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Bridging regional innovation – cross-border collaboration in the Øresund Region

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Bridging regional innovation – cross-border collaboration in the Øresund Region

Abstract

The topics of regional innovation systems (RIS) and cross-border regions attract increasing attention, but few studies combine the themes. Further, the existing empirical studies of cross-border innovation and knowledge creation analyse one case at one point in time, thus, making it difficult to assess the progress of integration in the regions, as well as the effect of cross-border innovation policies. Consequently, important questions are left unanswered, including the central research question of this paper: Does the sudden removal of significant physical barriers directly impacts collaboration activity in cross-border innovation systems?

This paper examines regional integration in the Øresund Region over time. It deals with a specific part of the RIS, as it analyses research collaboration between actors from the Danish and Swedish sides, with a specific emphasis on the biotech industry. Scientific collaboration constitutes an important element of a RIS, particularly in research intensive sectors. The quantity and quality of co-authorships are used as indicators for research collaboration. The results indicate that the removal of internal barriers in a cross-border region can have a substantial and long-term positive effect on knowledge flows if a targeted policy effort is made. In the absence of such policies, no effect is found.

Keywords

Cross-border innovation, cross-border regions, biotech, co-authorships, collaboration, Øresund Region

Bridging regional innovation – cross-border collaboration in the Øresund Region

1. Introduction

Borders between countries continue to impact economic development in today's globalised world. In economic geography, the literature on borders has also been associated with the rise of regional studies and the insight that economic progress must be founded on local characteristics, competences and institutions (Storper, 1997). However, as functional regions do not always follow the borders of national states, one specific topic of interest has been the integration of cross-border regions – defined as regions that continuously span over at least one national boundary – such as the Øresund Region (Denmark/Sweden), the Centroepe area (Austria/Czech Republic/Hungary/Slovakia) and Euregio (Netherlands/Germany). These integration processes are at the same time necessary and valuable; necessary as regions with fragmented economies have few chances of prospering in a highly competitive global economy, and valuable as the differences in development trajectories between neighbouring areas in separate countries can lead to complementarities and productive interactions. Naturally, such variations in culture, technological specialisation, institutions etc. are at the same time challenges which often act as barriers to cross-border integration.

Following the rise in the number of cross-border partnerships (Perkmann, 2003), several studies have analysed cases of regional integration in cross-border regions within the last ten years (see e.g. Bucken-Knapp, 2001; Bygvrå & Westlund, 2005; Matthiessen, 2004 for examples from the Øresund Region). However, most analyses focus on issues such as commuting and shopping behaviour, and few studies deal with the creation of common innovation and knowledge spaces (exceptions are Coenen et al., 2004; Hansen & Hansen, 2006; Hassink & Dankbaar, 1995; Koschatzky, 2000). Recently, theories on the formation of cross-border innovation systems have been proposed, drawing on the insights from the regional innovation systems (RIS) approach (Lundquist & Trippel, 2011; Trippel, 2010).

The process of developing a cross-border innovation system, from a low to a high level of integration, rarely progresses in a linear way. Some periods are characterised by rapid integration due to the elimination of barriers, e.g. political, such as the effect of the fall of the iron curtain on the Centrope Region, or physical, as in the case of the impact of the fixed link between the Danish and Swedish parts of the Øresund Region (Lundquist & Trippel, 2009). Despite the presumed considerable importance of such events, their effect on the creation of cross-border knowledge spaces is still more or less a black box and a number of key questions need to be addressed. The main research question that this paper is concerned with is: *Does the sudden removal of significant physical barriers directly impacts collaboration activity in cross-border innovation systems?* Related to this, the literature has yet to distinguish between the effect on the quantity and the quality in the cross-border knowledge creation processes. And an additional question is the effect of cross-border integration processes on extra-regional knowledge linkages – do they become less important as a cross-border RIS develops, or is it more a plus-sum than a zero-sum game?

Empirical – and particularly longitudinal – analyses of these questions are pivotal to understand the development of cross-border innovation systems over time. This paper contributes to uncovering these questions by analysing the regional integration of the Øresund Region in the period 1994-2009. The paper deals with a specific part of the RIS, as it analyses research collaboration between actors from the Danish and Swedish sides. It focuses on the biotech industry, as there has been made a designated policy effort to strengthen cross-border collaboration within this industry. Scientific collaboration constitutes an important element of a RIS, particularly in research intensive sectors such as biotech. The quantity and quality of co-authorships is used as an indicator for research collaboration.

The point of departure is the concept of RIS, which is discussed in the following section. The third section reviews previous work on cross-border regions with a focus on the creation of integrated innovation systems. Section four briefly presents the Øresund Region, while the fifth part

of the paper describes the applied methodology. Section six presents the analysis. The final section concludes and discusses the findings.

2. Regional innovation systems and knowledge creation

The development towards a learning economy has been fuelled by an increasing speed in knowledge diffusion, and a key characteristic is the rising long-term knowledge intensity of the economy (Amin & Cohendet, 2004). Acquisition, creation and utilisation of knowledge shape economic growth. A key insight from the last decades work within the social sciences is that external knowledge linkages are of increasing significance in the learning economy, as vertical disintegration becomes a widespread phenomenon. Links to customers and suppliers are crucial in both high- and low-tech industries in order to obtain market knowledge and feedback (Hansen & Serin, 1999; Hansen, 2010; von Hippel, 1988).

A focus on the importance of localised institutions for knowledge production and innovative collaborations has been associated with this development (Dosi et al., 1988). This has in particular been emphasised in the literature on regional innovation systems which stresses the systemic nature of innovation processes as well as the importance of agglomeration economies. Thus, a system of innovation is defined as (Edquist, 1997, p. 14) “[...] all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations.”

The RIS approach stresses the importance of the regional context for the functioning of innovation systems. According to Cooke (2001), many regions now have the resources and authority to promote their own regional agendas within areas such as research and development (R&D). Thus, there is a strong case for focusing on the regional meso level, which covers areas united by common institutions and a shared culture. Still, Cooke (2004a) notes that the internal functioning of the RIS should be seen in relation to actors operating in other regions or at different scales. By including these aspects of knowledge production in the framework, Cooke responds to the critique of among others Amin & Cohendet (2004) and Bunnell & Coe (2001) who highlight the importance of other

scales than the local and regional for the creation of knowledge. Yet, it also adds some ambiguity to the RIS framework. While it maintains the prominence given to the regional scale, it opens up for discussions of the general applicability of the theoretical framework – when is the regional context sufficiently important for an innovation system to justify the RIS label?

The work on local buzz and global pipelines seeks in a similar way to encompass both local and global knowledge linkages in one theoretical framework by emphasising both the significance of agglomeration economies and distanced knowledge links (Bathelt et al., 2004). Local and global flows of knowledge must be balanced in order to avoid technological lock-in for a region, while still allowing the exploitation of agglomeration advantages. Again, this raises the question of variation in the intensity of local and global knowledge linkages according to, e.g. industry characteristics.

One way of differentiating between innovation patterns in industries is by considering differences in their knowledge bases (Asheim, 2007). The knowledge base concept highlights differences between industries in the types of knowledge that are crucial for economic activity. A key characteristic of the *analytical knowledge base* is the use of scientific methods and modelling. Codified knowledge is both a major input and output of the knowledge creation process, implying that links to universities and research institutions are crucial to the innovativeness of firms with analytical knowledge bases. Innovations are often radical, contrary to the innovations of firms with *synthetic knowledge bases* which are predominantly incremental. These firms primarily utilise existing knowledge in the development of new products and processes, and tacit knowledge acquired through learning by doing and learning by using is therefore central to innovation processes. Up- and down-stream relations are important as innovation projects often revolve around solutions to customer specific problems. Finally, the *symbolic knowledge base* is predominant in industries where the value creation is associated with the production of immaterial characteristics – e.g. ideas, images and symbols. Networking, creativity and social skills are more relevant than formal

education and certified qualifications for such firms, as the knowledge creation process is often very context dependent.

Considering that research suggests that international and global knowledge linkages are of greater significance than national and regional partnerships within science and R&D (Cooke & Wills, 1999; Hilpert, 2006), it can be expected that firms from research intensive industries with an analytical knowledge base are primarily depending on global knowledge linkages. Work by Coenen et al. (2004), Gertler & Levitte (2005) and Moodysson (2008) on the biotech industry confirms this expectation and, in a recent interesting paper, Martin & Moodysson (2013) carry out a comparative study of the knowledge networks of industries with different knowledge bases from the same region. They find that global networks are particularly important for firms in the life science industry (analytical knowledge base), while the food industry (synthetic knowledge base) primarily sources knowledge from nationally and regionally configured networks. Lastly, they find that knowledge creation in the moving media industry (symbolic knowledge base) depends on highly localised networks, where the partners share a context specific knowledge on the local environment.

3. Cross-border regions

The results of the study by Martin & Moodysson (2013) suggest that the integration of cross-border regions might be of primary importance to industries with synthetic and symbolic knowledge bases, considering the global nature of knowledge linkages in industries with analytical knowledge bases such as biotech, IT and nanotech. However, this question and many others concerning the creation cross-border innovation spaces have so far remained untouched. The cross-border literature primarily focuses on topics such as the relationship of these regions vis-à-vis their national states and the importance of funding opportunities for the commitment to regional integration processes (Anderson & O'Dowd, 1999; García-Álvarez & Trillo-Santamaría, 2013). Many cross-border partnerships are in reality “grant coalitions” (Church & Reid, 1999, p. 645), leading Paasi (2002, p. 200) to conclude that today these areas are mainly “regions on paper”. While this is undoubtedly the

case in quite a number of regions, such statements highlight the importance of measuring real integration beyond cooperation in government sponsored programmes. Approaches to assessing these integration processes include analysing developments in transportation flows (Knowles & Matthiessen, 2009; Matthiessen, 2004), labour market dynamics (Schmidt, 2005; Van Houtum & Van Der Velde, 2004) and shopping behaviour (Asplund et al., 2007; Bygvrå & Westlund, 2005).

However, only a small number of cross-border integration studies deal with issues related to innovation and knowledge creation processes. Coenen et al. (2004) and Moodysson & Jonsson (2007) both show that global linkages are of greater importance than local collaborations for innovation projects in biotech firms located in the Øresund Region. Hassink & Dankbaar (1995) find that cross-border interaction is of little importance for innovation processes in the Euregio Mass-Rhine, and Koschatzky (2000) reaches a similar result in the case of Alsace and Baden. Finally, Leick (2011) finds that cost reduction and revenue increase are the primary positive outcomes of co-operation between German and Czech firms from Saxony and North Bohemia, while knowledge production is of little importance.

Yet, these studies all analyse one case at one point in time, thus, making it difficult to assess the progress of integration in the cross-border regions. Exceptions to this pattern are studies by Hansen & Hansen (2006), Krätke & Borst (2007), Hoekman et al. (2010) and Scherngell & Lata (2012). The findings of Hansen & Hansen (2006) indicate a growing integration in the years 1994 to 2005 in the Øresund Region within the scientific community. Krätke & Borst (2007) show that German-Polish integration primarily takes place between West German metropolitan regions and Polish regional economic centres, thereby overlooking the border regions, even though East Germany appears to be catching up. Both Hoekman et al. (2010) and Scherngell & Lata (2012) find that country borders have decreasing influence on research collaboration in Europe.

Apart from these few studies, work on cross-border innovation systems has so far been limited to theoretical contributions. Drawing on insights from the RIS approach, Trippel (2010)

describes five central dimensions in the creation of transboundary knowledge spaces: knowledge infrastructure, business characteristics, nature of relations, socio-institutional characteristics and governance. Lundquist & Trippel (2011) introduce a typology of cross-border innovation systems based on these five parameters as well as accessibility. The *weakly integrated system* is characterised by limited cross-border interaction and the relations which exist result from cost asymmetries. This situation might be due to a lack of synergies if the economic structure and specialisation between the various parts of the region are either too similar or too different to gain from an intensified relationship. However, it can also result from significant barriers which hinder exploitation of synergies. Naturally, accessibility can be one such barrier, but differences in, e.g. legislation and culture are other factors which may inhibit integration.

In the *semi-integrated system*, cross-border innovation networks are developed in some fields, but not throughout the innovation system. Travelling between the different parts of the region is not too costly and time consuming, thus, allowing frequent interactions. The integration process is supported by specialised organisations, and there is a general awareness in the region towards the possibilities offered by cross-border cooperation. Still, common innovation collaborations are not central to the competitiveness of the cross-border region. This is the case in the *strongly integrated system* – the cross-border RIS – where economic activity in the region is fully integrated. Knowledge flows are no longer confined to a few industries and no significant barriers to interaction remain. Lundquist & Trippel (2011, p. 12) characterise this last stage as “*the ‘utopia’ of cross-border region building*”, but note that it may be important in the development of visions for cross-border innovation systems.

4. The Øresund Region

The Øresund Region is constituted by the eastern part of Denmark and the southern part of Sweden. While the two urban areas of Copenhagen and Malmö-Lund make up the core of the region, the formal definition also includes the rest of Scania on the Swedish side and the whole of Zealand as

well as the islands of Bornholm, Lolland, Falster and Møn on the Danish side. The level of interaction in the region was very low before the opening in 2000 of the fixed link across the strait separating the two countries Matthiessen (2004). Post-bridge rail and vehicle traffic was initially below forecasts, but it increased significantly from 2004, and traffic has now exceeded pre-bridge expectations (Knowles & Matthiessen, 2009).

Thus, the construction of the fixed link has radically changed the conditions for creating a cross-border RIS. While the region could previously be characterised as a *weakly integrated system*, mainly due to a lack of physical accessibility, it can now be considered as a *semi-integrated system* (Lundquist & Trippel, 2009). The continuing presence of administrative and cultural barriers (Knowles & Matthiessen, 2009) are important reasons preventing the creation of a *strongly integrated system*, but it is of specific relevance for our analysis to note the variance in the economic structure between the two parts of the region. There are considerable differences between the Danish and Swedish national innovation systems and the way they react to the challenges presented by economic globalisation (Benner, 2003; Edquist & Lundvall, 1993). Thus, the fact that the region contains two different socio-economic trajectories poses an important challenge for the creation of a fully integrated RIS (Lundquist & Winther, 2006), even though it should be noted that the differences are likely to be larger in many other cross-border contexts, e.g. between countries which used to be on different sides of the Iron Curtain.

The decision in 1991 to construct the fixed link was followed by an increasing attention by policymakers towards stimulating collaboration across the strait. Public and private cross-border organisations were created and existing organisations from e.g. the business sector started to have an explicit focus on cross-border collaboration. This was particularly welcomed from a Scanian perspective, as it is a widespread opinion in the region that it is being increasingly marginalised by the central government in Stockholm (Knowles & Matthiessen, 2009; Matthiessen & Andersson, 2002). With the Øresund Bridge, Copenhagen becomes an alternative to the Swedish capital which is

located much further away. While no cross-border political unit has been created, a number of cross-border organisations were established to strengthen social relations and overcome institutional differences between the Danish and Swedish parts. In addition to funding from the two national governments, the European Union has in particular been an important source of resources for these activities. This effort has especially been fruitful within the life sciences. The biotech industry is of considerable economic importance in the Øresund Region (The Capital Region of Denmark, 2008), with 350 bio- and medtech firms (Medicon Valley, 2011), in addition to large pharmaceutical companies such as Novo Nordisk and H. Lundbeck. Policymakers have specifically focused on strengthening interaction among biotech firms as well as branding of the region as Medicon Valley within the last 15 years. The cluster organisation within the field, Medicon Valley Alliance, is broadly recognised as a very successful example of policy intervention stimulating cross-border collaboration, and it is promoted as an example towards other cross-border cluster organisations, both in the Øresund Region and in other contexts (OECD, 2003; 2009). Established in 1997, the organisation initially prioritised to build strong social relations between the Danish and Swedish parts. This initiative was well received by the actors in the region which increasingly participated in networking events. However, in 2004, the interest in these activities began to decrease, due to the fact that the necessary connections across the strait had been created at that point (Larsen, 2006). The focused effort on creating social relations within this industry makes it interesting to analyse the development of cross-border collaboration within the field of biotech.

5. Methodology

The difficulty of accessing data is probably a main reason for the lack of studies on cross-border RIS. While it is generally complicated to retrieve information on knowledge flows, it is even more difficult when the linkages cross national borders. In this study, the object of analysis is co-publications between scientists in universities, firms and NGOs from the Swedish and Danish parts of the Øresund Region, with a particular emphasis on progress in integration within the field of biotech. Thus, the

focus is on the intersection of the *knowledge infrastructure* and *nature of relations* dimensions in Lundquist & Tripp's (2011) cross-border innovation system framework.

As explained above, there has been made a designated policy effort to strengthen cross-border collaboration within biotech which makes this industry interesting to analyse. Furthermore, the industry is chosen as it is characterised by a pronounced analytical knowledge base with an apparent high importance of global knowledge flows. This makes it interesting to analyse if a considerable policy effort can stimulate the development of intra-regional knowledge flows in an industry characterised by a great emphasis on global knowledge flows.

The quantity of co-authorships can be seen as a representation of the extent of scientific collaboration. Data on scientific publications is obtained from the Science Citation Index Expanded (SCIE) database available through ISI Web of Knowledge, where all contributions are provided with subject codes and full affiliations for all authors. Following Sandström & Norgren (2003), biotech is defined as biochemistry and molecular biology, biomedical engineering, biophysics, biotech and applied microbiology, cell biology, genetics and heredity, immunology, medicinal chemistry, microbiology, neurosciences, and virology. Firstly, the number of co-authored papers across the Øresund is identified for each year in the period 1994 to 2009. Further, the number of citations in a two year window following publication is recorded as a proxy for the scientific quality of each paper. According to He et al. (2009), citations received in the first two years are a good predictor of the long-term number of citations. Furthermore, it is also the lag used by the ISI Web of Knowledge algorithm that calculates journal impact factors.

Secondly, the number of co-authorships between the Øresund Region and five biotech regions is also calculated for each year of the period. This makes it possible to assess whether the observed development between the Danish and Swedish parts of the region is atypical or part of a general trend. The selected regions are Basel, Massachusetts, New Jersey/New York, Île-de-France and Stockholm. These city regions are considered among the 20 bioscience mega centres in the

world, characterised by a concentration of large pharmaceutical firms' R&D laboratories, high-quality publicly funded biotech research centres and universities, a considerable presence of dedicated biotech firms, as well as sophisticated local suppliers (Cooke, 2004b; Zeller, 2010). The role of such regions of excellence for scientific co-publications is significant within biotech (Hoekman et al., 2009). Comparing the increase in co-authorships and citations between the Danish and Swedish parts of the Øresund Region, with the similar development between the Øresund Region and each of these regions, will give a clear indication on the progress of the cross-border integration.

The extent of collaboration with Stockholm is of particular interest, as it is located less than 500 kilometres from the Øresund Region. The city is a biotech node of significant importance, particularly due to the Karolinska Institute, a world leading public research organisation (Coenen et al., 2004). Thus, Stockholm has the status of the Øresund Region's "neighbouring biotech centre", and it is therefore particularly interesting to examine if the integration process in the Øresund Region affects the interactions and knowledge flows with Stockholm.

6. Empirical findings

6.1. Within the Øresund Region

The number of co-authorships between Danish and Swedish researchers in the Øresund Region has increased considerably during the years 1994-2009. The growth has been quite constant throughout the four periods shown in table 1. Hence, collaboration across the strait was already intensifying before the actual opening of the fixed link in 2000. Further, the share of co-authorships in the region represented by biotech publications has remained rather stable.

Table 1. Number of co-authorships between the Danish and Swedish parts of the Øresund Region

	1994-1997	1998-2001	2002-2005	2006-2009
All publications in SCIE	525	709	939	1282
Biotech publications	89	111	172	224
Biotech share	17.0%	15.7%	18.3%	17.5%

Source: Own calculations from ISI Web of Knowledge

Following the literature on innovation in the biotech industry (e.g. Liebeskind et al., 1996; McMillan et al., 2000) and previous findings on collaboration patterns within biotech (Ponds, 2009), it is hardly surprising to observe that collaborations between public institutions are the most frequent within this sector in the region (see table 2). However, while public-public co-authorships were very dominating in the first period, private firms and research institutes are increasingly engaged in cross-border collaboration. The private-private co-authorships are still rare, but the firms are gradually becoming more involved in partnerships with public organisations from the other side. It is particularly the case for Danish firms, and one in five co-authorships is now between Danish private and Swedish public organisations. This indicates that the cross-border collaboration is increasingly concerned with research of direct commercial relevance.

Table 2. Share of biotech co-authorships according to type

	1994-1997	1998-2001	2002-2005	2006-2009
Danish public - Swedish public	87.7%	80.1%	73.2%	71.7%
Danish public - Swedish private	1.8%	4.0%	3.3%	6.5%
Danish private - Swedish public	9.6%	14.6%	20.1%	19.9%
Danish private - Swedish private	0.9%	1.3%	3.3%	1.9%
Total	100.0%	100.0%	100.0%	100.0%

Source: Own calculations from ISI Web of Knowledge

The fact that the majority of the Øresund Region's biotech firms are located on the Danish side partly explains the large participation of the Danish private sector in the cross-border collaboration. However, a second factor of significant importance is the very high standard of research facilities at the University of Lund. In particular, the university's Biomedical Centre is an attractive collaborating partner for Danish firms, which offers access to a global centre of excellence, particularly within stem cell research (Benneworth et al., 2009; Hansen & Hansen, 2006).

The importance of Lund University as a hub of biotech research in the region is confirmed by table 3, which lists the six most important public and the four most important private organisations in biotech cross-border co-authorships. Being involved in 427 co-authorships over the 16 years, Lund University has more than twice as many co-authorships as the University of Copenhagen which is second on the list. Overall, researchers from Lund University participate in 72% of all the biotech co-authorships.

In terms of the private organisations, Novo Nordisk appears as a key actor with 31 co-authorships in addition to the 18 by Steno Diabetes Center, a private research hospital owned by Novo Nordisk. No private Swedish organisations appear on the list – the most active Swedish firm in cross-border co-authorships is AstraZeneca which participated in 8 publications throughout the period.

Table 3. Number of biotech co-authorships by key organisations

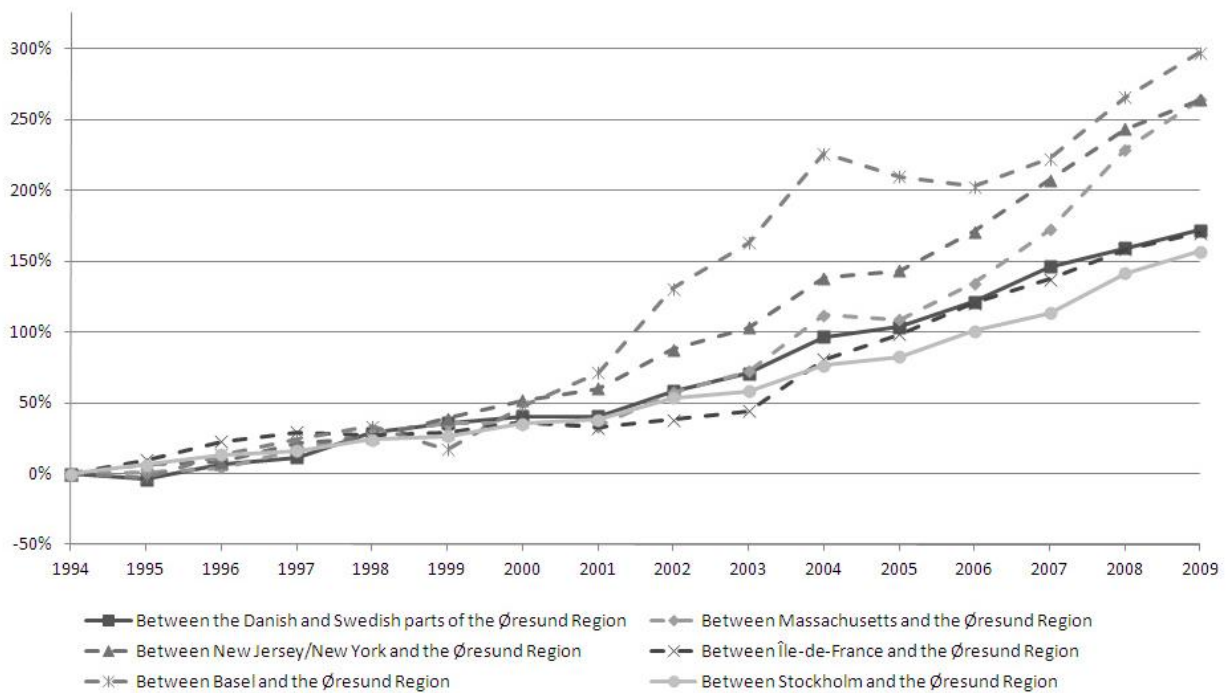
	1994-1997	1998-2001	2002-2005	2006-2009	Total
<i>Public</i>					
Lund University (S)	57	76	121	173	427
University of Copenhagen (DK)	15	37	46	83	181
Copenhagen University Hospital (DK)	20	26	35	52	133
Lund University Hospital (S)	26	28	34	41	129
Statens Serum Institute (DK)	19	12	15	13	59
Technical University of Denmark (DK)	2	12	13	31	58
<i>Private</i>					
Novo Nordisk A/S (DK)	4	11	3	13	31
Steno Diabetes Center A/S (DK)	1	0	2	15	18
NsGene A/S (DK)	0	3	7	6	16
The Danish Cancer Society (DK)	0	2	5	9	16

Source: Own calculations from ISI Web of Knowledge

6.2. International comparison

Although the results in the previous section indicate growing cross-border collaboration, these findings must be seen in the perspective of the general development in co-authorships due to two reasons. Firstly, the number of journals included in the database is not constant over time and, secondly, the increase in co-authorships in the Øresund Region might be part of an overall increase in the propensity of researchers to collaborate with partners outside of their local area. Scientific research collaboration has increased over the last decades and it is particularly a frequent phenomenon within interdisciplinary sciences such as biotech (Ponds et al., 2007). While an increase resulting from such a general growth in co-authorships does imply greater cross-border interaction, it does not point towards a real functional integration in the innovation system. Thus, to find indications of such a process, the development in co-authorships within the Øresund Region must be compared to the development of co-authorships with other regions.

Figure 1. Change in the total number of co-authorships in SCIE, 1994-2009



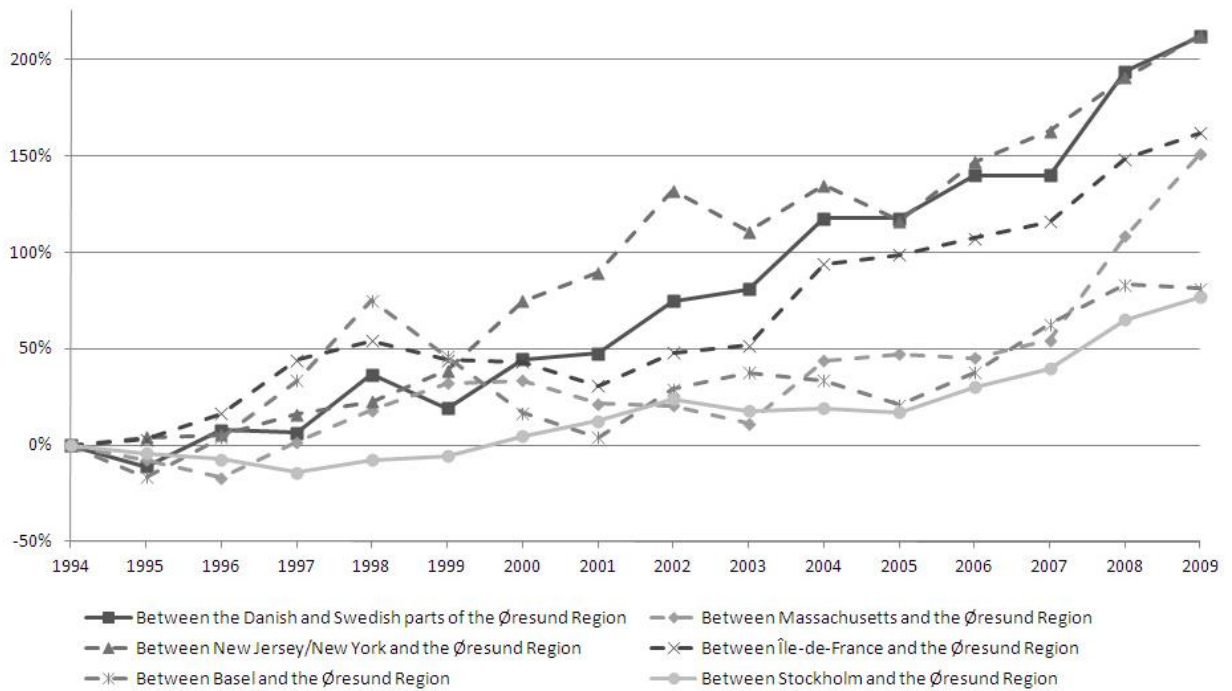
Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

Resulting from this line of analysis, figure 1 displays the development in co-authorships within all the disciplines included in SCIE. Clearly, little evidence for an increasing integration in the cross-border RIS can be found here. The largest increase is found in co-authorships with Basel, which is however also the region which the Øresund Region has the lowest amount of co-authorships with (see appendix table A1 for the absolute figures). Yet, the number of co-authorships with Massachusetts and New Jersey/New York has also grown faster than the development within the Øresund Region, particularly since the millennium, and the extent of partnerships with both of these regions is now substantial. The increase between the Danish and Swedish parts of the Øresund

Region is comparable to the development with Île-de-France, and it is only the Øresund-Stockholm collaboration which has experienced a slightly smaller growth.

Figure 2. Change in the number of biotech co-authorships, 1994-2009



Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

Following the development seen in figure 1, it is interesting to see that focusing on biotech presents a very different picture. As figure 2 shows, the growth in internal co-authorships in the Øresund Region is similar to the increase in co-authorships with New Jersey/New York, while the remaining four regions have considerably lower growth rates. The number of co-authorships has especially increased compared to the peers in the years following the opening of the Øresund Bridge in 2000. Again, it is worth noticing that the collaboration with Stockholm has seen the least increase

over the period. Growing consistently less than the internal partnerships in the Øresund Region, the gap has particularly widened since 2001.

Figure 3. Change in the average number of citations to biotech co-authorships, 1994-2008



Note: To reduce fluctuations, values are calculated based on 3-year averages of citations in the preceding, the actual and the following year. Values for 1994 and 2008 are 2-year averages. 2009 values are not available due to the 2-year citation lag.

Source: Own calculations from ISI Web of Knowledge

Turning to the qualitative side of the co-authorships, figure 3 depicts the development in the average number of citations received by the biotech co-authorships within a two year window following publication. Again, the intra-regional collaborations in the Øresund Region do very well compared to the peer-group. The average number of citations triples in the period 1994-2001, followed by a slight decrease until 2006 where the growth returns. The co-authorships with Basel are

the only among the peers which display similar growth rates, however, as the number of publications is much smaller, the development is also rather volatile. The development in citations to co-authorships between the Øresund Region and the other four regions remain relatively stable over time. The co-authorships with Île-de-France receive a decreasing number of citations over the years, while the collaborations with Stockholm improve towards the end of the period. The growth in co-authorships with Massachusetts and New Jersey/New York remains close to zero throughout the 15 years; however, the papers written with researchers from Massachusetts continue to receive the most citations among the six groups of co-authorships (see appendix table A2). Thus, while the quality of the biotech co-authorships between the Danish and Swedish parts of the Øresund Region has increased significantly, they are still not the most highly cited.

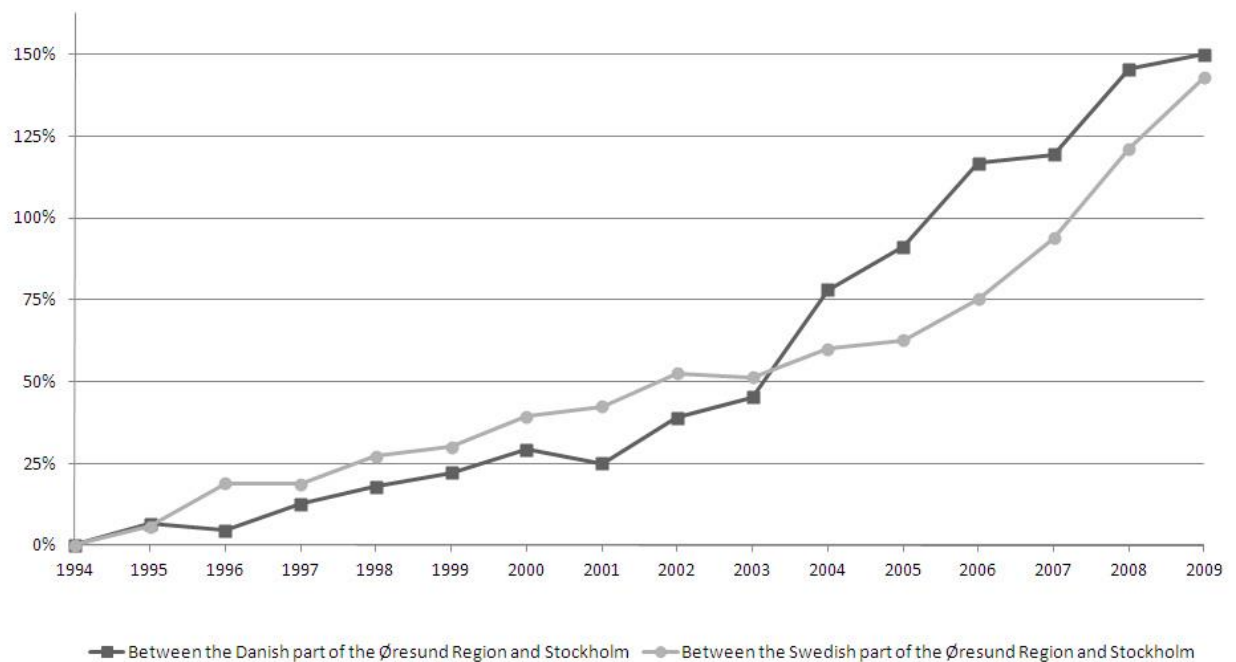
6.3. The Øresund Region and Stockholm

The graphs in the previous section demonstrate that the number of co-authorships with Stockholm has increased the least over the period, both overall and – particularly – within biotech. This section takes a closer look at the collaborations between the Øresund Region and Stockholm, distinguishing between co-authorships between the Danish and the Swedish parts of the Øresund Region. As mentioned previously, actors in Scania find themselves marginalised by Stockholm, and the Øresund Bridge provides them with an alternative (Knowles & Matthiessen, 2009; Matthiessen & Andersson, 2002). Thus, if the increasing integration in the Øresund Region affects the interactions with Stockholm, it can be expected that it will especially be researchers from Scania who will increasingly orientate themselves towards the Danish part of the Øresund Region rather than towards the Swedish capital.

In terms of all types of co-authorships included in SCIE, there appear to be only slight differences between the developments of the two parts of the Øresund Region (figure 4). The Scania-Stockholm collaboration has a higher growth in the first 10 years, but collaborations with the Danish part increase more towards the end of the period, and the overall growth over the 16 years is nearly

similar. While the increasing importance of the Danish side compared to the Swedish after the opening of the Øresund Bridge may indicate a changing focus of the research environment in Scania, it is nevertheless not a very large effect. However, considering the relatively low growth in total co-authorships within the Øresund Region over the period (see figure 1) this is not highly surprising. Thus, it is particularly interesting to analyse the development within biotech where the integration between the two parts of the region appears to progress quickly.

Figure 4. Change in the total number of co-authorships in SCIE with Stockholm, 1994-2009



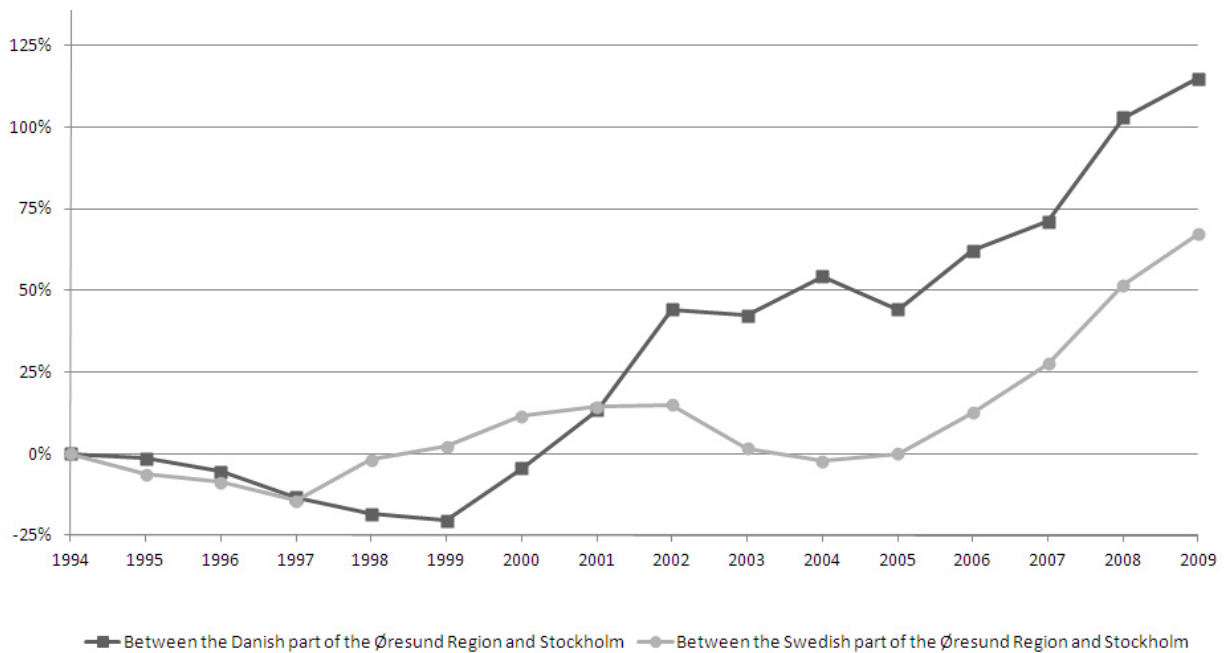
Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

As it can be seen from figure 5, the difference in the development between the Danish and Swedish collaboration with Stockholm is larger within biotech. After a decrease in the first part of the period, the number of co-authorships between the Danish part of the region and Stockholm starts

growing significantly in the years around the opening of the fixed link between Denmark and Sweden. In these years, the number of Scania-Stockholm co-authorships is stable, or even decreasing slightly, before the collaboration activity starts increasing in 2005. Hence, this indicates that the regional integration in the Øresund Region does indeed impact the interaction with Stockholm; however, the effect appears to diminish with time.

Figure 5. Change in the number of biotech co-authorships with Stockholm, 1994-2009



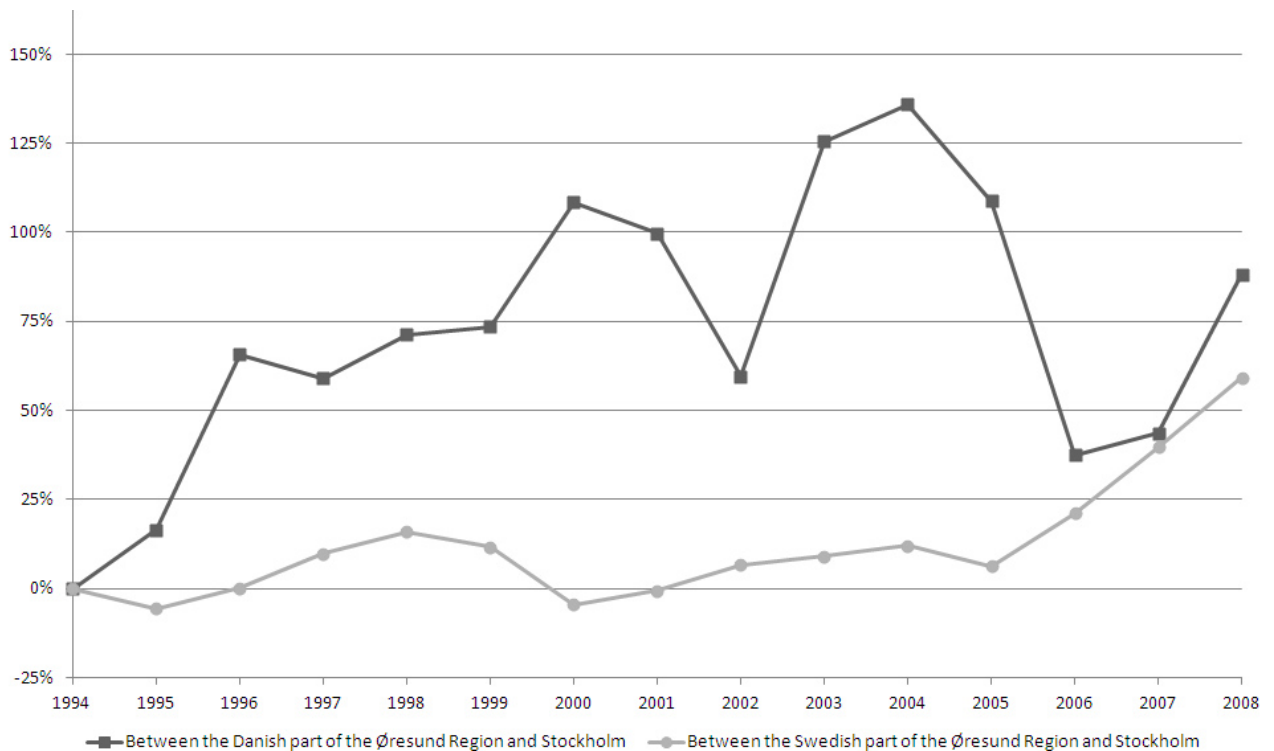
Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

Finally, figure 6 displays the development in the average number of citations to co-authorships with Stockholm. It is also seen that the growth in citations is significantly higher for the Danish part of the Øresund Region and Stockholm. Further, the development in citations to the Scania-Stockholm co-authorships is similar to the development in number of co-authorships: stable or slightly decreasing throughout most of the period, but increasing since 2005. Thus, in the years

before and after the opening of the fixed link, researchers from Scania did not improve the quality of the collaborations with partners in Stockholm to the same extent as their Danish colleagues. This provides further support for the hypothesis that the increasing collaboration between researchers in the Øresund Region affects the collaboration with Stockholm, as researchers in Scania seem to give less priority to collaborations with Stockholm.

Figure 6. Change in the average number of citations to biotech co-authorships with Stockholm, 1994-2008



Note: To reduce fluctuations, values are calculated based on 3-year averages of citations in the preceding, the actual and the following year. Values for 1994 and 2008 are 2-year averages. 2009 values are not available due to the 2-year citation lag.

Source: Own calculations from ISI Web of Knowledge

7. Conclusion and discussion

While a growing body of literature is concerned with the topic of cross-border regions, few studies analyse these areas from an innovation system perspective. Thus, processes of integration and creation of cross-border knowledge spaces are so far poorly understood. This paper contributes to the understanding of these processes by analysing co-authorships between the Danish and Swedish parts of the Øresund Region over the period 1994 to 2009. Three main conclusions can be drawn from this case.

Firstly, the analysis indicates that investments in physical infrastructure do not by themselves lead to a higher level of integration and cross-border collaboration in the knowledge infrastructure part of the innovation system. The growth in co-authorships between the two parts of the Øresund Region is relatively low over the period, compared to the development in collaboration with other major research hubs, and there seems to be little effect of the opening of the fixed link between Denmark and Sweden.

However, secondly, the study also suggests that the removal of physical barriers in a cross-border region can have a substantial positive effect on knowledge flows if a targeted policy effort is made. Apart from being an important sector in both parts of the region, the Øresund biotech industry is also characterised by such a targeted policy effort through the Medicon Valley Alliance which started to strengthen social relations across the strait several years prior to the opening of the fixed link. The increase in the number of biotech co-authorships and the amount of citations received by them, indicate that the combination of a competitive industry and designated cross-border policies makes it possible to exploit the possibilities offered by infrastructural investments in cross-border regions through intensified interactions of increasing quality. Notably, as the biotech industry is characterised by an analytical knowledge base and a high dependency on global knowledge linkages (Coenen et al., 2004), it seems likely that similar cross-border collaboration effects can be achieved within industries with synthetic knowledge bases that rely on regional networks to a larger

extent. Thus, as biotech is the type of industry where regional linkages are the least important, the indication that policies strengthen regional cross-border collaboration even in this industry, encourages an effort to identify other sectors in the region where the Danish and Swedish sides complement each other and, hence, cross-border policies may stimulate collaboration.

Thirdly, the results of the study suggest that cross-border integration may indeed affect the linkages to other regions. The relatively low growth in co-authorships with Stockholm, especially within biotech and by organisations from the Swedish part of the Øresund Region, indicates that the growing integration of the Øresund biotech industry increasingly directs the attention of researchers from Scania towards the Danish part of the Øresund Region, rather than towards the Swedish capital. However, the analysis also indicates that this effect is particularly strong in the years around the opening of the fixed link and it diminishes substantially from 2005.

In order to move the study of cross-border innovation systems forward, the conclusions presented in this paper must be examined in other cross-border contexts. While the effect of integration on external knowledge linkages is particularly a question that needs to be examined more closely in future research, the results of this analysis highlight important policy issues. At the most fundamental level, they point towards the relevance of cross-border policies as a crucial tool in the creation of integrated innovation systems. Improved accessibility is likely to have a natural positive effect on collaboration patterns in the long run through improved possibilities for encounters and the development of shared institutions. However, the results indicate that there is room for policies designated at stimulating social relations which may accelerate the effects on cross-border knowledge creation.

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Appendix A

Table A1. Number of co-authorships

	1994- 1997	1998- 2001	2002- 2005	2006- 2009	Total
<i>All SCIE co-authorships</i>					
Between the Danish and Swedish parts of the Øresund Region	525	709	939	1,282	3,455
Between Massachusetts and the Øresund Region	434	570	807	1,237	3,048
Between New Jersey/New York and the Øresund Region	573	784	1,161	1,699	4,217
Between Île-de-France and the Øresund Region	737	860	1,044	1,569	4,210
Between Basel and the Øresund Region	81	107	216	245	649
Between Stockholm and the Øresund Region	1,306	1,580	2,049	2,752	7,687
Between the Danish part of the Øresund Region and Stockholm	514	625	807	1,144	3,090
Between the Swedish part of the Øresund Region and Stockholm	928	1,128	1,335	1,757	5,148
<i>Biotech co-authorships</i>					
Between the Danish and Swedish parts of the Øresund Region	89	111	172	224	596
Between Massachusetts and the Øresund Region	100	158	149	213	620
Between New Jersey/New York and the Øresund Region	109	159	220	279	767
Between Île-de-France and the Øresund Region	122	170	188	252	732
Between Basel and the Øresund Region	32	44	43	52	171
Between Stockholm and the Øresund Region	325	358	431	540	1,654
Between the Danish part of the Øresund Region and Stockholm	126	124	200	250	700
Between the Swedish part of the Øresund Region and Stockholm	210	249	244	323	1,026

Source: Own calculations from ISI Web of Knowledge

Table A2. Average number of citations to biotech co-authorships

	1994-1997	1998-2001	2002-2005	2006-2008
Between the Danish and Swedish parts of the Øresund Region	4.5	6.8	7.2	11.0
Between Massachusetts and the Øresund Region	14.6	11.1	12.9	20.8
Between New Jersey/New York and the Øresund Region	11.2	12.5	12.6	13.1
Between Île-de-France and the Øresund Region	12.1	9.8	8.7	12.7
Between Basel and the Øresund Region	4.4	13.8	14.8	10.3
Between Stockholm and the Øresund Region	6.4	7.1	8.5	8.0
Between the Danish part of the Øresund Region and Stockholm	8.1	9.9	11.7	8.6
Between the Swedish part of the Øresund Region and Stockholm	5.4	5.7	6.2	7.9

Source: Own calculations from ISI Web of Knowledge

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Table 1. Number of co-authorships between the Danish and Swedish parts of the Øresund Region

	1994-1997	1998-2001	2002-2005	2006-2009
All publications in SCIE	525	709	939	1282
Biotech publications	89	111	172	224
Biotech share	17.0%	15.7%	18.3%	17.5%

Source: Own calculations from ISI Web of Knowledge

Table 2. Share of biotech co-authorships according to type

	1994-1997	1998-2001	2002-2005	2006-2009
Danish public - Swedish public	87.7%	80.1%	73.2%	71.7%
Danish public - Swedish private	1.8%	4.0%	3.3%	6.5%
Danish private - Swedish public	9.6%	14.6%	20.1%	19.9%
Danish private - Swedish private	0.9%	1.3%	3.3%	1.9%
Total	100.0%	100.0%	100.0%	100.0%

Source: Own calculations from ISI Web of Knowledge

Table 3. Number of biotech co-authorships by key organisations

	1994-1997	1998-2001	2002-2005	2006-2009	Total
<i>Public</i>					
Lund University (S)	57	76	121	173	427
University of Copenhagen (DK)	15	37	46	83	181
Copenhagen University Hospital (DK)	20	26	35	52	133
Lund University Hospital (S)	26	28	34	41	129
Statens Serum Institute (DK)	19	12	15	13	59
Technical University of Denmark (DK)	2	12	13	31	58
<i>Private</i>					
Novo Nordisk A/S (DK)	4	11	3	13	31
Steno Diabetes Center A/S (DK)	1	0	2	15	18
NsGene A/S (DK)	0	3	7	6	16
The Danish Cancer Society (DK)	0	2	5	9	16

Source: Own calculations from ISI Web of Knowledge

Figure 1. Change in the total number of co-authorships in SCIE, 1994-2009

Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

Figure 2. Change in the number of biotech co-authorships, 1994-2009

Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

Figure 3. Change in the average number of citations to biotech co-authorships, 1994-2008

Note: To reduce fluctuations, values are calculated based on 3-year averages of citations in the preceding, the actual and the following year. Values for 1994 and 2008 are 2-year averages. 2009 values are not available due to the 2-year citation lag.

Source: Own calculations from ISI Web of Knowledge

Figure 4. Change in the total number of co-authorships in SCIE with Stockholm, 1994-2009

Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

Figure 5. Change in the number of biotech co-authorships with Stockholm, 1994-2009

Note: To reduce fluctuations, values are calculated based on 3-year averages of the number of co-authorships in the preceding, the actual and the following year. Values for 1994 and 2009 are 2-year averages.

Source: Own calculations from ISI Web of Knowledge

Figure 6. Change in the average number of citations to biotech co-authorships with Stockholm, 1994-2008

Note: To reduce fluctuations, values are calculated based on 3-year averages of citations in the preceding, the actual and the following year. Values for 1994 and 2008 are 2-year averages. 2009 values are not available due to the 2-year citation lag.

Source: Own calculations from ISI Web of Knowledge