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CROSS-BORDER REGIONAL INNOVATION SYSTEM INTEGRATION: AN ANALYTICAL FRAMEWORK

ABSTRACT

The importance of inter-regional cooperation and innovation are widely accepted in the development rhetoric of the European Union. The highlighted importance of both themes in the context of borderlands has recently led to the coining of a new concept, cross-border regional innovation system. However, little attention has been given to the empirical analysis of the concept. This paper suggests a framework for empirically validating the concept by examining the levels of integration between cross-border regions. The outcome is a proposed framework can be operationalized by measurable indicators of cross-border cooperation in a regional innovation system setting. The framework was further tested with illustrative empirical cases that demonstrate its feasibility.

Keywords: Cross-border region; European Union; integration; knowledge transfer; proximity; regional innovation system

INTRODUCTION

Innovation and inter-regional cooperation are topical, persistent and recurrent themes in European Union (EU) policy concerns and documentation, with knowledge flows being integral to both themes. Therefore, understanding the obstacles and enablers of knowledge transfer is highly relevant for utilizing the potential for learning and innovation via inter-regional cooperation, as geographical proximity *per se* does not always lead to high levels of knowledge flows. The promotion of socio-economic, and in particular the socio-cultural development of Cross-Border Regions (CBRs) is highly significant for achieving the cohesion and cooperation goals of the EU and its neighbors (European Commission 2012; OECD 2013). However, border regions tend to be more integrated with national centers rather than with neighboring border regions (Prokkola 2008). Hence, the available empirical evidence, especially concerning the external borders of the EU, still highlights the importance of the nation state (Eskelinen & Kotilainen 2005).

There is considerable academic interest in cross-border networking and the integration of CBRs (Löfgren 2008; Platonov & Bergman 2012; Deconville *et al.* 2013). Recently, this has included the coining of a new innovation systems concept, namely the Cross-Border Regional Innovation System (CBRIS) (Trippl 2010; Lundquist & Trippl 2013). However, the tendency of most firms to belong (even if sometimes, only weakly) to national or regional innovation systems in their home countries is an obstacle to developing cross-border linkages (Koschatzky 2000; Lundquist & Winther 2006). Accordingly, border regions can be bypassed in firm level cross-border cooperation, which (more) commonly occurs between firms located in the economic centers (capitals) of the respective countries (Krätke & Borst 2007). However, firms which have strong national linkages may also be good at developing cross-border linkages. Therefore, exploration and validation of the theoretical proposition of there being relationships between CBRISs and different types of proximity will enable assessment of the long-term competitive advantage of CBRs and their ability to create common innovation systems (Lundquist & Trippl 2013). Given there has been little empirical application of the concept, the aim here is to address this research gap by summarizing the existing conceptual works and developing, for the first time, a systematic analytical framework for empirically studying the levels of integration of CBRISs. Although acknowledging the limits of "one-size-fits-all" solutions i.e. the shortcomings of quantitative cross-regional analyses in capturing the versatile nature of innovation cooperation processes, this paper identifies a set of measurable items in accordance with the dimensions of CBRIS development and proximity. In short, the paper will propose a set of indicators to enable researchers to analyze and compare different CBRISs in terms of their 1) distance in various dimensions of proximity as well as 2) levels of integration and intensity of cross-border knowledge transfer.

The remainder of this paper is organized as follows. First, the conceptual background of the CBRIS literature is presented. Second, the analytical framework is introduced together with reflections on the (relevant) geographical scales of analysis and illustrative empirical cases of CBRs which are indicative of its feasibility. Third, the utility of the proposed empirical validation, in the light of the conducted feasibility check and relevant literature, is discussed in the concluding section together with suggestions for further studies.

CROSS-BORDER REGIONAL INNOVATION SYSTEMS AND DIMENSIONS OF PROXIMITY

Originally the concept of Regional Innovation Systems (RISs) was introduced to the literature by Cooke (1992) and since then the concept has evolved through the contributions of several authors (Braczyk *et al.* 1998; Asheim & Gertler 2005; Cooke 2008) alongside its counterparts, that is national, sectoral and technological innovation systems (Lundvall 1992; Edquist 1997; Malerba 2002). At the heart of the concept lies the importance of interactions between local firms, universities, research centers, infrastructure, knowledge transfer mechanisms, innovation and development policies and the workforce. The strengthening of the actors in an innovation system and the links between them should, therefore, lead to heightened innovation capacity in a given region. For example, in the Nordic countries the concept of innovation systems has long been incorporated in national and regional technology policies (Edquist & Lundvall 1993; Miettinen 2002), which seems to have been reasonably effective as reflected in Denmark, Finland and Sweden consistently being ranked among the most innovative countries in the world (Dutta *et al.* 2014).

Whereas, in the context of Euroregions, Perkmann (2003) has defined CBRs as bounded regional units composed of the territories of authorities participating in cross-border cooperation, they can more broadly be defined as areas consisting of neighboring territories belonging to different nation states with political-administrative borders as well as economic, cognitive, cultural and social borders (see Weidenfeld 2013). These similarities and dissimilarities inherent in CBRs can both form major barriers but also offer potential for innovation cooperation and interaction (Koschatzky 2000). Thus, the role of policies in CBRISs is to support the exploitation of this potential. Consequently, the RIS theory has been applied to cross-border settings including the following key determinants of CBRIS development as: 1) business (economic structure and specialization), 2) knowledge infrastructure (science base), 3) relational (nature of linkages), 4) socio-institutional (institutional set-up), 5) governance (policy structures) and 6) accessibility dimensions, concluding that the emergence of a CBRIS depends on all these factors and their interplay (Trippl 2010; Lundquist & Trippl 2013). Since, the arguments made by the "proximity school" have been a major facilitator and the backdrop to the conceptualisation of the CBRIS concept, the discussion of CBRISs is (and its measurement should be) closely tied to that of different types of borders and proximity (physical and relational). At the same time, economic analysts pay particular attention to their impact on inter-regional knowledge flows, spillovers and cooperation networks (OECD 2013). Physical proximity is related to the geographical dimensions of transaction and transportation costs, whereas relational proximity is commonly used as an umbrella term consisting of a number of non-tangible dimensions including cognitive (similarity of knowledge bases), cultural (shared language, religion etc.), institutional (similarity of informal constraints and formal rules shared by actors), social (personal long standing trust based linkages) and technological (shared technological experiences) proximities (Boschma 2005; Knoben & Oerlemans 2006; Balland *et al.* 2015).

Given the nature of these different notions of relational proximity, being geographically close could potentially facilitate cooperation but does not necessarily result in high levels of knowledge transfer in CBRs.

The discussion on CBRIS specifically refers to the two sub-systems characterising RISs i.e. the knowledge generation (science base) and knowledge application and exploitation sub-systems (business dimension). These are supported by socio-cultural factors and regional policies. In an optimal case, there are intensive local and cross-border interactions between, and also within, the knowledge generation and the knowledge application and exploitation subsystems. Therefore, regional knowledge infrastructure plays a prominent role in innovation in CBRISs. Establishing mechanisms, and specialized bridging organizations, to promote the diffusion and sharing of knowledge across borders is crucial in supporting the business dimension of a CBR in its innovative activities (Trippl 2010). However, if there is too wide a gap in the innovation performance (R&D intensity, patenting and licensing behavior, new product launches, etc.) of regions, little knowledge will flow between them (Maggioni & Uberti 2007). Moreover in relation to cognitive proximity, distance in terms of a lack of a shared knowledge base and area of expertise hinders reciprocal (cross-border) learning (Asheim 2007). In short, cognitive proximity refers to individuals or companies sharing the same knowledge base and expertise for adopting a new technology or new knowledge (Boschma 2005). It is commonly considered to be a preliminary and necessary underlying condition for the influence of other types of proximities (Mattes 2012). Therefore, for example, technological proximity – relating for instance to shared job experiences – is perceived as a sub-dimension of cognitive proximity by some scholars (Boschma 2005; Huber 2012), but as a separate dimension by others; e.g. in the context of CBRISs. Following Lundquist and Trippl (2013), here they are examined separately to simplify the complex knot of relational proximities. According to Trippl (2010) and Lundquist and Trippl (2013) a further advantage can be described through the relational dimension and trans-boundary relationships (e.g. student exchanges, co-patenting, co-publications and trade relations). Similarly, shared socio-institutional conventions (common history, language, beliefs, values, jurisdiction, etc.) and good accessibility are important to the cross-border exchange of knowledge. Moreover, the establishment of a CBRIS essentially requires a sufficient degree of political autonomy for effective governance of the regions constituting a CBR i.e. the regions in question should have a direct say in cross-border relations and not be subject to dominantly top down directives from the national state.

INTEGRATION IN CROSS-BORDER REGIONAL INNOVATION SYSTEMS

The integration processes in CBRISs have been conceptualized in terms of having different stages of internal integration ranging from weakly, to semi-, to strongly integrated systems (Lundquist & Trippl 2013, p. 455). Each of these three forms has different levels of different types of proximity leading to various possibilities for cross-border knowledge transfer and interactions. According to Lundquist and Trippl (2013), weakly integrated systems are characterized by institutional thinness, strong embeddedness in the nation state, low levels of cross-border economic relations, knowledge interaction and innovation linkages. In semi-integrated systems, innovation cooperation occurs only in a selected few industries, but is not a region-wide phenomenon. There might be innovative cross-border agglomerations of specific industries, but not a common CBRIS. In contrast, strongly integrated CBRISs are characterized by high mobility of workers and students, firm-level networking, and academic collaboration as well as significant flows of knowledge, skills, expertise and organizational linkages. In reality, however, individual CBRISs are likely to exhibit varying stages of integration across their different dimensions. Trippl (2010) assumes that, even globally, only a few CBRs have favorable conditions for achieving a strongly integrated CBRIS.

Integration is likely to be strong where there are similarities in the specialization of economic structures, industrial sectors and activities between adjacent border regions as well as complementarities in knowledge expertise, skills and economic activities, which stimulate innovative collaboration and knowledge flows between regions (OECD 2013). This is closely tied to the Marshall-Jacobs debate in economic geography: in opposition to Marshall's (1961) views on the importance of industrial specialization, Jacobs (1969) has stressed the importance of the positive impacts of diversity and variety. Subsequently, this idea was extended to cover the synergies of different but technologically related sectors i.e. technological relatedness (Frenken *et al.* 2007; Cooke 2008). More recently, it has been clarified that "the principle of related variety is that economic development is driven by interactions between the sectors of regional economies that are related in terms of technology or industry" (Melkas *et al.* 2016, p. 490). Sufficient difference engenders novel re-combinations of different but complementary knowledge between technologically related sectors, and has potential for regional diversification and innovation (Frenken *et al.* 2007; Boschma & Frenken 2011). Related variety is pivotal in CBRIS development. This implies that the long term development of CBRs depends on their ability to diversify into new applications and new sectors, while building on their current knowledge bases and competences (Asheim *et al.* 2011; Weidenfeld 2013). Relational proximity must be limited as too much proximity might lead to overlap and create lock-in effects and competition. In contrast, limited relational distance engenders complementarities and interactive learning (Boschma, 2005). In particular, high levels of similarity in terms of sharing a technical language are important, but as shown by Huber (2012) a certain degree of dissimilarity in terms of know-how, know-what and the way of thinking can be fruitful for R&D workers. Therefore, balanced levels of relational proximity between sectors on both side of the border, including some degree of dissimilarities and complementarities, could increase integration while maintaining cross-border knowledge transfers. Hence, related variety would constitute a propitious base for collaboration leading to a higher degree of integration within CBRISs. Additionally, reflecting the current ethos of the European Union in promoting "smart specialization", the CBRIS concept could be discussed under "joint-specialization" (Muller *et al.* 2015). Knowledge producers on one side of the border could be linked to knowledge users and applicants on the other side. Nonetheless, this also requires a certain level of common knowledge base and shared technological expertise.

While there is an emerging conceptualization of CBRISs, in terms of related variety and the different dimensions of proximity, the empirical evidence remains limited. To date only a few studies have empirically tested or sought to validate CBRIS integration. Notably, with a specific emphasis on the biotech industry in the Øresund CBR, Hansen (2013) has emphasized the importance of the dimension of accessibility for heightened cross-border integration. However, he further underlined that improvements in accessibility do not in themselves guarantee intensified integration, if they are not supported by targeted policy measures. Additionally, the local Øresundskomiteen (i.e. the committee responsible for political collaboration in the Øresund CBR) has constructed and employed an index measuring the "growth of integration" in the CBR since the opening of the Øresund Bridge in 2000. Unfortunately, the index (http://www.oresundskomiteen.org/en/2013/10/the-oeresund-integration-index/) does not cover innovation cooperation, but measures cross-border mobility (traffic, migration and commuting), trade volumes and cross-cultural mingling. Other than this study, a rather descriptive attempt to define empirically the varying levels of integration according to different dimensions of proximity in the Øresund and Centrope CBRs (Lundquist & Trippl 2009) is the only existing attempt to validate the concept of CBRIS as a whole. It uses statistics on shares of employment, number of students and R&D

personnel, and is an important point of reference for the analytical framework discussed below. More recently, however, the concept has also aroused initial criticism: firstly, for its macro-level systems perspective that under-appreciates the role that individual actors and institutions can have in facilitating cross-border cooperation; and, secondly, for its focus on cross-border linkages that ignores the role that national and international networks can have in steering CBRIS integration (van den Broek & Smulders 2014; 2015). Therefore, while there is considerable debate about conceptualization of CBRIS, it is important to stress that for empirical purposes the concept of CBRIS adopted here is quite straightforwardly drawn from the publications by Trippl (2010) and Lundquist and Trippl (2009; 2013).

DEVELOPING AN ANALYTICAL FRAMEWORK

The suggested framework in this paper combines the importance of different types of proximities with the stages of integration of CBRISs in order to provide an approach to the empirical treatment and validation of the concept. However, the scaling used in for example Lundquist and Trippl's (2009) study is fairly subjective, and there are no readily available benchmarks on every dimension which allow the determination of what is close and what is distant in term of the various dimensions of proximity. Therefore, in order to investigate the concept of CBRIS we are faced with the question of how best to describe and measure the different dimensions presented in Table 1, that is, how to operationalize them. Keeping in mind the difficulties involved in collecting data for regions from various countries, and the fact that this is the first attempt to develop a comprehensive empirical framework for testing the feasibility of the CBRIS concept, the researchers proposed the operationalization of measures presented in Table 1.

<Table_1>

In relation to the scopes of study presented in the proposed analytical framework (Table 1), a distinction is made between quantitative and qualitative studies (Punch 2014). Preferably, both approaches should be applied in the study of CBRIS dimensions; quantitative accounts provide the big picture and generalizations and qualitative studies probe in greater detail what lies behind the observed numerical illustrations. Consequently, qualitative studies can be applied for building hypothesis to be tested with quantitative methods and larger sets of CBRs. However, in practice there are difficulties in operationalizing some dimensions of CBRIS into measurable indices discussed below.

Economic structures and specialization – The dimension of economic structures and specialization is closely connected to cognitive and technological proximity, which relate to shared educational and job experiences. Therefore, the dimension of economic structures and specialization is described here through the similarities and dissimilarities between the industrial bases of, and trade flows between, the regions. The scope of the studies can be quantitative. This does not, of course, exclude qualitative studies. In qualitative studies, the focus should be on investigating, utilizing interview or questionnaire data, how similarity or dissimilarity affects cross-border cooperation and its impacts. In quantitative terms the dimensions should be operationalized through the use of industrial or sectoral data on, for example, employment (accessible from Eurostat and various national databases) to determine how close or distant the opposing sides of the border are in terms of their economic structures. When the economic structures, in terms of industrial branches, are nearly identical on different sides of the border, there is a high probability of collaboration but there may be relatively little to learn from each other. In contrast, if there is very little in common between the local industries on the different sides of the border, the technical language is likely to be too dissimilar to facilitate common learning processes. Trade statistics, in turn, would enable the comparison of CBRs in terms of their economic integration. However, the mere presence of high levels of trade flows might signal the existence of (hierarchical) supply chains with little innovative collaboration. Thus, the relationship between technological proximity and knowledge transfer (and innovation) is likely to take the form of an inverted U-shape (Mowery *et al.* 1998).

Science bases and knowledge infrastructure – The cognitive dimension is about the distance between and balance of science bases, that is, being close enough to be able to cooperate, but also being far enough for effective learning through complementarities (Nooteboom *et al.* 2007). Interdisciplinary collaboration between the regions, is commonly expected to result in more novel findings, compared to intra-disciplinary research, as is also evident in the current emphasis in the EU's research funding calls (van Rijnsoever & Hessels 2011). Again, too much similarity can be an obstacle, whereas lack of similarities also hinders collaboration. The selection of an appropriate measurement of cognitive similarities and science bases in the regional context is contentious, but a well-documented source of data to investigate this dimension can be derived from scientific publications data (Hansen 2013; Makkonen 2015) obtainable from various publication databases such as Web of Science

(WoS), Scopus and Google Scholar. Accordingly, the application of a "Cognitive Proximity Measure" (CPM) based on similarities/dissimilarities of scientific fields in publishing, would be useful: a correlation measure (CPM_{ij}), where tf_{ir} and tf_{jr} (term frequencies) are the number of times a classification r is assigned to the regions i and j, can be calculated to investigate the extent to which two regions (i and j) publish in the same proportion in each research area. Identical profiles would be measured as a value of one, while completely different profiles would be measured as zero. Equation (1) takes the following form (Jaffe 1986; Peri 2005; McNamee 2013):

$$CPM_{ij} = \frac{\sum_{r(1)}^{r(n)}(tf_{ir})(tf_{jr})}{\sqrt{\sum_{r(1)}^{r(n)}(tf_{ir})^2}\sqrt{\sum_{r(1)}^{r(n)}(tf_{jr})^2}} \quad (1)$$

The index scores can then be compared to the numbers of cross-border joint-publications or patents and other innovation measures (R&D collaboration projects, licensing, etc.) to evaluate the impacts of cognitive proximity on the integration of science bases, cross-border knowledge flows and the overall innovativeness of the CBRs. Even though Jaffe's (1986) measure discussed here is one of the most popular ways for depicting cognitive proximity (McNamee 2013), it still has weaknesses since it does not differentiate between "close" and "far" classifications specifically in terms of complementarities. Therefore, the Mahalanobis similarity measure could be applied to identify the distance between different scientific or technological fields based on the frequency that they are observed conjointly within individual articles or patent applications (Aldieri 2013). Here too, the relationship between cognitive proximity and knowledge transfer (and innovation) is likely to take the form of an inverted U-shape (Broekel & Boschma 2011). The issue of science bases is also very much related to the existing knowledge infrastructure: if a CBR is thin on local research institutes, including universities, and high-tech firms, little knowledge can be expected to flow across the border in terms of co-authored publications or research collaborations.

Another measure to depict the level of integration of science bases (and knowledge infrastructure) could be derived from the numbers of exchange students (Pellenbarg & van Steen 2015) in a region that have come to study from the adjacent region. Since exchange students, and also possibly exchange teachers and research visits (Smeby & Trondal 2005), describe the process rather than the outcomes (publications) of collaboration in a CBRIS, these measures can be seen as complementary. Even though the dimension can be analyzed with quantitative data at the EU-level, the employment of qualitative study settings is advisable for detailed descriptions involving interviews with, or questionnaire surveys of, researchers, policy-makers, etc. Qualitative studies would help discovering the causes behind the limited levels of cross-border cooperation and the impacts of integration into other non-quantifiable aspects of cross-border scientific cooperation in relation to the regional science bases and knowledge infrastructures.

Nature of linkages – Similar innovation performances are critical for successful knowledge sharing between regions (Maggioni & Uberti 2007). Hence, if a CBR is constructed from regions with differing innovation performance (strong vs. weak) little knowledge is expected to flow between them. In addition to secondary descriptive innovation measurements (e.g. the Regional Innovation Scoreboard based on data from the Community Innovation Survey), the dimension of linkages should be operationalized through technological and cognitive proximity lenses. This can be achieved by exploring the similarity or dissimilarity of patenting behavior, whereas cross-regional knowledge flows and linkages can be analyzed through data on co-patenting (Jaffe & Trajtenberg 1999; Paci & Usai 2009), in this case, on the opposing sides of the border. Here again, a "Technological Proximity Index", operationalized in line with the CPM (Equation 1) – but according to the International Patent Classification (IPC) (Jaffe 1986; Peri 2005) – would provide useful information on the similarities/dissimilarities on patenting behavior across the border. Again, the expected outcomes are likely to resemble that of an inverted U-shape (Mowery *et al.* 1998; Nooteboom *et al.* 2007). Of course, patents are not the only type of cross-border knowledge flows with potential for innovations. Thus, in addition to the well documented joint-patent data (e.g. the PATSTAT database of the European Patent Office), additional measures on R&D collaboration (e.g. the CORDIS database of the European Commission) or outsourcing and product licenses would contribute to acquiring a fuller picture of integration in terms of (innovation) linkages between bordering regions. Again, as in the case of the science base and knowledge infrastructure, the use of qualitative study material should also be encouraged. Similarly, applying methods from social network analyses could provide valuable information on the personal and organizational linkages across the border in order to contribute to a better understanding of which types of cross-border linkages matter most in economic terms (Ter Wal & Boschma 2009).

Institutional set-up – There are three reference points for institutional set-up: institutional proximity, understood as differences in informal and formal rules, social proximity, i.e. long standing and trust-based linkages amongst partners co-operating across borders, and cultural proximity, for example a shared language (Lundquist & Trippl 2009). The institutional set-up is visible through the existence or non-existence of: 1) informal institutions, that is the social acceptance of CBRISs integration, 2) formal institutions, that is the existence of common institutions and practices (projects) aimed at enhancing the integration between the border regions, 3) social trust and 4) cultural similarities amongst the inhabitants of bordering regions. In operationalizing such an intangible dimension of CBRIS integration, the lack of available statistics describing the dimension means that secondary data offer little support for extensive quantitative analyses. In a quantitative approach, when using econometric and statistical methods, institutions could be modelled by employing dummy variables or indices based on various sources (see below). However, the institutional set-up dimension would benefit from being operationalized through qualitative studies. Formal institutions can, up to a certain point, be observed through desk studies. The informal and trust aspects of institutional set-up require primary data collection, typically via questionnaire and interview data, in order to derive a picture of the acceptance of CBRIS integration, and social trust, between the inhabitants of differing sides of the border (van den Broek & Smulders 2014).

Additionally, an all-encompassing feature is the importance of cultural proximity (Bhagat *et al.* 2002). However, while a common and shared culture strongly influences the other dimensions of proximity, it is of particular relevance for the notion of institutional proximity, since it includes a set of cultural habits, values and norms (Boschma 2005). These cultural dissimilarities can be measured quantitatively and qualitatively in terms of linguistic and ethnic distance or differences in values (Lundén & Zalamans 2001; Serva & Petroni 2008; Minkov & Hofstede 2014). In short, knowledge flows more easily across borders if the adjacent populations share common cultural features. However, in practice the intangible nature of institutional, cultural and social proximities, together with the problems in operationalizing the dimension into measurable items, render institutional set-up mostly outside the scope of quantitative EU-level analyses.

Policy structures – The dimension of policy structures is related to the formal dimension of institutional proximity. The factors which hinder integration are low levels of interest from the respective nation states, and an overly strong top-down direction of local actors in their corresponding regional and national innovation systems (Lundquist & Trippl 2009). Therefore, the policy structures dimension could be studied through shared (innovation, science and regional) policy goals at the national and local levels. That is, do both sides of the border consider cross-border collaboration, joint-innovation and R&D cooperation in similar ways, and do the existing policy documents recognize the importance of cross-border collaboration for innovation. The operationalization of policy goals into measurable indicators presents considerable challenges, and requires a qualitative approach. This would involve studying the documentation of existing policies and strategies complemented with interview or questionnaire data on the opinions of local and national policy-makers. Therefore, statistical EU-level studies with measurable data on shared policy goals at the national and local levels would require extensive amounts of data collection and subjective operationalization. A possibility exists, however, of constructing indices for tentative and illustrative analyses (see below) or using dummy variables for econometric analyses, but in practice detailed investigations of the dimension of policy structures are likely to lie outside the scope of further quantitative studies of CBRIS integration.

Accessibility – This dimension refers to physical proximity, which facilitates cross-border knowledge transfer (Lundquist & Trippl 2009). However, the absolute distance between regions is not as important as the actual time and costs of transactions – which to some extent can be captured by travel time calculators and the methods of transport geography (Salonen 2014). Therefore, the accessibility dimension should additionally be described through the ease and volume of cross-border traffic. Inside the Schengen Area, due to the freedom of movement provisions, measuring the ease of cross-border traffic is less acute compared to other parts of the world. However, in some circumstances, for example when examining case regions on the external EU-borders, the issue is highly relevant. In addition, the volumes of cross-border traffic can be employed to describe the intensity of cross-border flows in terms of tourism and commuting (Deconville *et al.* 2013; Weidenfeld 2013; Durand & Nelles 2014), which are both highly significant for knowledge transfer and CBRIS integration.

Geographical scale – The geographical scale to which the CBRIS framework refers poses an interesting question: does every region have a RIS, and every CBR a CBRIS? Moreover, it also re-introduces the problematic of delineating an innovation system (Isaksen 2001; Carlsson *et al.* 2002; Doloreux & Parto 2005). In addition to official EU-level classifications, such as NUTS and LAU regions, cross-border twin cities, for example, might offer interesting cases since the development of cross-border linkages is more concrete and mundane in twin cities than is evident at larger geographical scales (Eskelinen & Kotilainen 2005; Joenniemi & Sergunin 2011). Thus, twin cities are a fitting example of CBRs in the way that Perkmann (2003) has described them: indeed, they commonly are bounded regional units of authorities participating in cross-border cooperation. National policies also affect the reasoning here: in many countries, the regions have limited legislative and regulative power, whereas cities have a more direct influence, for example in the right to levy taxes. Therefore, even though large regions have greater possibilities (in terms of population, resources, etc.) for interaction, they commonly lack regulatory powers (Sotarauta & Kautonen 2007), which support the use of smaller regional scales, such as twin cities, in CBRIS analysis. Thus, the appropriate size of a region to be considered as an effective CBRIS remains an open question. Consequently, it is likely that the appropriate geographical scale is country- and CBR-specific, that is, it depends on the local peculiarities and flows of people, trade and knowledge, as well as on national and regional regulatory power divisions (see Weidenfeld 2013). In addition, rather than depicting CBRs with little or no cross-border interaction as weakly integrated systems, globally it might be more apt to designate some CBRs as lacking even the most basic characteristics (interaction, knowledge flows, significant cross-border traffic, etc.) of CBRISs, and therefore having no system at all. Quite simply, there is a need to recognize that, due to the nature of CBRs, the dynamics of innovation systems in cross-border regional settings may be absent.

Empirical application – In order to demonstrate the feasibility of our proposed analytical framework, we conducted a pilot study utilizing Danish CBRs including the Danish-Swedish CBR of Øresund and the Danish-German CBRs of Fehmarnbelt and Sønderlylland-Schleswig. The fact that one side of the cases are all from the same country helps to control for potential cultural specificities. Of these, Øresund is a well-known example of cross-border integration (Nauwelaers *et al.* 2013), whereas earlier literature has designated Sønderlylland-Schleswig and Fehmarnbelt as less integrated (Klatt & Hermann 2011; Makkonen 2015). For empirical purposes, we applied the principles stated above and delineated the CBRs as follows: 1) Øresund includes the Danish Capital Region (excl. Bornholm) and the Swedish Scania Region, 2) Fehmarnbelt includes the Danish municipalities of Lolland and Guldborgsund and the German district of Ostholstein and 3) Sønderlylland-Schleswig includes the Danish Municipalities of Åbenrå, Haderslev, Sønderborg and Tønder, and the German districts of Flensburg (urban), Nordfriesland and Schleswig-Flensburg (Figure 1).

<Figure_1>

Our measurement of the dimensions follows the methods outlined in Table 1. For example, in the case of the nature of linkages we extracted the patent data from the REGPAT database for each of our case study regions. The number of patents per patent class (IPC – main sections) on adjacent sides of the border correspond to tf_{ir} and tf_{jr} (term frequencies) in Equation 1. This procedure was similarly applied to the dimensions of economic structures and specialization, and science base and knowledge infrastructure, where the required term frequencies correspond, respectively, to the industrial sectors of employees (broad NACE codes – gathered from national statistical authorities) and the reported scientific fields of academic publications (in WoS database).

For institutional set-up, an index – comprised of the share of (ethno-linguistic) Swedes/Germans living on the Danish side of the border (see Schulze & Wolf 2009) and Hofstede's cultural dimensions on a national level (from Denmark Statistics and Hofstede Centre) – was constructed. The limitations of the latter in depicting regional variations (Minkov & Hofstede 2014) is acknowledged. For policy structures we relied on a rudimentary index score taking into account shared policy goals relating to formal institutions. That is, whether there is a (common) organization promoting cross-border integration, how long this organization has been active and whether the work done by the organization has been acknowledged with the "Sail of Papenburg Cross-Border Award" granted by the European Association of Border Regions. For accessibility, we relied on estimated numbers of daily commuters across the border in each CBR (Buch *et al.* 2009; Matthiessen 2010; Nauwelaers *et al.* 2013) normalised according to their total population. The proximity measures and index scores are illustrated in Figure 2. The higher the scores (on a scale from 0 to 1) the more proximate/integrated the adjacent sides of the border are (in relation to the other case CBRs) in each dimension. It must be stressed that while the other indices use established data sources, the institutional set-up and policy structures measures are more challenging, but even the explanatory measures proposed here indicate the potential for developing more sophisticated indices.

<Figure_2>

Figure 2 can be viewed in two ways. Firstly, the figure shows how empirical data can be used to describe CBRIS integration. However, further consistent measures that would address CBRIS integration in greater detail need to be developed. Secondly, the figure indicates the initial feasibility of our proposed framework: Øresund scores relatively high on all measured dimensions of cross-border integration, when compared to the less integrated Sønderlylland-Schleswig and Fehmarnbelt. Moreover, there are relatively large local minorities and high potential for integration in Sønderlylland-Schleswig, whereas Fehmarnbelt is a cross-border region at the initial stages of integration (Klatt & Hermann 2011). Further statistical analyses are needed to determine whether the CBRIS dimensions are equally important for cross-border integration or do some of them "weight" more than the others, and to test the hypothesised U-shaped relations between proximities and innovation, and could be the scope of future studies. However, this brief feasibility analysis does demonstrate that the framework can differentiate different types of CBRIS *vis-à-vis* their stages of integration.

CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

The possibilities of researching CBRIS integration have been discussed here in terms of the combination of varying dimensions of proximity. An analytical framework, with suggestions on measurable items and the scope of research, was proposed as a basis for further studies to validate the theoretical underpinnings discussed in the earlier literature on CBRIS integration (Trippl 2010; Lundquist & Trippl 2013). In line with this, the problematic of delineating a suitable geographical scale for analyzing CBRISs was discussed in the light of earlier critical reflections on the concept of RIS. In short, it is probable that world-wide many CBRs lack the preconditions for successful cross-border collaboration that are a precondition for developing into strongly integrated CBRISs. This, however, does not mean that the concept of CBRIS lacks utility when considering and analyzing the economic development and future prospects of CBRs, especially in the European context. On the contrary, the concept of CBRIS is advanced here as an interesting and important direction for further studies into borderlands and cross-border cooperation. The illustrative analysis of the empirical cases provide tentative but promising support for the feasibility of the framework for validating the conceptual remarks on CBRIS. The analysis indicates, that proximities do matter for CBRIS integration: more integrated regions score higher on the measured dimensions that are based on varying types of proximities. It also suggests that, once operationalized as in our examples, the concept of CBRIS can be useful for empirical cross-regional comparisons of border regions by revealing their levels of integration. However, it has to be kept in mind that, due to data availability issues, the suggested indicators (patents, publications, etc.) depict innovation in a rather narrow "Science, Technology and Innovation" mode. A broader view, including also the "Doing, Using and Interacting" mode of innovation (Jensen *et al.* 2007), would require other indicators that are more challenging in comparable cross-border contexts.

Therefore, since the framework presented here remains one of the first attempts to describe a feasible approach for further studies, further developments of the framework and empirical studies to validate it are required in order to draw more definite conclusions about the integration processes in CBRISs. Such research should encompass analysis, utilizing quantitative data to depict the impacts of different observable measures and dimensions (related to cognitive and technological proximities) on the ease, volume and impacts of knowledge flows in cross-border settings. As it stands, the relative availability of statistics on internal EU-borders offers a possibility for further statistical studies, using quantitative data, to test and model the impacts of different types of linkages and knowledge flows on the integration processes of CBRISs. However, in keeping with the ethos of the EU (European Commission 2012), the external EU-borders should not be excluded from these analyses, which signifies the need for more comprehensive data collection between the neighboring regions of the EU.

Further statistical studies should take advantage of the existing databases to combine a comprehensive dataset for analyses on a quantitative EU-level. In line with this, further elaborations of the more intangible aspects of CBRIS integration through the use of questionnaires and interviews directed at city officials, regional development agencies, local companies, etc. will contribute to drawing a more precise picture, for example, in terms of the impacts of formal and informal institutions and social acceptance of integration (i.e. institutional and social proximities). This is highlighted here as an important avenue for further studies. On a qualitative scale, this should include the operationalization of questionnaire items with survey data as well as a study approach that employs interviews to provide a better understanding of the processes that lie beneath the quantitative aspects of the integration of CBRIS.

To conclude, the conceptual literature on CBRISs has, thus far, only explored several related issues of innovation systems, proximity and integration without much emphasis on depicting these various strands of literature in a way that could guide potential attempts to analyze the concept empirically. Therefore, this paper has been the first systematic effort to derive an analytical framework to pave way for further empirical studies to focus more precisely on which dimensions of CBRIS development and types of proximity matter the most for CBRIS integration, what is the optimum amount of similarity to be considered as ideal for cross-border innovation cooperation and how to assign threshold values or pinpoint the differences between the various stages of CBRIS integration?

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Table 1. Analytical framework

RIS dimension	Types of Proximity	Scope	Operationalization	Prospective databases/sources for quantitative analyses
Economic structures and specialization	Technological Cognitive	Quantitative Qualitative	Sectoral statistics; Trade flows	National statistical authorities; OECD; Eurostat
Science base and knowledge infrastructure	Cognitive	Quantitative Qualitative	Publications; Exchange students	Web of Science; Scopus; Google Scholar
Nature of linkages	Cognitive Technological	Quantitative Qualitative	Patents; R&D collaboration; Licences	REGPAT; PATSTAT; CORDIS
Institutional set-up	Institutional (formal + informal) Social Cultural	Qualitative (Quantitative)	Acceptance of integration; Trust; Common values, institutions and practices	(National statistical authorities; Eurobarometer surveys; Hofstede Centre)
Policy structures	Institutional (formal)	Qualitative (Quantitative)	Shared policy goals at the local and national levels	(Association of European Border Regions)
Accessibility	Physical	Quantitative Qualitative	Cross-border traffic; Commuters	National statistical authorities

Source: authors' own elaboration

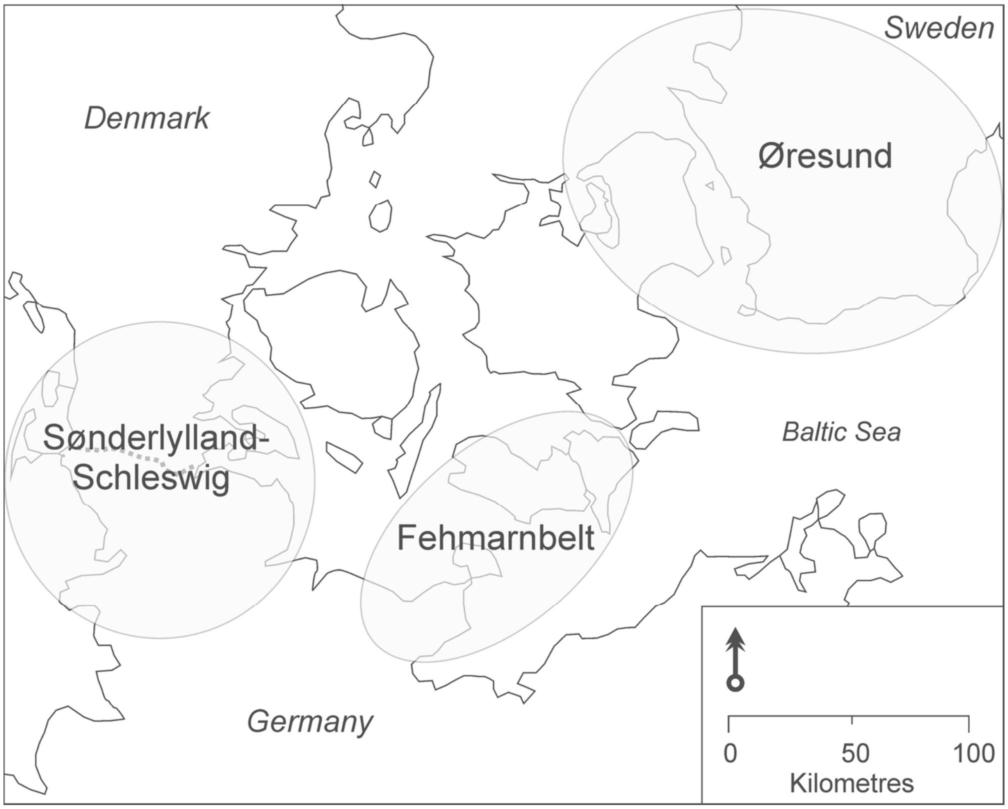

Figure 1. Øresund, Fehmarnbelt and Sønderlylland-Schleswig.
127x102mm (300 x 300 DPI)

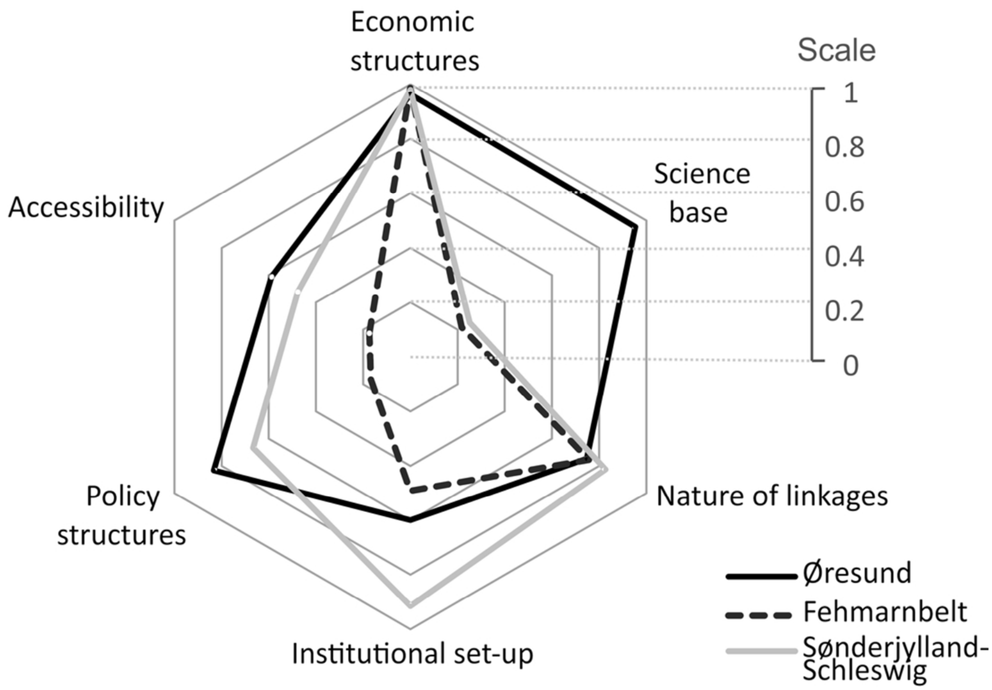

Figure 2. Proximity measures and index scores for the different dimensions of CBRIS integration in the selected regions.
94x66mm (300 x 300 DPI)