



**Cross-border regional innovation system integration: An analytical framework**

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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) (Trippel 2010; Lundquist & Trippel 2013). However, the tendency of most firms to belong (even if sometimes, only weakly) to national or regional innovation

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3 systems in their home countries is an obstacle to developing cross-border linkages  
4 (Koschatzky 2000; Lundquist & Winther 2006). Accordingly, border regions can be bypassed  
5 in firm level cross-border cooperation, which (more) commonly occurs between firms located  
6 in the economic centers (capitals) of the respective countries (Krätke & Borst 2007).  
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8 However, firms which have strong national linkages may also be good at developing cross-  
9 border linkages. Therefore, exploration and validation of the theoretical proposition of there  
10 being relationships between CBRISs and different types of proximity will enable assessment  
11 of the long-term competitive advantage of CBRs and their ability to create common  
12 innovation systems (Lundquist & Tripl 2013). Given there has been little empirical  
13 application of the concept, the aim here is to address this research gap by summarizing the  
14 existing conceptual works and developing, for the first time, a systematic analytical  
15 framework for empirically studying the levels of integration of CBRISs. Although  
16 acknowledging the limits of “one-size-fits-all” solutions i.e. the shortcomings of quantitative  
17 cross-regional analyses in capturing the versatile nature of innovation cooperation processes,  
18 this paper identifies a set of measurable items in accordance with the dimensions of CBRIS  
19 development and proximity. In short, the paper will propose a set of indicators to enable  
20 researchers to analyze and compare different CBRISs in terms of their 1) distance in various  
21 dimensions of proximity as well as 2) levels of integration and intensity of cross-border  
22 knowledge transfer.  
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36 The remainder of this paper is organized as follows. First, the conceptual background of the  
37 CBRIS literature is presented. Second, the analytical framework is introduced together with  
38 reflections on the (relevant) geographical scales of analysis and illustrative empirical cases of  
39 CBRs which are indicative of its feasibility. Third, the utility of the proposed empirical  
40 validation, in the light of the conducted feasibility check and relevant literature, is discussed  
41 in the concluding section together with suggestions for further studies.  
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## 48 **CROSS-BORDER REGIONAL INNOVATION SYSTEMS AND DIMENSIONS OF** 49 **PROXIMITY**

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

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

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

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3 applications and new sectors, while building on their current knowledge bases and  
4 competences (Asheim *et al.* 2011; Weidenfeld 2013). Relational proximity must be limited as  
5 too much proximity might lead to overlap and create lock-in effects and competition. In  
6 contrast, limited relational distance engenders complementarities and interactive learning  
7 (Boschma, 2005). In particular, high levels of similarity in terms of sharing a technical  
8 language are important, but as shown by Huber (2012) a certain degree of dissimilarity in  
9 terms of know-how, know-what and the way of thinking can be fruitful for R&D workers.  
10 Therefore, balanced levels of relational proximity between sectors on both side of the border,  
11 including some degree of dissimilarities and complementarities, could increase integration  
12 while maintaining cross-border knowledge transfers. Hence, related variety would constitute  
13 a propitious base for collaboration leading to a higher degree of integration within CBRISs.  
14 Additionally, reflecting the current ethos of the European Union in promoting “smart  
15 specialization”, the CBRIS concept could be discussed under “joint-specialization” (Muller *et*  
16 *al.* 2015). Knowledge producers on one side of the border could be linked to knowledge users  
17 and applicants on the other side. Nonetheless, this also requires a certain level of common  
18 knowledge base and shared technological expertise.  
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31 While there is an emerging conceptualization of CBRISs, **in terms of related variety and the**  
32 **different dimensions of proximity**, the empirical evidence remains limited. To date only a few  
33 studies have empirically tested or sought to validate CBRIS integration. Notably, with a  
34 specific emphasis on the biotech industry in the Øresund CBR, Hansen (2013) has  
35 emphasized the importance of the dimension of accessibility for heightened cross-border  
36 integration. However, he further underlined that improvements in accessibility do not in  
37 themselves guarantee intensified integration, if they are not supported by targeted policy  
38 measures. Additionally, the local Øresundskomiteen (i.e. the committee responsible for  
39 political collaboration in the Øresund CBR) has constructed and employed an index  
40 measuring the “growth of integration” in the CBR since the opening of the Øresund Bridge in  
41 2000. Unfortunately, the index ([http://www.oresundskomiteen.org/en/2013/10/the-oeresund-](http://www.oresundskomiteen.org/en/2013/10/the-oeresund-integration-index/)  
42 [integration-index/](http://www.oresundskomiteen.org/en/2013/10/the-oeresund-integration-index/)) does not cover innovation cooperation, but measures cross-border  
43 mobility (traffic, migration and commuting), trade volumes and cross-cultural mingling.  
44 Other than this study, a rather descriptive attempt to define empirically the varying levels of  
45 integration according to different dimensions of proximity in the Øresund and Centrope  
46 CBRs (Lundquist & Trippel 2009) is the only existing attempt to validate the concept of  
47 CBRIS as a whole. It uses statistics on shares of employment, number of students and R&D  
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3 personnel, and is an important point of reference for the analytical framework discussed  
4 below. More recently, however, the concept has also aroused initial criticism: firstly, for its  
5 macro-level systems perspective that under-appreciates the role that individual actors and  
6 institutions can have in facilitating cross-border cooperation; and, secondly, for its focus on  
7 cross-border linkages that ignores the role that national and international networks can have  
8 in steering CBRIS integration (van den Broek & Smulders 2014; 2015). Therefore, while  
9 there is considerable debate about conceptualization of CBRIS, it is important to stress that  
10 for empirical purposes the concept of CBRIS adopted here is quite straightforwardly drawn  
11 from the publications by Trippl (2010) and Lundquist and Trippl (2009; 2013).  
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### 20 **DEVELOPING AN ANALYTICAL FRAMEWORK**

21 The suggested framework in this paper combines the importance of different types of  
22 proximities with the stages of integration of CBRISs in order to provide an approach to the  
23 empirical treatment and validation of the concept. However, the scaling used in for example  
24 Lundquist and Trippl's (2009) study is fairly subjective, and there are no readily available  
25 benchmarks on every dimension which allow the determination of what is close and what is  
26 distant in term of the various dimensions of proximity. Therefore, in order to investigate the  
27 concept of CBRIS we are faced with the question of how best to describe and measure the  
28 different dimensions presented in Table 1, that is, how to operationalize them. Keeping in  
29 mind the difficulties involved in collecting data for regions from various countries, and the  
30 fact that this is the first attempt to develop a comprehensive empirical framework for testing  
31 the feasibility of the CBRIS concept, the researchers proposed the operationalization of  
32 measures presented in Table 1.  
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46 In relation to the scopes of study presented in the proposed analytical framework (Table 1), a  
47 distinction is made between quantitative and qualitative studies (Punch 2014). Preferably,  
48 both approaches should be applied in the study of CBRIS dimensions; quantitative accounts  
49 provide the big picture and generalizations and qualitative studies probe in greater detail what  
50 lies behind the observed numerical illustrations. Consequently, qualitative studies can be  
51 applied for building hypothesis to be tested with quantitative methods and larger sets of  
52 CBRs. However, in practice there are difficulties in operationalizing some dimensions of  
53 CBRIS into measurable indices discussed below.  
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**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,

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3 these measures can be seen as complementary. Even though the dimension can be analyzed  
4 with quantitative data at the EU-level, the employment of qualitative study settings is  
5 advisable for detailed descriptions involving interviews with, or questionnaire surveys of,  
6 researchers, policy-makers, etc. Qualitative studies would help discovering the causes behind  
7 the limited levels of cross-border cooperation and the impacts of integration into other non-  
8 quantifiable aspects of cross-border scientific cooperation in relation to the regional science  
9 bases and knowledge infrastructures.  
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16 **Nature of linkages** – Similar innovation performances are critical for successful knowledge  
17 sharing between regions (Maggioni & Uberti 2007). Hence, if a CBR is constructed from  
18 regions with differing innovation performance (strong vs. weak) little knowledge is expected  
19 to flow between them. In addition to secondary descriptive innovation measurements (e.g. the  
20 Regional Innovation Scoreboard based on data from the Community Innovation Survey), the  
21 dimension of linkages should be operationalized through technological and cognitive  
22 proximity lenses. This can be achieved by exploring the similarity or dissimilarity of  
23 patenting behavior, whereas cross-regional knowledge flows and linkages can be analyzed  
24 through data on co-patenting (Jaffe & Trajtenberg 1999; Paci & Usai 2009), in this case, on  
25 the opposing sides of the border. Here again, a “Technological Proximity Index”,  
26 operationalized in line with the CPM (Equation 1) – but according to the International Patent  
27 Classification (IPC) (Jaffe 1986; Peri 2005) – would provide useful information on the  
28 similarities/dissimilarities on patenting behavior across the border. Again, the expected  
29 outcomes are likely to resemble that of an inverted U-shape (Mowery *et al.* 1998; Nooteboom  
30 *et al.* 2007). Of course, patents are not the only type of cross-border knowledge flows with  
31 potential for innovations. Thus, in addition to the well documented joint-patent data (e.g. the  
32 PATSTAT database of the European Patent Office), additional measures on R&D  
33 collaboration (e.g. the CORDIS database of the European Commission) or outsourcing and  
34 product licenses would contribute to acquiring a fuller picture of integration in terms of  
35 (innovation) linkages between bordering regions. Again, as in the case of the science base  
36 and knowledge infrastructure, the use of qualitative study material should also be encouraged.  
37 Similarly, applying methods from social network analyses could provide valuable  
38 information on the personal and organizational linkages across the border in order to  
39 contribute to a better understanding of which types of cross-border linkages matter most in  
40 economic terms (Ter Wal & Boschma 2009).  
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3 **Institutional set-up** – There are three reference points for institutional set-up: institutional  
4 proximity, understood as differences in informal and formal rules, social proximity, i.e. long  
5 standing and trust-based linkages amongst partners co-operating across borders, and cultural  
6 proximity, for example a shared language (Lundquist & Trippel 2009). The institutional set-up  
7 is visible through the existence or non-existence of: 1) informal institutions, that is the social  
8 acceptance of CBRISs integration, 2) formal institutions, that is the existence of common  
9 institutions and practices (projects) aimed at enhancing the integration between the border  
10 regions, 3) social trust and 4) cultural similarities amongst the inhabitants of bordering  
11 regions. In operationalizing such an intangible dimension of CBRIS integration, the lack of  
12 available statistics describing the dimension means that secondary data offer little support for  
13 extensive quantitative analyses. In a quantitative approach, when using econometric and  
14 statistical methods, institutions could be modelled by employing dummy variables or indices  
15 based on various sources (see below). However, the institutional set-up dimension would  
16 benefit from being operationalized through qualitative studies. Formal institutions can, up to  
17 a certain point, be observed through desk studies. The informal and trust aspects of  
18 institutional set-up require primary data collection, typically via questionnaire and interview  
19 data, in order to derive a picture of the acceptance of CBRIS integration, and social trust,  
20 between the inhabitants of differing sides of the border (van den Broek & Smulders 2014).  
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34 Additionally, an all-encompassing feature is the importance of cultural proximity (Bhagat *et*  
35 *al.* 2002). However, while a common and shared culture strongly influences the other  
36 dimensions of proximity, it is of particular relevance for the notion of institutional proximity,  
37 since it includes a set of cultural habits, values and norms (Boschma 2005). These cultural  
38 dissimilarities can be measured quantitatively and qualitatively in terms of linguistic and  
39 ethnic distance or differences in values (Lundén & Zalamans 2001; Serva & Petroni 2008;  
40 Minkov & Hofstede 2014). In short, knowledge flows more easily across borders if the  
41 adjacent populations share common cultural features. However, in practice the intangible  
42 nature of institutional, cultural and social proximities, together with the problems in  
43 operationalizing the dimension into measurable items, render institutional set-up mostly  
44 outside the scope of quantitative EU-level analyses.  
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54 **Policy structures** – The dimension of policy structures is related to the formal dimension of  
55 institutional proximity. The factors which hinder integration are low levels of interest from  
56 the respective nation states, and an overly strong top-down direction of local actors in their  
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3 corresponding regional and national innovation systems (Lundquist & Trippel 2009).  
4 Therefore, the policy structures dimension could be studied through shared (innovation,  
5 science and regional) policy goals at the national and local levels. That is, do both sides of the  
6 border consider cross-border collaboration, joint-innovation and R&D cooperation in similar  
7 ways, and do the existing policy documents recognize the importance of cross-border  
8 collaboration for innovation. The operationalization of policy goals into measurable  
9 indicators presents considerable challenges, and requires a qualitative approach. This would  
10 involve studying the documentation of existing policies and strategies complemented with  
11 interview or questionnaire data on the opinions of local and national policy-makers.  
12 Therefore, statistical EU-level studies with measurable data on shared policy goals at the  
13 national and local levels would require extensive amounts of data collection and subjective  
14 operationalization. A possibility exists, however, of constructing indices for tentative and  
15 illustrative analyses (see below) or using dummy variables for econometric analyses, but in  
16 practice detailed investigations of the dimension of policy structures are likely to lie outside  
17 the scope of further quantitative studies of CBRIS integration.

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30 **Accessibility** – This dimension refers to physical proximity, which facilitates cross-border  
31 knowledge transfer (Lundquist & Trippel 2009). However, the absolute distance between  
32 regions is not as important as the actual time and costs of transactions – which to some extent  
33 can be captured by travel time calculators and the methods of transport geography (Salonen  
34 2014). Therefore, the accessibility dimension should additionally be described through the  
35 ease and volume of cross-border traffic. Inside the Schengen Area, due to the freedom of  
36 movement provisions, measuring the ease of cross-border traffic is less acute compared to  
37 other parts of the world. However, in some circumstances, for example when examining case  
38 regions on the external EU-borders, the issue is highly relevant. In addition, the volumes of  
39 cross-border traffic can be employed to describe the intensity of cross-border flows in terms  
40 of tourism and commuting (Deconville *et al.* 2013; Weidenfeld 2013; Durand & Nelles  
41 2014), which are both highly significant for knowledge transfer and CBRIS integration.

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51 **Geographical scale** – The geographical scale to which the CBRIS framework refers poses an  
52 interesting question: does every region have a RIS, and every CBR a CBRIS? Moreover, it  
53 also re-introduces the problematic of delineating an innovation system (Isaksen 2001;  
54 Carlsson *et al.* 2002; Doloreux & Parto 2005). In addition to official EU-level classifications,  
55 such as NUTS and LAU regions, cross-border twin cities, for example, might offer  
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3 interesting cases since the development of cross-border linkages is more concrete and  
4 mundane in twin cities than is evident at larger geographical scales (Eskelinen & Kotilainen  
5 2005; Joenniemi & Sergunin 2011). Thus, twin cities are a fitting example of CBRs in the  
6 way that Perkmann (2003) has described them: indeed, they commonly are bounded regional  
7 units of authorities participating in cross-border cooperation. National policies also affect the  
8 reasoning here: in many countries, the regions have limited legislative and regulative power,  
9 whereas cities have a more direct influence, for example in the right to levy taxes. Therefore,  
10 even though large regions have greater possibilities (in terms of population, resources, etc.)  
11 for interaction, they commonly lack regulatory powers (Sotarauta & Kautonen 2007), which  
12 support the use of smaller regional scales, such as twin cities, in CBRIS analysis. Thus, the  
13 appropriate size of a region to be considered as an effective CBRIS remains an open question.  
14 Consequently, it is likely that the appropriate geographical scale is country- and CBR-  
15 specific, that is, it depends on the local peculiarities and flows of people, trade and  
16 knowledge, as well as on national and regional regulatory power divisions (see Weidenfeld  
17 2013). In addition, rather than depicting CBRs with little or no cross-border interaction as  
18 weakly integrated systems, globally it might be more apt to designate some CBRs as lacking  
19 even the most basic characteristics (interaction, knowledge flows, significant cross-border  
20 traffic, etc.) of CBRISs, and therefore having no system at all. Quite simply, there is a need to  
21 recognize that, due to the nature of CBRs, the dynamics of innovation systems in cross-  
22 border regional settings may be absent.

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

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

27 The possibilities of researching CBRIS integration have been discussed here in terms of the  
28 combination of varying dimensions of proximity. An analytical framework, with suggestions  
29 on measurable items and the scope of research, was proposed as a basis for further studies to  
30 validate the theoretical underpinnings discussed in the earlier literature on CBRIS integration  
31 (Trippel 2010; Lundquist & Trippel 2013). In line with this, the problematic of delineating a  
32 suitable geographical scale for analyzing CBRISs was discussed in the light of earlier critical  
33 reflections on the concept of RIS. In short, it is probable that world-wide many CBRs lack the  
34 preconditions for successful cross-border collaboration that are a precondition for developing  
35 into strongly integrated CBRISs. This, however, does not mean that the concept of CBRIS  
36 lacks utility when considering and analyzing the economic development and future prospects  
37 of CBRs, especially in the European context. On the contrary, the concept of CBRIS is  
38 advanced here as an interesting and important direction for further studies into borderlands  
39 and cross-border cooperation. The illustrative analysis of the empirical cases provide  
40 tentative but promising support for the feasibility of the framework for validating the  
41 conceptual remarks on CBRIS. The analysis indicates, that proximities do matter for CBRIS  
42 integration: more integrated regions score higher on the measured dimensions that are based  
43 on varying types of proximities. It also suggests that, once operationalized as in our  
44 examples, the concept of CBRIS can be useful for empirical cross-regional comparisons of  
45 border regions by revealing their levels of integration. However, it has to be kept in mind  
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3 that, due to data availability issues, the suggested indicators (patents, publications, etc.)  
4 depict innovation in a rather narrow “Science, Technology and Innovation” mode. A broader  
5 view, including also the “Doing, Using and Interacting” mode of innovation (Jensen *et al.*  
6 2007), would require other indicators that are more challenging in comparable cross-border  
7 contexts.  
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12 Therefore, since the framework presented here remains one of the first attempts to describe a  
13 feasible approach for further studies, further developments of the framework and empirical  
14 studies to validate it are required in order to draw more definite conclusions about the  
15 integration processes in CBRISs. Such research should encompass analysis, utilizing  
16 quantitative data to depict the impacts of different observable measures and dimensions  
17 (related to cognitive and technological proximities) on the ease, volume and impacts of  
18 knowledge flows in cross-border settings. As it stands, the relative availability of statistics on  
19 internal EU-borders offers a possibility for further statistical studies, using quantitative data,  
20 to test and model the impacts of different types of linkages and knowledge flows on the  
21 integration processes of CBRISs. However, in keeping with the ethos of the EU (European  
22 Commission 2012), the external EU-borders should not be excluded from these analyses,  
23 which signifies the need for more comprehensive data collection between the neighboring  
24 regions of the EU.  
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36 Further statistical studies should take advantage of the existing databases to combine a  
37 comprehensive dataset for analyses on a quantitative EU-level. In line with this, further  
38 elaborations of the more intangible aspects of CBRIS integration through the use of  
39 questionnaires and interviews directed at city officials, regional development agencies, local  
40 companies, etc. will contribute to drawing a more precise picture, for example, in terms of the  
41 impacts of formal and informal institutions and social acceptance of integration (i.e.  
42 institutional and social proximities). This is highlighted here as an important avenue for  
43 further studies. On a qualitative scale, this should include the operationalization of  
44 questionnaire items with survey data as well as a study approach that employs interviews to  
45 provide a better understanding of the processes that lie beneath the quantitative aspects of the  
46 integration of CBRIS.  
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56 To conclude, the conceptual literature on CBRISs has, thus far, only explored several related  
57 issues of innovation systems, proximity and integration without much emphasis on depicting  
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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

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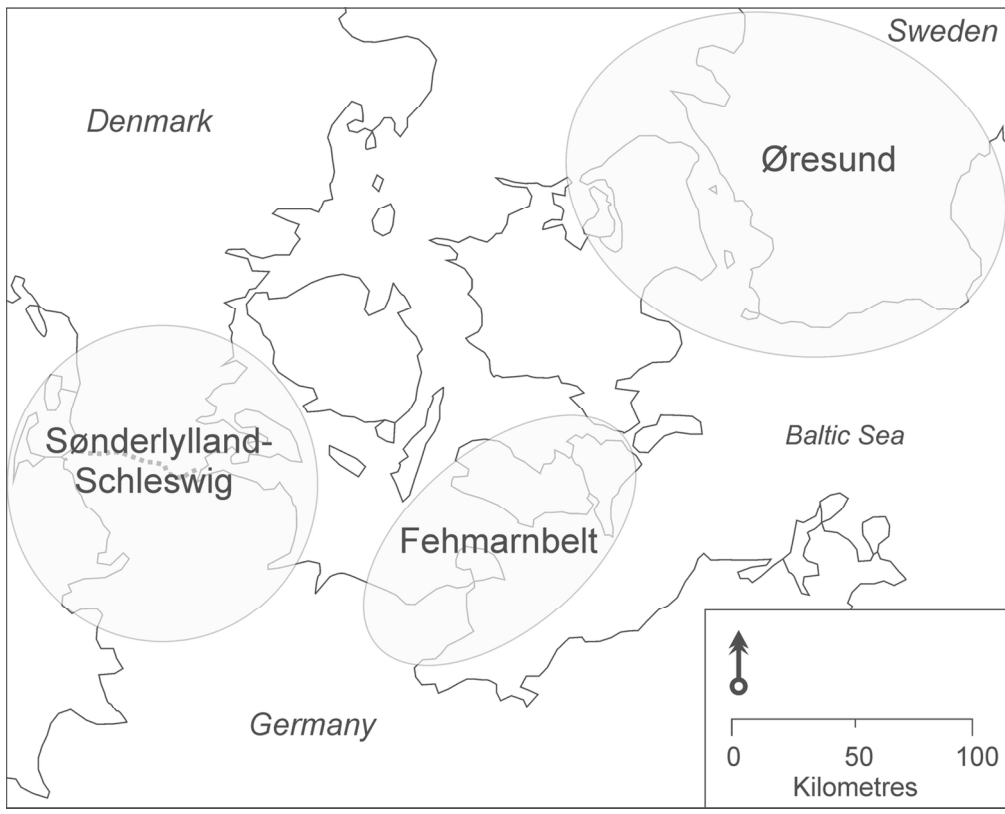


Figure 1. Øresund, Fehmarnbelt and Sønderjylland-Schleswig.  
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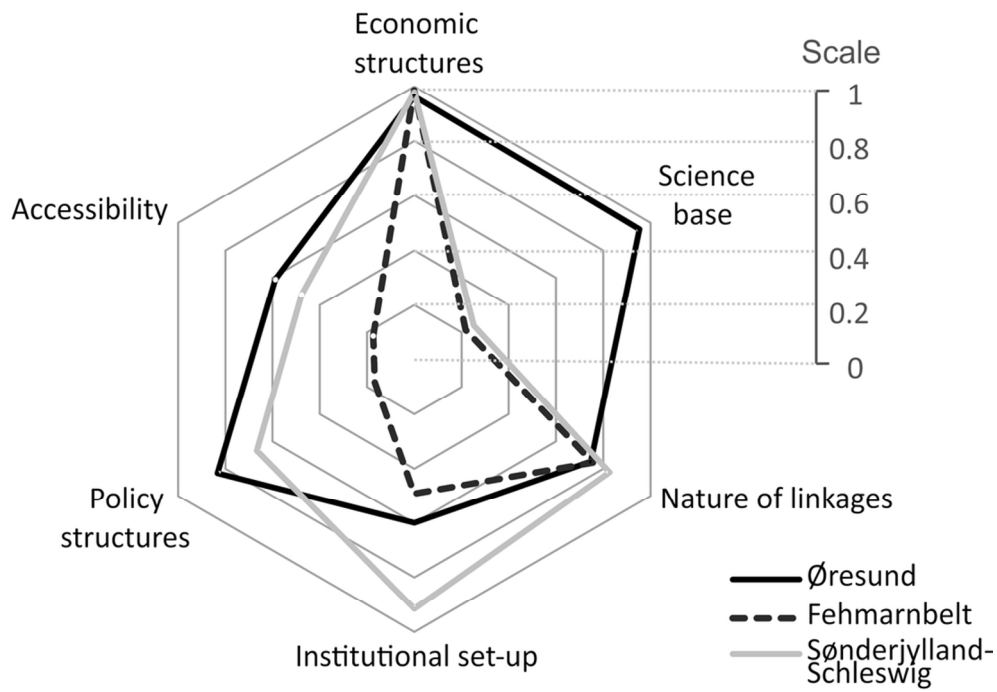


Figure 2. Proximity measures and index scores for the different dimensions of CBRIS integration in the selected regions.  
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