purposes of this paper, the first key concept, *knowledge networks*, are conceptualised as 'pipelines' for individual and groups of actors (Bathelt et al., 2004) for exchanging geographically dispersed information and knowledge (Owen-Smith and Powell, 2004), which may lead to innovation outcomes in due course. They derive from informal ties between individuals, or they can be formally defined as contracts or strategic alliances (Owen-Smith and Powell, 2004; Sun, 2016; Wanzenböck et al., 2014). The network perspective emphasises the role of relations and structures in determining the behaviour of actors (Stuck et al., 2016). Knowledge networks include weak and strong ties, cut across departmental and organisational boundaries and range from local to global with cognitive and social similarities being important factors influencing their formation, rather than mere geographical proximity. Therefore, there is a need to take a relational perspective considering both local and global networks and acknowledge that the more regions host such networks, the more they become a hub of intra- and interregional flows of knowledge (Benneworth et al., 2014). This perspective bridges between economic, social, and geographic issues by including both social and more formal understanding of relational processes, which has been largely neglected (Glückler et al., 2017).

Interregional networks have received growing attention in the EU (Balland and Boschma, 2020; Bergé et al., 2017; Cortinovis and van Oort, 2019; Hazir et al., 2018; Mitze and Strotebeck, 2018; Sebestyén and Varga, 2013; Wanzenböck and Piribauer, 2018; Wanzenböck et al., 2014) and China (Sun, 2016; Sun and Cao, 2015; Sun and Liu, 2016; Zhang et al., 2016) as well as in global inter-city and inter-country networks (Guan et al., 2015), because they contribute to technological

diffusion and enrich both individual firms' and organisations' internal knowledge creation processes and the innovation capacity and productivity of entire regions (Wanzenböck et al., 2014). This applies particularly for firms in less technologically advanced regions learning from Research and Development (R&D) investments in more advanced regions (Cortinovis and van Oort, 2019) implying a positive relationship with the probability of regions to diversify and enhance regional capabilities (Balland and Boschma, 2020). Interregional networks connect knowledge resources and possibly compensate for weak or missing knowledge production capabilities between regions, which is particularly helpful in increasing less advanced regions' ability to generate knowledge. Interregional linkages give access to complementary and additional capabilities as long as they are related to existing ones. Such linkages enhance regions' ability to diversify, particularly that of peripheral ones (Wanzenböck and Piribauer, 2018). KNoRs' role is assumed to be a mechanism which facilitates knowledge exchange among its members, between them and other KNoRs (e.g. policy learning, training, running seminars) as well as connecting them to external partners in other KNoRs or non-member regions. This may include codified and tacit knowledge or any of the knowledge bases including symbolic, aesthetics, synthetic and analytic.

This perceived importance of interregional knowledge networks has been adopted into the policy level. Specifically, the S3 agenda, underpinning EU Cohesion Policy reforms and diffused into other OECD countries, calls for regional branching and diversification not only at the intraregional but also at the interregional levels through its "outward looking approach" (McCann and Ortega-Argilés, 2014; Miörner et al., 2018). The outward looking approach of Smart Specialisation Strategy (S3) is oriented towards global value chains and emphasises that cross-regional projects and networks are means to achieve greater related variety (European Commission, 2012). In particular, S3 requires identifying potential links between privileged domains (Balland and Boschma, 2020). It challenges traditional models, which conceptualise development and innovation as endogenous phenomena, and may result in new knowledge combinations, competencies and complementarities between endogenous and exogenous potentials through the in-flow of non-local knowledge in different forms, such as patents and new machinery, knowledge intensive services, partnerships, human mobilities (Saxenian, 2006) as well as flows of R&D and Foreign Direct Investment (FDI) (Miörner et al., 2018).

The second key concept of this paper, the RIS (Cooke, 1992), exists if the following criteria are met: coherence, unified function, and boundedness (Edquist, 2004a). Coherence implies the presence of feedback loops, common developmental trajectories and complementary competencies between agents (Roper et al., 2006). This, in turn, suggests that i) the collective properties of the system differ from those of individual constituents, and ii) an evolutionary capacity. A unified function involves identifiable aims to which all elements of the system contribute, while boundedness requires a sensible delineation between the system itself and the 'rest of the world'. Nevertheless, these criteria, individually and in combination, do not necessarily imply the existence of a RIS dichotomously. Thus, assessing whether these are present will not generate a simplistic yes/no answer. Instead, the use of these three criteria suggests a continuum ranging from no systematic properties on the one hand to fully a functioning system on the other.

Systems therefore constitute an array of organisations and their relationships (Roper et al., 2006), i.e. both the components and the set of relations between them (Edquist, 2004a). As such, 'the institutional set-up i.e. a set of routines, rules, norms, and laws,' is a necessary dimensions in Innovation Systems (ISs) (Lundvall, 1992). The institutional approach (North, 1990) implies that formal and informal institutions are equally important in the development and function of an IS. Institutions in ISs can be classified as formal such as bridging organisations and their regulatory regime, universities etc., which define the 'rules of the game' for all agents in an explicit top-down manner, and informal institutions that emerge bottom-up from the interactions between actors, such as

social and corporate ‘praxis’, ways of doing things, norms etc. (Borrás, 2004). Informal institutions thus complement formal institutions by fine-tuning agents’ behaviour and expectations – to perform a kind of matching function of conventions and norms established between groups of individual agents, but which cannot ultimately depart from the rules set by the formal institutions (Coriat and Weinstein, 2002).

To determine the relationships between *networks and systems*, the question as to whether regional knowledge networks include individuals as members and/or organisations is pivotal. Networks of individuals can be conceived as a necessary but insufficient aspect of a fully functioning system; in other words, networks of organisations generate informal institutions, which thereafter become inextricable to the operation of the future formal institutions. As such, Edquist (2004) perceives networking of individuals as key within an IS, and although networks tend to evolve over time, they cannot spontaneously transition into systems without some type of formal institutions. However, if regional knowledge networks include organisations or strategic alliances (e.g. networks of universities, commercial associations), they can function as formal institutions.

2.2. Rationale for interregional knowledge exchange and innovation

Knowledge transfer is a purposeful transmission of knowledge, whereas knowledge spillovers are an undeliberate diffusion of knowledge (Smeets, 2008). Interregional knowledge spillovers emerge when regions’ R&D efforts also contribute to the knowledge creation processes of other regions (Greunz, 2005). Purposeful knowledge transfer mechanisms include intra- and inter-firm collaboration between different plants and subsidiaries of large companies that link actors across regions (von Proff and Brenner, 2014). Knowledge exchange takes place through different channels including co-patenting, co-publications, formal and informal networking, trade, labour mobility and interaction of employees in social, civic and professional organisations. This discussion also relates to the concept of Global Production Networks (GPN), i.e. a set of internationally connected actors (households, firms, governments, etc.) centred around the production, distribution and consumption of a specific product or commodity (Fuenfschilling and Binz, 2018). The GPN literature underlines the importance of successful knowledge diffusion between multinational corporations and their local suppliers as it facilitates firms and industrial districts, particularly in developing countries, to reap benefits from these international linkages (Ernst, 2002). However, in this paper the focus is laid on the potential emergence of knowledge networks between regional groups of organisations, rather than on the knowledge diffusion processes within geographically dispersed technological or industrial production systems commonly led by “flagship” multinational corporations (cf. Binz and Truffer, 2017; Binz et al., 2014; Ernst and Kim, 2002).

The existing literature on the spatial network analysis of knowledge exchange and spillovers mainly pertains to cooperation between specific actors (such as firms and universities) located in the regions under study. This literature underlines the importance of accessing geographically distant knowledge (Huggins and Thompson, 2017) but at the same time acknowledges that knowledge transfer is subject to distance decay and that national borders still constitute “barriers” to it (see e.g. (Audretsch and Feldman, 2004; Basile et al., 2011; Naveed and Ahmad, 2016). Distance in other relational aspects (discussed in greater detail in Section 3) such as dissimilarity in terms of technological specialisation can further hinder interregional knowledge flows (Basile et al., 2012). Due to geographical distance and unlike intraregional collaboration, interregional “pipelines” are less spontaneous, require more effort and tend to focus on a few selected issues or sectors, such as S3 policies advocating regions to seek partners with similar industrial backgrounds and prioritised themes (Bathelt and Glückler, 2011; Iacobucci and Guzzini, 2016). Earlier studies on interregional knowledge networks within the EU have described them as “oligarchic”, i.e. commonly led by few

(institutions in) highly developed regions (Breschi and Cusmano, 2002). Still, there is a positive relationship between having interregional partners and the regional effectiveness in knowledge generation (Sebestyén and Varga, 2013) and, thus, it would be important for less technologically advanced regions to tap into these networks.

Nevertheless, interregional knowledge exchange with a variety of partners also carries risks of low levels of trust and high communication costs, which are a barrier for knowledge exchange (von Proff and Brenner, 2014). Therefore it is surprising that in spite of the well-acknowledged inappropriateness of the “one-size-fits-all” policy and the need to consider different conditions of differentiated and region-specific innovation policy targets (Tödtling and Trippel, 2005), interregional cooperation, including knowledge exchange between neighbouring and distant regions in S3 remains largely ignored. The EU’s new cohesion policy has encouraged increasing interregional collaboration in Research and Innovation (R&I) by focusing on low-intensity activities, e.g. information sharing. Moreover, these linkages bring more direct and immediate benefits for the planning stages of the S3 process, analysis, design and decision-making rather than for implementation. Nonetheless the emphasis laid on interregional collaboration has been perceived as beneficial for supporting S3 activities in the EU (Sörvik et al., 2016). In other countries like China, intraregional collaboration remains more common but recent policies encouraging interregional collaboration, particularly in research, have also been advocated and require further systematic and empirical studies on this topic (Sun and Cao, 2015). Understanding the obstacles and enablers of interregional knowledge exchange is highly relevant for utilising the potential for learning and innovation via interregional cooperation in S3 (Uyarra et al., 2014).

Therefore, several rationales underlie interregional collaboration in knowledge exchange and innovation, including overcoming barriers such as fragmentation, insufficient critical mass in public investments for R&I and in achieving economies of scale and scope and accessing complementary assets (e.g. human capital and knowledge infrastructure) (European Commission, 2012). They also underpin sharing resources, specialist skills, services and costs particularly in peripheral regions (OECD, 2013) while avoiding spatial lock-in effects or myopia (generated by the propensity to collaborate intra-regionally) by allowing access to complementary and diversified sources of knowledge and regional branching and related diversification across regions (Boschma and Gianelle, 2014; Uyarra et al., 2014). Nonetheless, success depends on interregional relatedness, which, in turn, depends on historical trajectories (Boschma, 2017).

2.3. Different types of interregional knowledge networks of regions

KNoRs include several types, which have to be identified in order to understand their importance and contribution to regions’ knowledge and innovation. A typology of KNoRs is needed not only to understand their importance and impact in line with acknowledging that no one size fits all (Tödtling and Trippel, 2005) but also to underlie the more general IRKES concept. Elaborating Uyarra et al.’s (2014) typology, there are four types of KNoRs depending on interregional distance and their national (2, 4) or international nature (1, 3) as networks can include members from the same country or from different countries (Table 1).

The territorial dimension of KNoRs is questionable; to what extent are they based on sharing territorial aspects particularly in networks of distant regions which do not share any physical borders? These networks may be described as sectoral rather than regional and are likely to have the potential for innovation in only some industries, because they share little or no underlying territorial attributes to their knowledge exchange. The question, however, remains whether KNoRs could “evolve” into more systemic forms of economy-wide collaboration.

Table 1
Typology of Knowledge Networks of Regions (KNoRs).

	International	National
Neighbouring regions	<p>1. Cross-border regional knowledge networks: Linkages between neighbouring regions with adjacent borders from at least two countries or involve a large continuous set of regions from several different countries (i.e. transnational macro regions) covering a wide territorial area.</p> <ul style="list-style-type: none"> • e.g. the Danish-Swedish Medicon Valley bi-national life science cluster and the Danube transnational macro region. 	<p>2. National knowledge networks of neighbouring regions: Coalitions of close-by regions collaborating with each other within the context of a single country,</p> <ul style="list-style-type: none"> • e.g. Northern Ireland Local Governments Association.
Distant regions	<p>3. International knowledge networks: A (small) number of non-contiguous territories, that share certain common characteristics, from different countries</p> <ul style="list-style-type: none"> • e.g. ERRIN (European Regions Research and Innovation Network). 	<p>4. National knowledge networks of distant regions: Promoting knowledge exchange among regions and/or cities within national boundaries that share some common characteristics</p> <ul style="list-style-type: none"> • e.g. the 6AIKA network of the six largest Finnish cities.

3. The role of proximities and similarities in interregional knowledge exchange

Knowledge exchange between regions from different countries remains uncommon even between neighbouring regions that share broadly similar economic and technological backgrounds (Greunz, 2003, 2005; Moreno et al., 2005; Sörvik et al., 2016; Van Gorp, 2009). As such, interregional R&I collaboration is dominated by linkages within national boundaries rather than international collaborations (Kroll, 2015), which is more common between regions of excellence measured by publishing and patenting activities (Hoekman et al., 2009). This is explained by specific socio-institutional conditions, including similarities at the entrepreneurial and sectoral levels as well as spatial and relational proximity, which depend on regional similarities and differences. These different proximities have an understudied impact on interregional knowledge transfer/flows (Balland and Boschma, 2020).

3.1. Geographical

Geographical proximity enables serendipity, joint learning and knowledge spillovers through face-to-face communication and the sharing of tacit knowledge (Uyarra et al., 2014). Convincing arguments for such interactions of this nature are increasingly accepted (McCann, 2008). Therefore, it determines the intensity of interregional spillovers as interregional distance is negatively related to maintaining knowledge exchange linkages and establishing new ones (von Proff and Brenner, 2014). It is therefore assumed that geographical proximity engenders the development of interregional learning networks in neighbouring regions (types 1, 2). However, leading regions from different countries tend to exchange knowledge with their peers rather than with lagging regions. As such, interregional knowledge exchange and spillovers are engendered by conditions of connectivity, and that from different countries is also influenced by permeability between border regions.

Interregional connectivity refers to the mobility of entrepreneurs, managers and labour which can diffuse internationalised knowledge and has a potential to create ‘innovative milieus’ particularly between connected neighbouring border regions (Williams and Shaw, 2011) and potentially when distant regions are well connected by air. Border permeability is crucial for interregional learning, since it “dictates” the levels of international interactions and mobility. Border permeability

can vary from being open to limited or entirely impermeable with almost no border crossings. Economic and social activities encourage interactions and movement between countries (Martinez, 1994) and therefore enhance knowledge transfer and innovation (Marrocu and Paci, 2011). However, while geographical proximity is essential for transferring tacit knowledge (Wijngaarden et al., 2020), codified knowledge can be transferred even over large distances without regular face-to-face contact (Bathelt and Turi, 2011). Therefore, the role of geographical proximity should not be assessed in isolation to the other dimensions of proximity (Boschma, 2005). Essentially geographical proximity is neither a necessary nor sufficient condition for learning to occur; rather the key role of geographical proximity can be thought of as enhancing the effect of other forms of proximity, discussed further below.

3.2. Relational

Interregional knowledge transfer depends on “relational proximity”, which is the capacity of economic agents in a regional context to cooperate (Basile et al., 2011) and measured in terms of the interregional differences or similarities in shared behavioural codes, common culture, mutual trust, sense of belonging and cooperation capabilities (Balland and Boschma, 2020; Bottazzi and Peri, 2003). As such, relational proximity is an umbrella term encompassing institutional, organisational, cognitive, cultural and technological proximity dimensions.

3.2.1. Institutional

Interregional collaboration is influenced by the degree of decentralisation and regional autonomy present in the national context. By definition this varies more between countries than regionally. The institutional setting covers both the formal and informal, which shape the relations between actors and organizations (Lundquist and Trippl, 2013). As such, when regions belong to different national settings (Lundquist and Winther, 2006), they often have interregional institutional gaps between them. Differences in the formal jurisdiction of regions hinder the possibilities of collaboration; if a region has weak juridical and regulatory power, its regional organisations have to rely on state innovation policy which might not always align with the interests of regional organisations participating in KNoRs (Broek and Smulders, 2014). Unlike regions from the same country (type 2 and 4), which tend to have high institutional proximity, distant regions from different countries (type 3) are likely to have relatively low *institutional proximity*.

Where asymmetric devolution (Cooke and Clifton, 2005), i.e. an arrangement within which the constituencies (territories, regions, provinces) do not possess equal powers (e.g. Spain, Italy, the UK), interests may be articulated at different political levels by regional actors within national boundaries, with the associated risk of opportunistic ‘venue shopping’ (Baumgartner and Jones, 1991) as actors in different policy fields seek influence at different levels. Thus, there may not be a consistent territorial policy community in existence for any given region (Keating et al., 2009), leading to low interregional institutional proximity even within national boundaries. As for neighbouring regions from different countries, they are more likely (but not necessarily) to be institutionally closer than distant regions from different countries. For example, in many European cross-border neighbouring regions with similar institutional and legal systems, there are some innovation and business development mandates such as in Tornio-Haparanda on the Swedish-Finnish border (Nauwelaers et al., 2013).

So far little attention has been given to the above institutional dimensions with the exception of Mörner et al.’s (2018) study of the role of actors in changing the institutional conditions for cross-border knowledge exchange taken from a multi-scalar perspective. This includes the intertwined nature of relationships between formal and informal institutions with these perceived as important facilitators of cross-border knowledge flows. However, forming new or adapting or dismantling existing institutions remain rare compared to adapting to the existing

institutional framework via "... information campaigns, overcoming formal institutions by relying on informal ones, and lobbying that lead to alternative interpretations of laws and regulations (Mjörner et al., 2018, p. 215). Indeed, regions or 'non-state nations' with stronger policy communities will typically have a greater external lobbying presence, e. g. at the European level (Clifton and Usai, 2019).

3.2.2. Organizational

Organizational proximity refers to the degree of control that is exerted between actors via mutual organisational arrangements (Boschma, 2005). Thus, rather than a binary choice, a continuum of organisational proximity ranges from internal hierarchy at one extreme to one-off market transactions at the other. Between these, a set of intermediate relationships can be explained by an increasingly complex environment in which the gains from access to specific forms of knowledge that exist outside the internal hierarchy may begin to exceed the transactions costs involved in accessing it, particularly if appropriate investments are made in relational proximity (Clifton, 2001). Relations of this nature have been characterised by (Helper, 1991) as 'voice-based' as opposed to 'exit-based'. Moreover, there is evidence that organisations have been making use of network-based relationships to access the specific knowledge of external suppliers for some time (Clifton, 2001), while (Huggins et al., 2010) demonstrate the value of external knowledge sourcing practices which make extensive use of networks and intermediaries. Thus, KNoRs will involve intermediate levels of organisational proximity.

Differentiation between the four types of networks specified on the basis of organisational proximity is quite nuanced given the degree of interdependence between organisational proximity and the other (non-geographical) types. For example, universities may be involved in multinational research consortia (types 1 and 3) or have bilateral strategic alliances or memorandums of understanding. On the contrary, geographically proximate universities could be in looser groupings (type 2), while within some regions they might actually be in competition with each other. Conversely, networks within national boundaries (types 2, 4) are more likely to involve higher levels of organisational proximity with respect to bodies which are quasi-governmental in nature, i.e. regulated by closely aligned governance arrangements. One caveat refers to regions with high levels of devolution from their host nation state having more scope for developing organisational proximity internationally (types 1, 3).

Proximity between entrepreneurial cultures and practices can also explain interregional differences (or similarities). Since entrepreneurs are important facilitators and/or intermediators of knowledge networks, the role of entrepreneurial culture in KNoRs determine the intensity of knowledge exchange and local companies' decisions on implementing innovation strategies (Tripl, 2010). The combination of interregional similarities in socio-economic attributes (e.g. job or market opportunities) and institutional settings, which include both informal (e.g. attitudes concerning self-employment) and formal (e.g. regulations to employment protection, tax policies) factors (Bosma and Schutjens, 2009). Regional similarities in entrepreneurial culture refer to the organisational culture as well as to individual members of staff, who are engaged in innovative processes as innovators and/or entrepreneurs. Interregional differences between entrepreneurial ownership, size, structure, culture (both of the population and of institutions within the region), professionalism and local demand (e.g. disposable income) (Smallbone et al., 2007) affect regional innovativeness and interregional knowledge transfer processes positively (Sundbo et al., 2007).

3.2.3. Cognitive, cultural and technological

Cognitive proximity is a precondition for mutual understanding and communication (Huber, 2012) and includes resources that provide shared representations, interpretations and understanding according to mental categories that people developed in interaction with their physical and social environments (Thomas, 2008). Factors such as attitudes

towards new ideas, mentality, language and awareness to foreign technology constitute the cornerstone of cognitive proximity, which determines the intensity and successfulness of interregional knowledge transfer (Weidenfeld et al., 2016). However, too much proximity or distance might reduce learning and knowledge transfer when actors are too similar or too different (Boschma and Frenken, 2010). The same is germane for sectoral knowledge transfer, which is engendered by 'related variety' between sub-sectors in different regions. Related variety is defined based on shared and complementary knowledge bases and competences (Asheim et al., 2011b). The concept has been in common use when examining knowledge spillovers between different economic sectors and sources of regional knowledge (Frenken et al., 2007; Hassink and Klaerdi, 2011). Thus, balanced product similarities, complementarities and sectoral-related variety engender interregional knowledge transfer (OECD, 2013; Tripl, 2010).

Cognitive as well as *cultural proximity* is deeply embedded in national stereotyping and can hinder or enhance interregional knowledge exchange particularly in international KNoRs (types 1,3) (Weidenfeld et al., 2016) but also in within national boundaries KNoRs (types 2, 4) with considerable cultural differences such as those between peripheral and core regions. Cultural proximity or similarity is determined by shared ideologies, values and similarities in the ways of thinking, behaving and solving problems as well as other elements of cognitive and cultural proximities, which may stimulate or impede the motivations to exchange knowledge and engage in interregional innovation processes (Weidenfeld et al., 2016). So far there is little evidence that cultural proximity engenders interregional knowledge transfer (Kaasa and Vadi, 2010). Moreover, differences in values and lack of political will to cooperate hinder initiatives to set up and the interests of regional organisations to participate in KNoRs and consequently interregional knowledge flows, while language issues (still) constitute barriers for practical cross-border and interregional cooperation (Makkonen et al., 2018b).

Technological proximity refers to the understanding of shared technological knowledge amongst actors (Menzel, 2005) and to a similar knowledge base, which engender the absorption and mastering of technological know-how (Guan and Yan, 2016). At the interregional context, it is defined as "...proximity of regions whose technological profiles are similar to its own" (Greunz, 2003, 657). Knowledge spillovers are common among neighbouring regions with similar technological profiles and tend to diffuse from specialised leading regions to others (Greunz, 2003). By contrast, market similarity is negatively related to such spillovers, for generating a lack of trust and competition for the same markets (von Proff and Brenner, 2014). Given that regions within national boundaries often use similar technologies, technological proximity might be a barrier for interregional learning networks types 1 and 3 and encourage those of types 2 and 4. Conversely, market similarity, which tends to exist among regions in networks within national boundaries, is negatively related to such interregional spillovers because of increased competition for the same markets and a lack of trust (von Proff and Brenner, 2014).

The interrelationships between different proximities, whether complementary or substitutional, shape different types of KNoRs considering the particularities of each type. So far, the impact of these have been studied to some degree in cross border regions. Cross-border regions provide a fertile ground for intercultural and international knowledge exchange because of interactions between different perspectives, mentalities, perceptions of ideas and ways of thinking. However, it requires cross-cultural understanding and sufficient geographical proximity, accessibility and cognitive proximity between regions to generate knowledge (Weidenfeld et al., 2016). Still, there is little empirical evidence on interregional knowledge networks and other mechanisms whereby neighbouring cross-border regions exchange knowledge. Interregional geographical proximity between regions is considered a decisive factor in explaining the degree of (intentional or unintentional) knowledge exchange, where national borders are commonly perceived as a barrier for such processes (van den Broek et al., 2018). However,

studies have shown that (to a degree) the importance of geographical distance and country border effects have been decreasing at least within the EU (Scherngell and Lata, 2013).

4. Interregional Knowledge Exchange Systems

Based on our understanding of interregional knowledge exchange and KNoRs, this paper suggests a new concept – and a strategic tool for implementing S3 – namely the InterRegional Knowledge Exchange System (IRKES). An IRKES is an institutional mechanism for defining the relationships among regions, formal and informal institutions and other organisations, which underlie interregional knowledge exchange and facilitate joint innovation processes. Unlike other entities such as networks, it provides a long-term, coherent and functional mechanism with a clear spatial boundedness and shared aims for its members. Thus, analogous to other ISs, IRKESs possess the non-binding criteria of *coherence*, *unified function* and *boundedness*, which can determine whether an interregional mechanism of innovation and knowledge exchange can be described as a system or having systemic orientation (Edquist, 2004). Each of these criteria articulated by (Edquist, 2004) (and developed by other authors) specifically in relation to RISs, and the underlying assumptions regarding the impact of different types of proximity on the three criteria defining are discussed below and in Table 2 with particular reference to IRKESs.

4.1. Coherence

This criterion refers to the extent to which a system's elements are consistently articulated and form a meaningful constellation implying on its functionality. This constellation of belief and values behind attitudes and social interaction in a given society determine and characterise the way it conducts innovation processes (Borrás, 2004). It is also characterised by regions with 'inward orientation' including complementary skills, knowledge base and competence among their actors (Edquist, 2001). It implies the presence of feedback loops, common developmental trajectories and complementary competencies between agents (Roper et al., 2006). This, in turn, suggests that i) the collective properties of the system differ from those of individual constituents, and ii) an evolutionary capacity. Low coherence systems are characterized by loosely connected or isolated elements that are unlikely to produce meaningful collective output (Rakas and Hain, 2019). In line with Boschma (2005) *Coherence* is characterised by institutional, cultural and cognitive proximity, that are not too high or too low. It is often associated with optimal enabling conditions for knowledge transfer and innovation Boschma (2005), that engender feedback loops and common developmental trajectories, building competitive advantage and evolutionary capacity, which are higher than for each individual region within the IRKES. The impact of the above proximity dimensions is assumed to differ between IRKESs depending on various under-studied factors such as interregional cultural diversity, levels of devolution and whether the IRKESs are national or international. Spatial proximity's role is questionable; on the one hand, it is considered to be a potential enabler of knowledge exchange, cognitive and cultural proximity (Mattes, 2012). On the other hand, complementarities can emerge between actors regardless of their locations. Therefore, spatial proximity's role is assumed to be of low to

medium level in its importance, but high in IRKESs of neighbouring regions, and will depend on the scale, size and distance between regions in the network (Table 2). For example, it can be assumed that it will have a higher impact on a national IRKES of a few neighbouring regions in a small country like Austria compared to that of many regions scattered in a large country such as Poland.

The role of proximity in explaining the respective roles of formal and informal institutions, and the interplay between them in forming the three non-binding criteria that determine the potential for different KNoRs to develop into IRKESs also requires further conceptual and empirical work. Spatial proximity may engender directly and indirectly the evolution of informal institutions into formal ones by giving rise to other forms of proximity (cognitive, cultural and institutional) through face-to-face meetings between actors. This will have a direct shared impact on beliefs and values behind attitudes, and on social interaction enabled particularly by cultural and cognitive proximity and therefore on the way regions conduct innovation processes. This is consistent with Miorner et al's (2018) argument that informal institutions are more malleable than their formal counterparts, with these informal institutions of an IS generating the implicit 'rules of the game' for knowledge production and diffusion (Borrás 2004; 428). Thus, neighbouring regions and/or well-connected regions are likely to develop the evolutionary capacity of their informal and formal institutions mediated by spatial proximity, cultural and institutional proximity. This, in turn, will also strengthen coherence by developing complementary skills, competences and knowledge bases among their actors.

4.2. A unified function

This criterion draws on the underlying concept of a functional region, whose mechanisms are important in the systemic approach (Andersson and Karlsson, 2004) and involves identifiable aims to which all elements of the system contribute (Rakas and Hain, 2019). In ISs a function includes identified themes, specific priorities (as in S3) and/or innovative activities of a specific sector and/or addressing common challenges or threats, which require innovative solutions. These activities include creating new knowledge, competence building, training and others and may also maintain and enhance the abovementioned qualities associated with coherence (Edquist 2004, 2006). This criterion can exist in different levels of proximity, as dissimilar actors can be motivated or agree to address different objectives, priorities, regardless of their proximities. Regarding types of proximity, it is assumed that only institutional proximity (in relation to formal institutions which provide the incentives and determine policies) where high levels are required. Institutional proximity may have a higher impact on IRKESs in a centralised country like Poland compared to less centralised ones such as Germany. Proximate regions also tend to have shared interests and development goals and externalities translated into functions, through interregional interactions e.g. labour movements between border regions, encouraging them to collaborate. Thus, spatial proximity is likely to be positively related to a unified function. Institutional proximity is likely to facilitate the evolution of informal institutions into formal ones particularly through binding regulations and rules, which are able to incentivise adopting and addressing shared aims. This is of course likely to happen when the formal institutions do not emerge arbitrarily but are selected carefully to support and complement the existing informal ones. Thus, unified function can be potentially enhanced by spatial and institutional proximity, which in turn, support systemic orientation of an IRKES.

4.3. Boundedness

Regardless of their regional dimension ISs can be narrowly approached by specifying sectors that generate and distribute innovations and are supported by specific institutions. In this context, an IS would have clear sectoral boundaries though other boundaries, including technological and cognitive, are often considered to be meaningful (see Asheim et al, 2011a).

Table 2

The proximity dimensions required for Interregional Knowledge Exchange Systems.

Proximity dimension	Innovation System Criteria		
	Coherence	Unified function	Boundedness
Spatial	Low to High	Low to High	High
Institutional	Medium	High	Low to High
Cultural	Medium	Low to High	Low to High
Cognitive	Medium	Low to High	Low to High

With the broader and more popular approach in the literature, the system includes all ordinary economic activities, such as procurement, production and marketing that generate innovations (Andersson and Karlsson, 2004). Regions can be a spatial entity characterised by homogenous specific criteria and can be distinguished from bordering areas by a particular kind of association or related features while possessing some type of internal cohesion and cultural embeddedness (Doloreux and Parto, 2005). Boundedness requires a sensible delineation between the system itself and the 'rest of the world' (Edquist, 2006). The boundary between the system and its environment can be specified in many ways, largely depending on what is the purpose of the systems analysis (Edquist 2004a). Thus, several ways are considered to be appropriate. First, RISs can be specified according to administrative boundaries and consider areas for which the

degree of coherence is high in relation to innovation processes measured in terms of localised learning spillovers among actors associated with the exchange of tacit knowledge. Secondly, boundedness may be determined by functionality of the region i.e. frequency or intensity of economic interactions (Andersson and Karlsson, 2004). This may include interactions such as localised mobility of skilled workers as knowledge carriers and a minimum proportion of innovation related collaborations among actors taking place with partners within certain regional boundaries (Edquist, 2006). In both, a sufficient scope for interaction and coherence as well as a unified function to enhance collective external economies within a certain set of boundaries can determine the area of an IS (Asheim et al., 2011a).

Thus, boundedness adds the spatial dimension to determining the systemic orientation of networks by delineating an IRKES's geographic

Table 3
Systemic qualities of different types of Interregional Knowledge Exchange Networks.

Type	KNoR	Coherence	Unified Function	Boundedness	Systemic qualities
1. International knowledge network of neighbouring regions	Danish-Swedish Medicon Valley bi-national life science cluster http://mva.org/about-mva/	<i>High</i> A comprehensive range of actors (government, firms, universities) underpinned more generally by the Oresund cross-border actors as per Miörner et al. (2018) to frame interaction beyond the formal institutions. Identifiable sectoral interregional networks and Triple Helix.	<i>Medium</i> Centred around the long-standing (over 20 years) R&D function of a cross-border life sciences/ pharma cluster. However long-term strategy with precise tangible goals is somewhat lacking for the cluster (Nauwelaers et al., 2013).	<i>Medium</i> Geographically clear i.e. Zealand in Denmark (comprising the two administrative regions of Hovedstaden and Sjælland) and the Swedish county of Scania, but boundaries are blurring due to need for global, specialist contacts (Moodysson et al., 2008).	Medium / High Includes the range of actors that constitute a system in combination with indefinable objectives. However the boundaries are unclear, aligned with the fluid nature of an industrial cluster (Achiche et al., 2012; Steinfield et al., 2010) .
2. National knowledge network of neighbouring regions	The Northern Ireland Local Government Association (NILGA) https://www.nilga.org/nilga-networks	<i>High</i> A council for local authorities and strategic key private partners including associations of small businesses and a network of community enterprise practitioners. Public bodies include universities, sectoral associations such as tourism and networks for public sector and local government professionals. A clear "Quadruple Helix" is identified.	<i>High</i> Supported by policy and learning networks, partnerships, which inform and are drawn from local authorities. These are strategically aligned to NILGA's full membership and executive committee, ensuring a dynamic, inter-dependent and integrated policy development and communication system aimed at exchanging and disseminating knowledge and best practices.	<i>High</i> A clear map indicating the boundaries of each member region is provided. All members are located in Northern Ireland.	High Includes the range of actors that constitute a system in combination with indefinable objectives.
3. International knowledge networks of distant regions	ERRIN (European Regions Research and Innovation Network) https://errin.eu/who-we-are	<i>High</i> a well-established platform of around 125 regional stakeholder organisations from 22 European countries including a wide range of complementary members in terms of knowledge and skills including regional authorities, SMEs, universities and chambers of commerce. Evidence of effective communication and knowledge sharing including feedback (Braun, 2018). Triple Helix is identified.	<i>High</i> Clear shared and identified objectives underlying knowledge exchange, research and innovation policy and funding programmes, as well as project development.	<i>Low</i> Many organisations from regions which are members but do not necessarily represent a well-defined boundary. There are no representative maps with identifiable borders.	Medium Apart from weak boundedness, it demonstrates high systemic qualities.
4. National knowledge networks of distant regions	6Aika Strategy of the six largest cities in Finland https://6aika.fi/en/frontpage/	<i>High</i> A unique network of specialists from various fields including actors of the so-called "Quadruple Helix": companies and R&D&I organizations test products and services supported by local governments in urban environments to obtain feedback from users (i.e. society) to develop better services (Anttiroiko, 2016).	<i>Medium</i> Tackling urbanisation challenges and supporting related climate goals (i.e. a clear shared objective). However, linking this objective to existing strategies varies between the individual cities (some of the cities do not have a clear implementation strategy). Thus, creation of joint innovation is not yet noticeable (Vironen, 2018)	<i>Medium</i> A clear membership scheme includes the six largest cities in Finland. This inter-city cooperation including organisations and sectors is internationally rare. However, the boundaries are blurred between the city (LAU-2) and the regional levels (NUTS-3), since regional councils (representing NUTS-3) are also involved in projects funding decisions (Hokkanen, 2019).	Medium Includes the actors that can constitute a system, but the cooperation is based on (short-term) projects. A need to further clarify the roles of the different actors remains.

boundaries. It helps to identify the extent of the “system” via including or excluding regions based on knowledge exchange related interactions between regional actors. In this case, i.e. measuring boundedness based on functionality, boundedness helps in detecting the real outcome of knowledge exchange, and/or adding another criterion to delineate the geographical boundaries of an IRKES in addition to coherence and unified function. Boundedness is expected to be clearer and more spatially contingent in cases of systems of neighbouring regions than distant regions: spatial proximity is positively related to boundedness though more limited in the case of systems of distant regions. Other proximities are not directly relevant to boundedness and therefore may be present in varying levels. The importance of boundedness to the evolution of networks into systems may lie in the ability to delineate the regional boundaries of where informal rules are followed by actors and are complemented by the emergence of formal ones which, in turn, indicates systemic orientation of an IRKES. This may include mapping knowledge exchanges against actors’ perceived values, and informal and formal practices, behaviours, etc.

The above three criteria by no means individually or collectively imply a dichotomous presence of an IRKES among regions exchanging knowledge. Instead, a continuum ranging from no system (or the existing of KNoRs only) to a fully functioning system can be conceived for identifying and studying IRKESs. For this purpose, we go back to identifying the above three non-binding criteria of a ‘system’ in examples of existing KNoRs and exploring their proximity perspective.

5. Systemic qualities of different types of interregional knowledge exchange networks

In order to link back to the discussion on the potential of interregional networks developing into systems, the exemplars (Table 3) referring to each type of identified KNoRs (i.e. delineated by geographical proximity and whether within a single nation state or spanning national borders) and their systemic qualities is fleshed out by providing a brief review of their coherence, unified function and boundedness (Roper et al., 2006). An empirical investigation employing primary sources is beyond the scope of this paper (and indeed constitutes an activity for future research). However, a review of evidence from published sources – the policy and strategy documents of the networks themselves, complemented by other third-party reports, evaluations and academic literature where available – is presented.

In populating Table 2, the reference material was examined in relation to the coherence, unified function and boundedness criteria (Roper et al., 2006). Each case was investigated by one member of the research team, moderated by a second member to ensure consistent interpretation and subsequently summarised as presented in the table. The exemplar cases of KNoRs show that the levels of systemic orientation are medium to high levels. The clearest example of high systemic qualities can be found from type 2 KNoRs exemplified here by NILGA. The Medicon Valley’s and ERRIN’s systemic orientation is medium because of extra-regional partners. This indicates that their systemic orientation is rather sectoral than regional. In KNoRs where there is more diversity at the strategic levels, systemic orientation is lower such as in 6Aika. Further, the international and distant cases show lower levels. As such, it seems that the potential for IRKES development is still subject to distance decay (geographical proximity) and negative effects of national borders. However, as already mentioned this preliminary indication deserves in-depth investigation and further empirical evidence.

Knowledge exchange facilitated by both informal and formal institutions, indicating systemic orientation of networks, is more likely to engender interregional innovation processes. Therefore, IRKESs are likely to emerge from KNoRs with complementary formal and informal institutions as the latter improve the relevance of the former to the operation and management of activities and collaboration among its members. IRKESs can be used as a useful mechanism for interactions between well- and less-developed RISs benefitting particularly the less

advanced regions with underdeveloped knowledge endowments and mechanisms. The latter can benefit from economies of scale generated by the services and access to knowledge from more advanced regions. This is particularly relevant in terms of management and administrative costs related to interregional projects often constituting a considerable drain on resources (Wanzenböck and Piribauer, 2018). Therefore, RISs of regions and representative institutions of non-RIS regions can constitute IRKESs, which implies that IRKESs differ and could potentially be classified into different types depending on the RISs involved: 1) IRKESs consisting of well-developed RISs; 2) IRKESs consisting of less-developed RISs; 3) IRKESs consisting of both well- and less-developed RISs.

5. Discussion and implications

Complementary and diversified interregional knowledge exchange is vital for innovation, which helps regions remain competitive and economically resilient in a globalised business environment. This is particularly germane given the devolution of governmental powers to regions and the S3’s ‘outward looking’ approach in Europe raising the need to explore appropriate understudied mechanisms of interregional knowledge exchange. This paper has focused on networks of collective regional groups of organisations with knowledge exchange as key in their strategies and activities, defined as KNoRs. Cross-border regional knowledge networks, international knowledge networks, national knowledge networks of neighbouring regions and national knowledge networks of distant regions constitute a new suggested typology of KNoRs.

The role of proximities and similarities between regions as barriers and enablers of knowledge exchange in KNoRs would depend on the type of KNoRs. Balanced product similarities, complementarities and sectoral related variety facilitate interregional knowledge exchange. Related variety may be similar among regions in the same country but still depend on their geographical proximity (unless culturally different). Similarly, cross-border regions tend to be influenced differently from international distant regions by different types of proximity. Thus, the role of substitution of geographical proximity in intraregional contexts (Hansen, 2015; Huber, 2012) may be explored in interregional context. This agenda includes differences and similarities as well as questioning whether relational proximity can “substitute” geographical proximity: in the absence of geographical proximity collaboration is driven by relational proximity. We also need to consider whether and how there may be a difference between the role of proximity in knowledge exchange (more common in RIS) compared to spillovers (more common in networks).

This paper proposed a novel IS concept, namely the IRKES, and described its structure and how KNoRs may become IRKESs. As an institutional mechanism the IRKES defines the relationships among members including at least one regional network from each of its member regions and the necessary participation of a set of both formal and informal institutions. An IRKES has non-binding criteria including coherence, unified function and boundedness. The interrelationships between these criteria and the role played by proximity dimensions in shaping them (both in RISs and IRKESs) are under-studied; we have in this paper taken the first steps in sketching them out. Further research, including empirical studies, will be required in order to fully investigate these relationships, determine their relative strengths and weaknesses, the contingent conditions that apply and the causal relationships involved. The proximity perspective should be addressed in each of the three system criteria separately as each may engender or hinder these differently. The assumptions regarding the levels of each proximity in relation to each criterion provides a further conceptual dimension to elaborate and examine its complexities. It might depend on and interrelate with other dimensions including i) the interplay between the three non-binding criteria; ii) the proximity dimensions and their interrelationships; and iii) the interplay between i) and ii) in different types of KNoRs.

Informal institutions improve the relevance of the formal ones to the operation and management of KNoRs and therefore are crucial for their

development into IRKESs. The potential for developing IRKESs varies among different types of KNoRs. Fundamentally, an IRKES involves higher levels of organisational proximity than a KNoR, although only until higher coordination levels and alignment are not outweighed by lock-in and bureaucracy. Empirical research could further explore these trade-offs in the specific context of IRKESs.

The interrelationship between proximity dimensions, formal and informal institutions and the three non-binding criteria are likely to differ between different IRKESs and change at the stages of IRKES evolution. Several assumptions were suggested to be examined. Proximities may support coherence by engendering the development of complementary skills, competence and knowledge base among their actors. As for unified function, institutional and spatial proximity can motivate the evolution of informal and complementary formal institutions thereby incentivising shared aims among regional actors resulting in greater unified function. Boundedness determined by spatial proximity and mediated by the other proximity dimensions is likely to define the regional boundaries of an IRKES where informal rules are complemented by formal ones. It is noteworthy that addressing these will require additional thorough investigation of proximity and its impact in interregional knowledge exchange, which should be the scope of future studies.

S3 policy has only been operational since 2014. Thus, it is too early for identifying fully developed IRKESs in Europe because they are still at various stages of emergence. This does not invalidate the concept, but rather positions KNoRs and IRKESs as part of the necessary future S3 toolkit, i.e. the very idea of S3 means that IRKESs have to be effectively conceptualised. If IRKESs (or at least likely candidates) cannot be found, this would question key aspects of the whole S3 rationale. As such further research is needed to validate the feasibility of IRKES emergence. Consequently, peripheral regions increasingly develop interregional linkages over time. However, without a universally observed trend, there is evidence that firms in peripheral regions tend to be in local, more socially-focused networks (Cooke et al., 2005). Possibly, regions are simply at different points on this path. A snapshot of regions would provide one data source (Makkonen et al., 2018a), whereas for a more complete picture longitudinal analysis is required. Table 2 presents four exemplar KNoRs. More research is needed to validate this framework by employing methodologies such as mapping, surveying and interviewing actors, social network analysis and innovation biographies which by mapping knowledge diffusion can help define the system that generates them.

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