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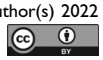

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Bringing borders back into cross-border regional innovation systems: Functions and dynamics

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Abstract
International boundaries have been mainly considered as barriers in literature on the 'cross-border regional innovation system' (CBRIS), in line with their traditional understanding. In this paper, we underline that such a perspective presents limits, and argue in favour of an understanding of multidimensional borders that are subject to dynamic change over time. By mobilizing conceptualizations from the field of border studies, we examine the various functions of borders to explain the innovation-led development potential in cross-border regions. In this view, international borders can function as an interface, a marker of difference or a symbol, rather than a mere barrier that separates regions. Further, we suggest that these border functions are key factors in explaining the 'fluctuating' integration dynamics of regional innovation systems across the border. Mobilizing evidence from two case studies in European and North American contexts, the paper sheds light on the border as a potential resource for innovation and discusses implications for future research.

Keywords
Border, cross-border regional innovation system, innovation, border studies, integration

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Introduction

The *cross-border regional innovation system* (CBRIS) is a concept coined by Trippl (2010) and further developed as a conceptual model by Lundquist and Trippl (2013). It applies the well-known economic-geographical framework of the *regional innovation system* (Cooke, 1992; Cooke et al., 1998) to cross-border regions (CBRs) and draws attention to a joint innovation[1] system inducive to regional economic development and planning. One of the main contributions of the CBRIS concept has been to grasp a fuller, system-wide integration across the border as the 'spark that could ignite' innovation-led economic development in CBRs. The CBRIS model by Lundquist and Trippl (2013) is based on various forms of proximity[2] and devises three ideal integration stages (weakly integrated, semi-integrated and strongly integrated systems) to assess CBRs and, arguably, to assist in designing cross-border innovation policies. In short, the more a CBR is integrated, the more innovation is to be expected.

Following these seminal contributions, a multitude of studies have addressed innovation and integration in CBRs by scrutinizing barriers resulting from the lack of geographical as well as relational facets of proximity. Case-study research has notably shown that the relationship between the different proximity types and integration is much more ambivalent than suggested by the CBRIS concept. For example, in contrast to what would be expected, even CBRs with high relational proximity are very rarely strongly integrated (Peck and Mulvey, 2018; van den Broek et al., 2018a, 2018b, 2019; Cappellano and Makkonen, 2020a), whereas differences in culture and institutions do not necessarily create barriers to – and sometimes even facilitate – joint cross-border innovation processes (Makkonen et al., 2018a). The different aspects that form the CBRIS model seem not to be related in a linear fashion: some improvements in terms of cross-border integration can spur innovation, whereas other cross-border integration patterns do not – or are less prone to – do so.

Against this background, the aim of this paper is to propose a conceptualization of CBRIS that takes better into account the multidimensional and dynamic character of borders as a key aspect in innovation-driven cross-border integration processes. The premise underlying this claim is that borders are dynamic institutions and exert different and often ambivalent effects over cross-border integration (Decoville and Durand, 2019). As such, the process of opening borders does not necessarily follow a linear trajectory. Instead, pitfalls and successes can alternate, originating in what border scholarship has termed as 'de-bordering' and 're-bordering' (Cassidy et al., 2018). Those processes yield ambivalent implications to the local and regional actors sharing knowledge and resources to spur innovation in CBRs. Notably, we contend that in cross-border contexts, innovation does not simply develop thanks to the dismantling of the barrier effects of borders (despite its benefits), but that a combination of different border functions is involved. The opening of borders may facilitate CBRIS integration dynamics, but at the same time barrier effects linked to cultural or institutional differences may persist (Miörner, et al., 2018; van den Broek et al., 2018a). In contrast to the main rhetoric of the CBRIS concept, which considers borders mainly as barriers or filters, we argue that borders can take on different 'functions' (Sohn and Licheron, 2018) that either favour innovation in CBRs or hinder it. The research questions addressed in this paper are: (1) What are the effects of the different border functions on the development path of CBRIS? (2) To what extent does the border functions approach allow to better understand regional interaction processes at the cross-border level?

While the concept of cross-border integration has been extensively debated there is no consensus on its exact definition (Sohn, 2014). Hereinafter, we mainly focus on considering CBRIS integration dynamics (i.e. cross-border knowledge flows, cross-border innovation cooperation, etc.), while using cross-border interaction as a broad umbrella term for other 'types' of cross-border integration not strictly related to innovation (i.e. cross-border commuting, cross-border shopping, delivery of cross-border public services).

We examine the role of border functions on the integration dynamics of CBRIS in two stages. First, we identify on a theoretical level what the expected impacts of borders are on the formation of regional innovation systems (RIS) reaching across national boundaries. We discuss the ambivalent effects of the functions of 'separation', 'contact', 'differentiation' and 'affirmation' and highlight the added value of this conceptualization in relation to the conventional CBRIS model based on the proximity framework. Secondly, we use two case studies to empirically illustrate the conceptual advances that we propose and scrutinize their analytical relevance: the Øresund region at the Danish–Swedish border and the San Diego–Tijuana region at the US–Mexican border. They appear as highly contrasted cases marked by an open border for the European case and a heavily controlled border for the North American case. The conventional approach of CBRIS tends to consider the Øresund region as an example of high cross-border integration and the San Diego–Tijuana region as an instance of a CBR not conducive to this type regional development. The mobilization of the border functions analytical grid offers a more nuanced reading of the trajectories of cross-border innovation at work. The limits encountered in the development of a CBRIS in the Øresund region thus find new explanations, as does the emergence of integrated innovation patterns in the San Diego–Tijuana region despite an unfavourable border context.

The remaining part of the paper is structured as follows: the subsequent section will present an overview of the CBRIS concept and provide a critical review of its limitations. The section 'Multiple functions of borders in cross-border regional innovation systems' outlines the main innovative aspects of our approach: that is, to explore how to complement the CBRIS model with the literature on border functions. The section 'Case study analysis' investigates the cases of the Øresund region and the San Diego–Tijuana region in order to provide empirical evidence supporting the conceptual arguments of the paper. Lastly, the concluding section discusses the implications of the suggested framework for research.

Critical review of the cross-border regional innovation system model

The cross-border regional innovation system model and its main contributions

The literature on CBRIS draws from several earlier concepts of localized learning and innovation, such as clusters and learning regions (Maskell and Törnqvist, 1999; Rohde, 2016), but is particularly embedded in the literature on RIS. Since the establishment of the concept in the early 1990s, the literature on RIS has investigated their development in different geographical settings. Research has derived extensive empirical evidence supporting the view that facilitating the functioning of RIS (e.g. by increasing interaction between local organizations) increases regional innovativeness and subsequent economic development. Therefore, the RIS approach has become both a powerful framework for explaining the uneven geographical distribution of innovation, and a policy tool for facilitating innovativeness (Asheim et al., 2019). The RIS model centres around two elements: (1) the knowledge generation and diffusion subsystem (universities, research institutes, etc.) and (2) the knowledge application and exploitation subsystem (companies). Extensive interaction within and between these sub-systems is expected to create the foundations for enhanced regional innovativeness. Interaction is supported by local socio-cultural factors and can be facilitated by regional policies.

The basic idea behind CBRIS is that in cross-border settings, two separate RIS exist on opposite sides of a border. The integration of these systems should thus increase the innovativeness on both sides of the border, in turn leading to subsequent economic growth. Extending RIS across the border should therefore create a larger knowledge pool and generate the potential for benefits from synergy, and so on. This realization led Trippl (2010) and Lundquist and Trippl (2013) to coin the CBRIS model as a conceptual framework to investigate the potential and effects of the

cross-border integration of RIS. In the CBRIS model, integration is expected to depend on several dimensions: (1) economic structure, (2) science base/knowledge infrastructure, (3) nature of linkages, (4) institutional set-up, (5) policy structures and (6) accessibility. These dimensions are heavily influenced by the level of proximity within and between the subsystems across the border. The assumption is that the easier it is to cross the border (geographical proximity), the fewer legislative and norm-related barriers to cooperation (institutional proximity), and the more the actors across the border understand each other (cognitive, cultural and social proximity), then the more intensive the cooperation within a CBR. In short, a high degree of proximity is expected to facilitate integration. Therefore, the concept of proximity constitutes the second major conceptual foundation that the CBRIS model builds on.

Lundquist and Trippl (2013) also proposed a simplified model for CBRIS integration. It envisions three ideal stages of integration: (1) weakly integrated, (2) semi-integrated and (3) strongly integrated systems. In a weakly integrated system, each side of the border is embedded in its own regional and national innovation systems, with limited cross-border interaction due to low proximity and the strong barrier effect imposed by the border. The model outlines a stylized development pattern from this weakly integrated system through an emerging semi-integrated system (as the border's separation effect diminishes) towards a final stage of a strongly integrated system. In this final stage, the border (almost) completely 'vanishes' due to high proximity and the RIS on both sides of the border are intertwined into a common interconnected CBRIS.

The relevance of the CBRIS concept is based on the idea that the economic success of CBRs will increasingly depend on their ability to create cooperative ties and economic interactions with neighbours across the border (Lundquist and Trippl, 2013); a view shared by policymakers (OECD, 2013; European Commission, 2017). Consequently, the CBRIS approach has had an impact on scholarly debates concerning the benefits of cross-border cooperation in driving the economic development in borderlands. It has led researchers to focus on the factors that facilitate or hinder cross-border cooperation, and on the effectiveness of policies to promote it. Both topics are highly relevant for policymakers interested in the socio-economic development of border regions. However, as the CBRIS is a relatively new concept, the literature still rests on a thin empirical evidence base (Wang, et al., 2021) and thus leaves room for further conceptual and analytical improvements.

Earlier literature and the shortcomings of the cross-border regional innovation system model

As a start, it is important to recognize that some of the shortcomings of the CBRIS model were already underlined by Lundquist and Trippl (2013: 454) in their seminal paper:

> Firstly, the three stages represent ideal types. In the real world the distinction between the three stages might not be as clear-cut as in the conceptual model. Cross-border areas which, for instance, display semi-integration in one dimension can be more or less strongly integrated in other dimensions. Secondly, although conditions for further development will be discussed, this does not imply that cross-border areas move necessarily or automatically from one stage to the next one.

These two considerations are important. The first recognizes that cross-border integration in real-world cases (i.e. CBRs) is not a monolithic reality but rather that CBRIS occurs in a 'selective' manner, concerning certain domains or sectors of activity but not necessarily the entire regional economy. As a result, CBRs are often positioned somewhere between the different stages of integration (most probably between stage one and stage two, as stage three seems somewhat utopian). The second point recognizes that there is no straightforward and incremental development

trajectory or pathway. In fact, little is said about how a CBR can actually expect to move from one stage to another (i.e. what dimensions and what type of proximity are crucial to develop some form of systemic innovation dynamics?). Hence, the limited practical use of the CBRIS model for analytic and policymaking purposes.

Further, Lundquist and Trippl (2013) acknowledge the complexity of the proximity framework, and state that cross-border differences in economic structures and innovation capabilities can both hinder and drive cross-border integration processes. They mobilize the concept of 'related variety' to postulate that regions on both sides of the border should be close but not too close in terms of the different dimensions of proximity. They claim that at their highest stage of integration two border regions can reach a degree of variety which allows sharing similarities and complementarities in their industry sectors, knowledge bases and proximity dimensions. However, they leave it open in what circumstances differences across the border can act as the driving force behind cross-border integration.

Subsequent literature on CBRIS has made an effort to elaborate this conundrum. A review by Makkonen and Rohde (2016) summarized the literature on CBRIS up to 2015, arguing that at this early stage the field was suffering particularly from fuzziness in the varying definitions of proximity and from difficulties in empirically analysing complex issues such as the process of cross-border integration. There have been more recent attempts to offer potential methodological solutions and metrics for combining knowledge about the measurement of proximity into the CBRIS literature (see e.g. Makkonen et al., 2018a). However, the conclusion in these quantitative studies has been that although there are opportunities for operationalizing some aspects of proximity (e.g. cognitive), measuring most of the dimensions (e.g. institutional) is by no means a straightforward task. This shortcoming in the analytical treatment of the model – coupled with the non-existence of comparable regional and cross-border data, and the labour-intensive nature of collecting such data (Kaisto, 2016) – has resulted in a relatively small number of CBRIS studies that utilize quantitative methods.

Most of the insights concerning the CBRIS model are therefore derived from qualitative case studies. These studies include investigations into company-level cross-border innovation cooperation (van den Broek et al., 2018a, 2018b), the role of universities and non-profit organizations in cross-border integration (van den Broek et al., 2019; Cappellano and Makkonen, 2020b; Cappellano et al., 2020), the impact of institutional change and funding programmes on cross-border innovation cooperation (Peck and Mulvey, 2018; Makkonen et al., 2018b; Miörner et al., 2018) and the potential for adopting common cross-border innovation policies (Tõnurist and Kattel, 2017; Muller et al., 2017). These studies have shown that even CBRs with relatively high levels of (cognitive, cultural, institutional, social or geographical) proximity report low levels of cross-border innovation connections and integration, in contrast to what is suggested in the conceptual definition of a strongly integrated CBRIS by Lundquist and Trippl (2013). For example, van den Broek et al. (2018a) show how companies seeking partners and knowledge resources across the Dutch–Flemish border (characterized by considerable similarities) still need to 'cross' the border and address the various effects it brings. These border effects differ at each stage of the development of cross-border innovation networks, and stem from the different roles borders play in various domains (e.g. delimiting typical networking areas, administrative systems, working cultures, etc.).

Lastly, by scrutinizing the actors involved in cross-border innovation activities, it appears that the presence of relational distance across the border does not always play a negative role, as could be expected based on the conceptual definition of a weakly integrated CBRIS by Lundquist and Trippl (2013). Of course, cultural differences such as different languages typically increase transaction costs and may therefore represent a barrier to cross-border communication (Nijkamp et al., 1990; Capello et al., 2018). However, cultural differences can also create learning

opportunities, thereby facilitating knowledge transfer and acting as catalysts for engaging in collaboration in the first place (Makkonen et al., 2018b). In the realization phase, differences in language, norms, values and business culture do not necessarily influence the collaboration substantially (van den Broek et al., 2018a). Border-induced economic differentials, such as differences in price levels or cost structures, appear to have contrasting effects on CBRIS integration. Trippl (2010) considers this type of 'exploitation' of cross-border differentials as a 'low-road' to cross-border integration and contrasts it with a 'high-road' path to integration induced by innovation-driven development. However, she also states that such economic differentials based on exploitation may – although this is considered as challenging – pave the way for future innovation. Cross-border differences in economic development levels can also appear as complementary and be considered key drivers for regional innovation (or innovation diffusion), as evidenced in the case of tourism products and services (Makkonen et al., 2018b).

These results suggest that there is a need to rethink how borders and cross-border integration are approached in the CBRIS model. As it is, the model treats the border almost as a binary function. On the one hand, borders constitute barriers that hamper cross-border cooperation. On the other hand, borders also provide opportunities to benefit from cross-border differentials. We argue that the CBRIS model would benefit from a multidimensional and dynamic understanding of borders that would be more in line with how they are approached in contemporary border studies literature.

Multiple functions of borders in cross-border regional innovation systems

In a practical sense, borders are commonly assumed as territorial boundaries that divide countries and delineate national sovereignty. However, under the impetus of social and (geo)political changes that have occurred over the last three decades, borders do not appear as fixed or given, but as fluid and multifarious. Within border studies and cognate fields, borders are considered to emerge through social and political processes of border-making that take place in society. Hence, they are constantly (re)produced and contested (Kolossov and Scott, 2013; Newman, 2003).

The idea that international borders play multiple functions informing innovation dynamics in CBR is seeded in the literature: van den Broek et al. (2018a) describe how international borders work both as a 'portal' and a 'barrier' facilitating and hindering local actors to interact and share resources for innovation. In order to take into account the multidimensional and dynamic nature of borders, we seek to complement the CBRIS model with four border factors that Sohn and Licheron (2018) have outlined as potential positive/negative externalities for urban and regional development in CBRs. We adapt their framework to understand different functions that borders may represent for a CBRIS. In so doing, we conceive borders as an opportunity structure, that is to say, a set of constraints and opportunities that are characteristic of the context actors' practices are embedded in, and which contribute to shaping these practices (Horstmann and Wadley, 2006). This means that the different effects that borders can have on the formation of CBRIS should not be taken for granted. Local and regional actors need to activate these opportunities by perceiving them as such and by mobilizing them. In other words, our approach is awarding emphasis on the role of strategic agency played by (heterogeneous groups of) actors, which receives little attention in the CBRIS model by Lundquist and Trippl (2013).

Table 1 displays the four border factors: separation, contact, differentiation and affirmation. **Separation** is essentially the conventional negative impact of borders' barrier effects induced by contiguity diseconomies. The **contact** function – which is, in essence, complementary to the separation function – considers borders as an interface or contact zone. The expected effect of such a function on the economic development of border regions is ambivalent. According to economic theories

Table 1. The multiplicity of border effects.

	Main rationales for:	
Border factors	Expected negative effect	Expected positive effect
Separation (Barrier)	Barrier effect	N.A.
Contact (Interface)	Negative cross-border spillovers	Positive cross-border spillovers, Scale and agglomeration economies, Gateway functions
Differentiation (Marker)	Cross-border economic differentials ('low-road' exploitation) Institutional and cultural differences Social and mental distances	Cross-border economic differentials (potential starting point for integration), Cross-border economic complementarities, Institutional and cultural hybridization
Affirmation (Symbol)	National identity Reinforcement of 'us' versus 'them' Socio-spatial differentiation	Regional identity and external marketing and branding

Source: Adapted from Sohn and Licheron (2018).

(in particular New Economic Geography models), border regions face two counteracting forces: increased market access and increased import competition (Brülhart, et al., 2004). On a theoretical level, there is no consensus on whether border regions benefit from opening borders and cross-border integration (Niebuhr and Stiller, 2004). There are also no clear-cut conclusions in empirical studies concerning the impact of interaction on border regions. Among the reasons that plead in favour of a positive effect of the contact function of border regions, one can highlight scale and agglomeration economies (i.e. increased market access), cross-border spillovers (i.e. positive effect of flows from the neighbouring region or country) and territorial gateway functions (i.e. polarization of flows in specific border-crossing locations). Yet, all these aspects can also turn out to have a negative impact for border regions. In some instances, import competition can downplay the potential advantage of increased market access. Cross-border spillovers can have a negative impact on a CBRIS, especially if they result from economic downturns, political crises or violence occurring in the neighbouring country. Flows of goods, persons or information can also circumvent or simply pass-through border locations without generating specific activities or synergies. Therefore, it is only through contextualized analyses that one can determine if and to what extent the contact function of borders can be beneficial for CBRs and innovation-led patterns of development.

In the original CBRIS framework, the separating and connecting effect of the border is mainly considered in terms of geographical proximity. The more a border is open and the more efficient the border-crossing infrastructures, the better the effect on CBRIS. While we agree that this might be the case in some instances, the contact function of the border shows that the expected effects are multiple and more complex to grasp. An open border that plays the role of a contact zone does not necessarily mean that there will be increased cross-border interactions or that these increased interactions will be beneficial for innovation-led developments within the CBR. Secondly, the conceptual CBRIS literature discusses the potential for cross-border spillovers and the emergence of agglomeration economies but pays little or no attention to the fact that the border creates gateway functions for goods, people and knowledge that regions at the boundary can either suffer or benefit from.

The **differentiation** function refers to cross-border differentials in economy, institutional structure, culture and so on. These can also play out in a negative or a positive way. On the negative side,

institutional and cultural differences lead to transaction and communication costs (van den Broek and Smulders, 2015), whereas economic differentials can induce the exploitation of the adjacent side of the border rather than integration (Krätke, 1999). However, in certain circumstances economic differentials can be a starting point for deeper integration. This can take place, for example, when the 'deprived' side of a border benefits from the education of its workforce, the re-location of research and development facilities to its territory and trade flows supporting its economy. We shall see later that such an evolutionary trajectory is at work in the San Diego–Tijuana region. Furthermore, the meeting and negotiation of different ideas, values, signs or norms in daily exchanges can also result in processes of adaptation and mutual learning (Newman, 2003). Such cultural or institutional hybridization processes (see notably Dear and Burridge, 2005; De Sousa, 2013) can be sources of innovation beneficial to the formation of a CBRIS. These processes may lead to new patentable technologies produced by companies combining prior practice with their own ideas (Griffith et al., 2017).

Lundquist and Trippl (2013) recognize that the effect of relational distances can be either negative or positive. Trippl (2010) also alludes to the fact that economic differentials can be a starting point for deeper integration but considers a shift towards a more innovation-led integration path extremely challenging. However, cross-border hybridization processes that can be induced in certain border contexts are absent from the original CBRIS conceptualization. We believe that these processes are important for the development of CBRIS because they can be sources for innovation and because they facilitate encounters and co-mingling, which supports actors in having a common understanding based on what they have learnt together in their daily exchanges.

Lastly, the **affirmation** function means that borders entail a symbolic dimension capable of influencing identities and preferences. The presence of the border is a lever that can help to reinforce the international character of a CBR through a strategy of place branding and territorial marketing. More specifically, cross-border place branding can be a way to advertise the multicultural character of a CBR and the potential this represents at the national or on a cross-border scale, in order to attract businesses and qualified workers (Hospers, 2006; Oliveira, 2015; Witte and Braun, 2015). When focused on the internal recognition of the CBR, the border can be mobilized to foster a regional identity. The creation of a brand, an image or an identity is similar to the creation of public or club goods that are expected to have positive effects for CBRIS development (OECD, 2013). At the same time, there might be a 'gap' between the objectives and what is achieved by branding efforts. When cross-border flows and mobility remain strictly controlled or, a fortiori, when a border is fenced, its symbolic meaning as a protection against external 'threats' or as the affirmation of binary categories such as 'us' versus 'them' or 'here' versus 'there' may be detrimental to the development of a CBRIS.

The affirmation function of borders is not explicitly taken into consideration in the CBRIS conceptualization. The importance of the existence of a cross-border regional identity for the branding of the CBR is mentioned by Lundquist and Trippl (2013: 456). But this point is an additional aspect and not integrated in their conceptual framework. We believe that the symbolic dimension of borders plays a key role in the success of CBRIS formation. More specifically, the creation of a shared regional identity can foster cross-border place branding and therefore contribute to enhance the attractiveness of the CBR. It can also create trust among stakeholders (they share a common sense of belonging or other values that facilitate communication and mutual understanding). In both cases, the meanings and images local and regional actors attach to the border in their discourses are important.

All the above discussed functions owe their existence to the border: they would not emerge without it. We therefore contend that a multidimensional approach to borders, rather than the concept of proximity, enables to better highlight the complex and ambivalent effects borders have on the formation and development of a CBRIS. Even when borders are opening up (i.e.

de-bordering dynamics), they do not simply disappear but continue to exist and produce different effects (Nitsch and Wolf, 2013). Such an understanding allows explaining how also weakly integrated CBRs have the innovation potential to spur linkages across the border. In other words, rather than stating that borders can constitute both opportunities for and barriers to cross-border innovation, the border functions approach allows to identify the precise circumstances under which these contrasting effects might arise. In the next section, we will present two case studies that provide empirical evidence to underline the value added and feasibility of the border functions framework.

Case study analysis

The following case study analysis draws insights from two CBRs reflecting opposite degrees of integration, according to the CBRIS framework by Lundquist and Trippl (2013). On the one hand, we examine the Øresund region which is located at the Danish–Swedish border across the Øresund strait. It has around 4 million inhabitants and its major cities on either side of the strait are the capital of Denmark, Copenhagen (800,000 inhabitants), and Malmö (350,000 inhabitants) in the Swedish Skåne region. As an internal EU CBR, it enjoys a supra-national policy framework conducive for cross-border cooperation. In fact, it is a textbook example of cross-border integration with open borders (since the Nordic Passport Union implemented in 1958) and three decades of intensive policy efforts to promote the building of a bi-national region. On the other hand, we discuss the San Diego–Tijuana region which spans across the US–Mexico border. Around 5 million people live in this binational region, among which 1.4 million in the city of San Diego and 1.8 million in the city of Tijuana. Despite the presence of a heavily controlled border and recurrent security issues, this bi-national region is also strongly integrated from an economic point of view and shows interesting signs of cross-border innovation synergies. The two CBRs differ significantly in terms of their institutional settings – supra-national policy frameworks and relationships across the countries – population distribution, geographical scopes, cultural and language differences and economic power asymmetries. However, the regional stakeholders in the two CBRs have similar aims in promoting their regions as global hubs in high-tech industries.

The Øresund region

The construction of the Øresund bridge, which was completed in 1999, marked a significant improvement in cross-border infrastructure between Denmark and Sweden and, as such, enhanced the potential **contact** function of the border. This large-scale border-crossing infrastructure ignited the premises to create an internationally competitive CBR (Lundquist and Trippl, 2013). It notably had positive effects on the integration of the cross-border economy in the form of knowledge flows and agglomeration economies – both are conducive to innovation – particularly in high-tech industries. As some scholars (hastily) claimed: 'Øresund quickly transformed into Scandinavia's Silicon Valley' (Bucken-Knapp, 2003: 76). A key mechanism behind the positive development was the knowledge workers attracted to the region following the construction of the bridge. In particular, this has facilitated the transformation of the Swedish side of the border, Malmö region, from an economy based on declining traditional industries into one of the most innovative metropolitan regions in the world (Nauwelaers et al., 2013; Ejermo, et al., 2021). After the construction of the bridge, cross-border interaction became a desirable solution for regional stakeholders – mediated through cross-border policy organizations – to invigorate the region in terms of job opportunities and attracting foreign investors. The Øresund committee (since 2016, the Greater Copenhagen and Skåne committee) initially chaired the process of cross-border interaction in the region and sought to brand the region as a life science cluster, rallying universities, medical companies and

public stakeholders around the concept of 'Medicon Valley Alliance' (Olesen and Metzger, 2017). Recent evidence has suggested that the construction of the Øresund bridge has indeed led to a significant increase in the innovativeness of (at least) the Swedish side of the CBR (Ejermo et al., 2021), but little is known whether the CBR has become more integrated in terms of innovation. Some attempts have been made (Hansen, 2013; Makkonen, 2016) showing that the increase in knowledge flows and innovation cooperation across the border was particularly strong after the opening of the bridge but that the growth has thereafter diminished substantially. Nonetheless, improved contact (heightened by border permeability or other cross-border initiatives facilitating it) can be expected to impact the level of cross-border knowledge flows and innovation cooperation positively, at least in the short run.

While cultural and institutional differences between Denmark and Sweden can lead to uncertainty and misunderstandings, to some extent cross-border knowledge flows can also be facilitated by the **differentiation** function marked or generated by the border. According to Miörner et al. (2018), these differences have had a positive effect on cross-border policy network organizations which have combined the Swedish consensus-based decision-making culture with the Danish operational decision-making culture and faster processes, thereby creating conditions for cross-border knowledge flows and innovation.

Yet, the main reason behind increased cross-border interaction has not been CBRIS integration (in terms of increased knowledge flows or innovation cooperation). Rather increased interaction has been driven by the differences in housing-prices and wages between Copenhagen and the Skåne region in Sweden. Lower prices for housing on the Swedish side of the CBR and higher wages on the Danish side of the CBR have prompted many Danes to move to Sweden while still continuing to work in (and commute to) Denmark. The potential impact of these commuting flows on innovation is uncertain and difficult to access (Makkonen, 2016). Moreover, this situation has deteriorated after 2008 when the Danish economy got seriously hit by the financial and economic crisis. The number of cross-border commuters stopped growing, and even declined during the following years: from 25,000 in 2008 to 15,000 in 2015 (Øresund Institute 2021). The re-enforcement of the border controls across the region in the aftermath of external shocks (e.g. the so-called European refugee crisis in 2015 and the COVID-19 pandemic since 2020), have further hindered the ease of crossing the border. This has led to a drop in cross-border traffic flows and, thus, is likely to hamper the potential for knowledge flows and CBRIS integration in the region (see Madsen, 2017).

In terms of borders' **affirmation** function, the Øresund region is a case in point. The border and the bridge (as a visible landmark) have been utilized as a symbol to brand the Øresund region as an international cross-border metropolis (Hospers, 2006). The main argument has been that together, the economic areas of the Danish and Swedish sides 'sum up' and make the region one of the creative hubs of Europe. Furthermore, multiple endogenously promoted initiatives such as the 'Medical Valley Alliance Ambassador' and the 'Øresund Food Network' were implemented to market the region globally as the home of highly knowledge-intensive industry sectors. The Øresund committee also sought to develop a joint Øresund identity at local level through dedicated cultural events (Øresund day and Øresund festival) and media coverage (Olesen and Metzger, 2017; Miörner, et al., 2018). However, as argued by Hospers (2006: 1015), the cross-border place branding efforts did not match with the reality: 'The Øresund Region is an "imagined space": the conurbation is branded as an exciting Euregional hub, whereas the region's inhabitants still cope with many day-to-day problems of cross-border interaction'. In other words, despite all the cross-border place branding efforts, the bridge still marks a national border for many of the inhabitants of the region. Further, there is a gap between the objectives of attracting knowledge workers and becoming a world-leading scientific hub and what has actually been achieved by these cross-border place branding efforts. While 'Øresund is slowly but surely re-uniting itself' (Hospers, 2008: 231), it seems that the branding efforts have worked best in the case of the Medicon Valley Alliance,

which has become an internationally recognized cluster brand (Steinfield and Scupola, 2008). Statistical measures on cross-border knowledge flows and innovation cooperation confirm this, as CBRIS integration has been rather limited to a few core high-tech sectors such as life sciences (Hansen, 2013).

To sum up, the Øresund region represents a commonly utilized example of CBRIS integration with relatively high level of cross-border interaction and cross-border complementarities that have led to the development of measurable innovation outcomes. Still, the actual process of CBRIS integration cannot be said to have followed the envisioned premises. Despite the construction of the bridge (contact), the work done by cross-border policy network organizations (differentiation) and the branding efforts (affirmation) undertaken to accrue knowledge flows and innovation across the two sides of the border, the region is (still) characterized as a semi-integrated CBRIS (Madsen, 2017). CBRIS integration in the Øresund region is neither a 'success story' nor a 'failed case', but a nuanced experience that shows how the presence of a border can have both advantages and drawbacks and how the border does not tend to disappear even when open but rather transforms itself both in its material role and symbolic meaning. The Øresund case shows how reaching a certain integration stage does not mean that the region will stay there. Integration stage in Øresund has experienced swings back and forth depending on the 'level' of contact, differentiation and affirmation induced by bordering dynamics.

The San Diego–Tijuana region

In contrast to the Danish–Swedish border, the US–Mexico border is closely guarded and can only be crossed through specific border crossing points. The cities of Tijuana and San Diego are divided by a border fence, yet, they are connected by the busiest checkpoint (San Ysidro) in the Northern hemisphere. The interaction between the two sides of the border was boosted by the establishment of NAFTA in 1994. The NAFTA agreement streamlined common rules for trade and work across the North American continent. It enabled companies to reap benefits from cross-border economic differentials which led to higher integration of the economies of the USA and Mexico. As such, this shift in the **contact** function facilitated a remarkable boost in cross-border trade and growth of companies operating across the border (also) in the San Diego–Tijuana region (Mendoza and Dupeyron, 2020). Local stakeholders – in particular, planning agencies such as the San Diego Association of Government (SANDAG) – have continued to work to increase cross-border mobility and interaction by investing in transportation infrastructures in order to open up access to a larger (or shared) labour pool. These infrastructures include new pedestrian border facilities and a tramway extension service close to the border. Regional businesses organizations (such as the San Diego and Tijuana Economic Development Corporations) and local universities on both sides of the border have also worked closely together to strengthen their partnerships for spurring innovation across the border (Cappellano and Makkonen, 2020b). The securitization of the border in the aftermath of 9/11 and the enforcement of harder immigration policies under President Trump's administration have hampered cross-border collaboration and interaction in the CBR. The border has lost some of its contact function and it has become more of a separating than a connecting factor in the development of the CBR. However, the stricter border control has also triggered (at least) some individual innovations. One such example, advocated by a coalition of local business on both sides of the border (namely, the Smart Border Coalition), is a technological service that allows fast border crossing for pre-screened residents and commuters.

The San Diego–Tijuana region is an excellent example of a CBR where the early exploitation of the **differentiation** function (in particular the wage differentials) has slowly started to pave the way for some innovation-led integration. Since the mid-1960s, this region has attracted companies from other parts of the US and abroad (notably from Japan) that have established or relocated their production facilities (i.e. maquiladoras) on the Mexican side of the border. Based on Trippl's (2010)

model, this is an instance of a 'low-road' to integration: exploitation of labour cost differentials and regulatory arbitrages (firms capitalizing on more favourable laws in one jurisdiction to circumvent less favourable regulation elsewhere). However, over the years, the 'Maquiladora program' has improved the socio-economic status of local people and promoted the training of the local workforce improving the availability of knowledge workers, which has been important for cross-border knowledge flows and innovation cooperation. This has helped to leverage innovation in the CBR, as companies in Tijuana have also been increasingly developing their production processes in collaboration with partners from the US side of the border to match the needs of the high-tech industries present in San Diego (Cappellano and Rizzo, 2019). As a result, innovation cooperation across the border is slowly becoming more evenly balanced (Sandoval, 2020; Cappellano and Makkonen, 2020b). Furthermore, the CBR has gained a foothold in many highly innovative sectors such as aerospace, biotech and IT (Celaya Tentori and Almaraz Alvarado, 2015). Last, domestic and foreign companies have also set up high-tech facilities (such as R&D centres) in the CBR (Cappellano and Rizzo, 2019; Cappellano and Makkonen, 2020b; Pérez Núñez and Serrano Santoyo, 2020).

In terms of the **affirmation** function, stakeholders in the San Diego–Tijuana region have tried to mobilize the border as an object of recognition to promote the CBR. Organizations, such as the San Diego Dialogue, have been promoting the idea of a binational region since 1990s (Christensen and Rongerude, 2004). Recently, start-up business fairs and exhibitions on both sides of the border (e.g. Tijuana Innovadora) have also leveraged the cross-border identity of the bi-national region. A successful example of the cross-border branding efforts is the joint bid by the cities of San Diego and Tijuana to become the Design World Capital 2024[3]. One of the most visible attempts has been the effort to brand the region as 'Cali Baja' (merging of the names of the US California and the Mexican Baja California), through a federally funded initiative launched in 2008 and aiming at supporting the development of a competitive bi-national mega-region. Local business organizations, for example in the food and beverage sector, have used the brand to market their products and claimed that it has supported entrepreneurial and business opportunities in the CBR and intensified cross-border knowledge flows (Cabrera-Flores et al., 2019; Nunez and Musteen, 2020). They also argue that the brand has facilitated economic integration in the CBR by helping companies to attract foreign investment in order to enlarge production and enhance product development (Castillo-Villar, 2020; Mendoza and Dupeyron, 2020). However, despite the claimed benefits of the branding efforts, views on the purposefulness of the initiative were not shared by all but only the minority of entrepreneurs and residents. Therefore, the 'Cali Baja Bi-national Mega-Region' project was discontinued in 2019 due to differing views and disagreements between the partners.

The case of San Diego–Tijuana shows that even when the initial preconditions for CBRIS integration are far from evident in terms of the contact (the border remains strictly controlled), differentiation (cooperation is mainly based on the exploitation of cost and regulatory differentials) and affirmation (differing views about the spatial identity in the CBR) functions, at least some CBRIS integration can occur. The utilization of cross-border differentials (maquiladoras) and the branding efforts based on the border have slowly paved the way for a more balanced development across the boundary, facilitated (more equal) cross-border knowledge flows and nurtured the 'birth' of cross-border innovation cooperation. Yet, the CBRIS integration across San Diego and Tijuana remains limited and fluctuates, as shown by the discontinuation of the 'Cali Baja' initiative and the on-going securitization of the border, these early successes in the integration of the CBRIS have experienced swings back and forth.

Conclusions

This paper has discussed the role and significance of international borders in CBRIS. Borders are commonly considered merely as administrative barriers to trade and business. We have stressed that they also perform manifold functions that can both hinder and pave the way for innovation in CBRs.

This paper contributes to the CBRIS in the following ways. We show, firstly, that the conception of borders cannot be reduced to a simplistic binary function of not being or being 'open enough' for a CBRIS to emerge. Usually, cross-border knowledge flows and innovation cooperation (and, thus, CBRIS integration) are expected to benefit from open borders, but as shown here the link between border permeability and cross-border integration is much more complex than assumed in the CBRIS model. The border persists in different forms with ambivalent implications even in CBRs with high border permeability. The case of the Øresund region illustrates how there are lasting forms of barrier effects (such as institutional differences) and stagnant development of knowledge flows and innovation cooperation across the border despite the relatively high openness of the Danish–Swedish border. Contrarily, some cross-border knowledge flows and innovation cooperation can emerge even in CBRs with a controlled border. CBRIS in the San Diego–Tijuana region has been slowly progressing towards a more integrated stage despite the fenced and militarized border.

Secondly, cross-border integration evolves over time but not necessarily to a higher integration stage as assumed in the CBRIS model: the San Diego–Tijuana region evidences the pitfalls of emerging CBRIS integration, while the Øresund region illustrates that even a relatively highly integrated CBRIS can 'fail' in keeping up with the momentum of integration.

Thirdly, our empirical cases show that there is an underlying trend of local institutions attempting to drive further cross-border interaction. Border permeability has been hampered in both CBRs due to national border regulations (e.g. the so-called refugee crisis in the Øresund region and the securitization of the border by the US administration in San Diego–Tijuana), while the local institutions are continuously adapting and trying to reconfigure their policies (through border affirmation and hybridization processes) in order to promote integration. Therefore, while having only a marginal role in the CBRIS model, we argue that the role of local agents is essential in explaining CBRIS integration. They are of utmost importance for facilitating (and also reaping the benefits of) the discussed border functions. For CBRIS integration, border-related resources need to be recognized and mobilized on both sides of the border. This requires a very particular set of skills. Local entrepreneurs, business organizations, companies, R&D centres, policy network organizations, universities and so on with these resources and skills can change the development trajectories of CBRISs.

Fourthly, borders can be utilized as material and symbolic assets to brand CBRs. While not entirely a success story, the branding efforts in the Øresund region have resulted in growth and increased CBRIS integration, at least in some specific industry sectors (like the life science industry). The 'Cali Baja' brand, although discontinued, helped to transmit a message of a unique binational region. This has arguably helped in increasing knowledge flows across the border or at least attracting high-tech facilities and international events (e.g. San-Diego–Tijuana was designated, as the first bi-national region, for World Design Capital 2024) into the CBR.

In sum, the border functions approach utilized in this paper allows identifying different roles that borders play in CBRISs, and, more precisely, the circumstances in which borders act as barriers or opportunities for cross-border innovation activities and integration. From a cross-border metrics perspective, we argue that the proximity dimensions – to which the CBRIS model is analytically based upon – fail to capture entirely this complexity of cross-border integration processes. In empirical terms, we dispute that summing up 'high' proximity scores – while helpful in assessing some of the measurable aspects of cross-border innovation cooperation such as cross-border patenting – will assist in detecting the actual level of CBRIS integration.

Our paper paves the way for some important future research avenues. Mechanisms and processes that underpin the development of CBRIS would need to be examined with in-depth case studies to deepen our understanding of the border functions and their significance in cross-border innovation activities and integration of innovation systems across borders. There is a need to study both people and institutions involved in innovation activities and the border contexts in which they operate. The

border functions conceptualization lends itself especially well into detailed analysis of micro-level perspectives of actors involved in cross-border innovation activities. Comparative studies of CBRIS in different locations and border contexts would enable learning more about regional specificities but also drawing general lessons for policymakers and practitioners. In terms of specific research topics, further studies could investigate how much the physical boundary and its openness impacts CBRIS development and integration, when much of cross-border collaboration (especially since the COVID-19 pandemic) takes place virtually. Likewise, more information is needed about the connection between the sense of cross-border regional identity and cross-border innovation dynamics.

Finally, we recognize that in empirical research, the border functions approach has its challenges just as the proximity approach or any other conceptual model. The reality is often complex and border functions are ambiguous, having at the same time positive and negative effects for CBRIS integration. Such ambivalent effects are difficult to disentangle empirically, and one could be tempted to privilege one aspect at the expense of the other that goes against it. Deciding upon the methodologies and comparative frameworks also come with challenges and set certain limitations to research, especially in cross-border settings (see Németh et al., 2013). Nevertheless, as illustrated here, border functions offer a promising starting point into expanding our knowledge of CBRISs.

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Notes

1. We understand innovation here broadly as the implementation of something new (giving rise to business opportunities) and discuss both innovation input (skilled workers, R&D funding, etc.) and output (such as product, process, marketing or organizational innovations).
2. The fivefold proximity framework (Boschma, 2005) includes cognitive, cultural, institutional, social – that is, relational – and geographical dimensions.
3. See: https://home2024.com/.

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