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Rekers, Josephine; Hansen, Teis

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Interdisciplinary research and geography: Overcoming barriers through proximity

Josephine V. Rekers* and Teis Hansen

Post-Doctoral Researchers, Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University

* Corresponding Author

Abstract

Contributions on interdisciplinary research have so far focused on barriers to such collaborations and strategies for overcoming these. In this paper, we propose that a geographical perspective contributes to understand the formation of successful interdisciplinary research collaborations. The empirical analysis of a centre for clinical cancer research illustrates the importance of considering the role of geographical proximity to collaborators and decision makers, as well as the co-location of excellent research groups within different fields, in overcoming barriers to interdisciplinary research. We suggest that policies aimed at stimulating lasting interdisciplinary research collaborations should take the distance between collaborators into account.

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Abstract

Contributions on interdisciplinary research have so far focused on barriers to such collaborations and strategies for overcoming these. In this paper, we propose that a geographical perspective contributes to understand the formation of successful interdisciplinary research collaborations. The empirical analysis of a centre for clinical cancer research illustrates the importance of considering the role of geographical proximity to collaborators and decision-makers, as well as the co-location of excellent research groups within different fields, in overcoming barriers to interdisciplinary research. We suggest that policies aimed at stimulating lasting interdisciplinary research collaborations should take the distance between collaborators into account.

1. Introduction

This paper is concerned with interdisciplinary research, geography and policy. Interdisciplinarity in research is a growing phenomenon and has previously been considered in a special issue of *Science and Public Policy* (2006). Still, as pointed out by Paletz, *et al.* (2010) our knowledge of the causal mechanisms that predict successful interdisciplinary collaboration is far from satisfactory.

An important current gap in our knowledge on interdisciplinarity is the role of policy in stimulating such collaborations. On the one hand, it is argued by some that “the building of interdisciplinarity” (p. 457) is orchestrated by funding agencies (Kwa 2006). Similarly, Jeffrey (2003) proposes a number of tools, such as story-lines and intermediaries, which can be applied to stimulate successful interdisciplinary collaboration. Thus, this position suggests that policy can indeed steer the sciences toward greater interdisciplinarity. On the other hand, Rosenberg (2009) argues that “...successful interdisciplinary research is [...] unlikely to be successfully planned” (p. 241) due to the complexity and subtlety of interdisciplinary organisational environments. According to Rosenberg, it is simply too difficult for policymakers to construct interdisciplinary research. Rather, increasing interdisciplinarity should be considered a bottom-up process, resulting from the observations of individual scientists that solutions to problems within their own fields are often found in neighbouring or distant disciplines.

In this paper, we acknowledge that facilitation of interdisciplinary research is a highly complex process, which has often been treated too simplistically in previous research. However, we do not consider that policymakers should simply abstain from the topic of interdisciplinarity as suggested by Rosenberg (2009). After all, synthesising knowledge from different disciplines and creating new interdisciplinary fields of research are considered

crucial for economic development and the creation of innovations (Leydesdorff and Etzkowitz 2001). Thus, we maintain that the topic of interdisciplinarity is too important to be disregarded by policymakers and that there is a need to better understand the conditions where policy intervention may stimulate fruitful interdisciplinary research.

In this paper, we suggest that an explicitly geographical perspective may advance an understanding of the possibilities for overcoming the barriers to interdisciplinary research. Multiple contributions within economic geography have highlighted the importance of geographical proximity and the regional environment for the development of individual organisations (e.g. Morgan 1997; Cooke 2001; Asheim, *et al.* 2011). We draw on these insights to suggest that geography has two main influences on the development of interdisciplinary research. Firstly, contextual factors such as strong research environments within different fields are important supporting factors. Secondly, geographical proximity has a strong facilitating effect on the creation of social networks. We distinguish between the effect of geographical proximity in the formation phase and in the initial collaboration phase of interdisciplinary research.

The empirical context for this paper is the formation of a centre for clinical cancer research in Southern Sweden. This centre, founded in 2006 with funds from a national foundation for strategic research, brings together clinicians from the university hospital and researchers from the university's faculties of medicine, natural sciences and engineering to develop novel diagnostics and therapeutics for cancer treatment. Although funding agencies provided financing and a timeline for the emergence of this interdisciplinary research organisation, other factors also contributed to its formation. Indeed, antecedents can be identified over a much longer time-period, and across a broader set of economic actors. In this paper, we analyse the trends and triggers in technological trajectories, research environments and science funding that led to the formation of the centre and their initial collaboration. Through the intensive study of this single case, we demonstrate that this is a process shaped by geographical conditions.

Thus, the main contribution of the paper is to show the benefits of a geographical approach in analysing interdisciplinary research. While interdisciplinary research is a topic of growing interest and importance (e.g. Science and Public Policy 2006; Yang and Heo 2014), no contributions in this literature have so far analysed these processes from a geographical perspective. In this paper, we draw on insights from economic geography and show that the geographical proximity between involved actors is important to understand the development of interdisciplinary research, and we highlight how the influence of geography varies between the formation phase and the initial collaboration phase.

The paper is structured as follows. In the next sections, we review and combine insights from contributions on interdisciplinarity and economic geography, which lead us to suggest that a geographical perspective can offer valuable insights into the formation of successful interdisciplinary research collaborations. We then draw on a case study of such a research environment, a strategic centre for clinical cancer research, to highlight the ways in which a geographical perspective is able to offer new insights into the preconditions for successful

interdisciplinary research collaborations, thus, pointing to important implications for interdisciplinary research policy, which is discussed in the final section.

2. Interdisciplinarity

The collaboration between partners from different fields or disciplines is variously referred to as interdisciplinary, multidisciplinary, cross-disciplinary or trans-disciplinary, depending on their functional arrangement and the context in which they are discussed. While such differences in definition can be important, our focus in this paper is on the common idea of exchanging and creating knowledge across disciplinary boundaries, and we refer to this as interdisciplinarity (Jacobs and Frickel 2009; Lyall and Fletcher 2013). A growing body of research examines the rise of interdisciplinarity in scientific research, roughly covering three main areas: the added value of interdisciplinary research, barriers to establishing and benefiting from interdisciplinary research, and solutions or best practices as to how such barriers can be overcome.

2.1. Value

Interdisciplinary consortia are portrayed by policy-makers, public funding agencies and leaders of research centres as a desirable and promising form of organising research, in particular when dealing with complex societal problems or so-called ‘grand challenges’ (Metzger and Zare 1999 ("mantra"); Pregernig 2006 ("fashionable"); Boardman and Corley 2008; Lyall, *et al.* 2013). Climate change, aging societies and the transition of energy systems are complex technical as well as social processes that demand multiple bodies of expertise to work together. By collaborating, these actors not only contribute their respective state-of-the-art knowledge, but they also help to question (and break down) conventional, ‘business as usual’ ways of doing things; interdisciplinary teams are, thereby, more than the sum of their parts (Klein 1990; Rosenberg 2009). Phrases such as ‘real-world problems are not defined by disciplines’ are often invoked by policy-makers in support of problem-oriented and interdisciplinary research initiatives. Today’s complex societal problems require ‘horizontal’ collaboration across different academic disciplines, but also ‘vertical’ collaboration to connect to policy and other implementation arenas (Lyall and Fletcher 2013).

Naturally, given the buzz and growing popularity of the term, there is disagreement over the assumed value-added of interdisciplinary research (Pregernig 2006; Boardman and Corley 2008). Sceptics question the potential for effective communication, and in turn true collaboration, among actors from different epistemic communities (Caplan 1979). A growing body of work therefore evaluates the impact of interdisciplinarity on research productivity, measured at the level of the individual researcher as well as the research centre (Boardman and Corley 2008). Findings on this issue are mixed. Some studies suggest that the increase in a researcher’s social capital associated with joining an interdisciplinary research centre has a positive impact on his or her human capital as measured by the number of publications (Ponomariov and Boardman 2010). Others argue that scholars early in their career can risk losing out on advancement when they do not follow conventional career paths, such as publishing in traditional discipline-specific journals (Metzger and Zare 1999; Pfirman and

Begg 2012). There appears to be general agreement however, that interdisciplinary collaboration holds potential, although it faces numerous challenges that demand organisational investments (Boardman and Corley 2008; Lyall and Fletcher 2013). A process view of interdisciplinarity (Lengwiler 2006; Pregernig 2006) therefore offers valuable insights in terms of identifying barriers to collaboration and collecting strategies that are able to support interdisciplinary initiatives realise their potential.

2.2. Barriers and strategies

The main challenge in interdisciplinary research is that they lack the mechanisms that support knowledge creation, diffusion and evaluation, commonly found in traditional disciplines (Lyall and Fletcher 2013). This affects processes both internal to the group, and between the group and other organisations. Communication is much less efficient between actors that do not share a common language, discourse, methodology or standards of evaluation (Rich 1991). As Rosenberg (2009) elegantly puts it “boundaries have frequently been barriers” (p. 235). A lot of time therefore needs to be invested in learning about other partners, in order to learn from them. This problem stems from both cognitive and institutional distance, and is often referred to as the two-community gap (Snow 1959; Dunn 1980; Rich 1991; Pregernig 2006): a cultural gap between research collaborators that explains knowledge (non)utilisation. While original formulations referred to the relations between the natural sciences and humanities (Snow 1959), later contributions applied these ideas to the relations between social scientists and policy-makers (Caplan 1979), the fundamental idea being that these actors live in “separate worlds with different and often conflicting values, different reward systems and different languages” (Caplan 1979, p. 459). The problem of knowledge use is considered “fundamentally cultural, that is, they depend on the subjective interpretation of meaning attached to ‘knowledge’ by members of particular subcultures or “epistemic communities”” (Dunn 1980, p. 516). A second challenge for interdisciplinary research centres is that they often experience difficulties obtaining institutional support from universities and funding agencies. These environments are characterised by a certain level of inertia and 'narrow perspectives': “a resistant system, one built on the proven belief that excellence in science meant disciplinary excellence...success has cloaked substantial failures of omission occasioned by disciplinary and similar rigidities on the part of agencies and the research communities” (Metzger and Zare 1999, p. 642).

In order to cope with the absence of discipline-specific mechanisms of knowledge creation, diffusion and evaluation, alternative practices need to support knowledge dynamics. There is a fair amount of work that focuses on managing interdisciplinary research at the project level. Various case studies of single research centres or funding agencies’ programs report on practices including weekly meetings, mentorship and leadership as examples of lessons learned (Bammer 2008; Lyall and Fletcher 2013). Other studies collected survey and bibliometric data to examine the impact of organisational features of research centres on research productivity (Ponomariov and Boardman 2010, for example). As a whole, this body of work argues that there are practical organisational steps that can help to promote and support interdisciplinary research projects. However, going beyond individual projects, the literature on strategic management of interdisciplinary research at the national funding levels

is more sparse (a notable exception being Lowe and Phillipson 2009; Lyall, *et al.* 2013). Moreover, Pregernig (2006) suggests that interdisciplinary research emerges, establishes and evolves in a multi-leveled context that includes interpersonal relations as well as institutions of research and professional subcultures. How these levels interact and ultimately align to create and support projects remains an open question. And here, we argue, a geographical perspective can offer valuable insights.

3. Geographical proximity and interdisciplinarity

In this paper, we suggest that a geographical perspective advances the understanding of successful interdisciplinary research. (2006) Insights from economic geography (e.g. Gordon and McCann 2000; Knoblen 2009) highlight that two geographical proximity effects influence the performance of firms: localised inter-organisational linkages and the characteristic of the geographical context. In the following, we draw on economic geography literature to suggest that these effects may also be important in overcoming central barriers to successful interdisciplinary research: the two-community problem and the lack of institutional support.

Firstly, there is abundant evidence in the literature that geographical proximity has a positive influence on collaboration results through its facilitating effect on social proximity. Spatial co-location increases the likelihood of accidental encounters and reduces communication costs. Thus, “common external structures of collaborative projects” (Dettmann and Brenner 2010, p. 10) resulting from geographical proximity can stimulate the emergence of trustful relations through shared norms and values, repeated exchanges, the possibility of observation and a loss of anonymity (Gössling 2004; Morgan 2004; Storper and Venables 2004). In fact, geographical proximity may be a necessity for some collaborations, as it allows for the creation of specific social relations and social proximity (Zeller 2004). This is in particular likely to be important for collaborations in interdisciplinary research where the participants come from different backgrounds. Ponds, *et al.* (2007) find that geographical proximity is highly valuable in collaborations between dissimilar organisations, while less so in partnerships between organisations that are similar. Similarly, Hansen and Winther (2011) stress the importance of limited geographical distances between collaborators from high- and low-tech industries due to differences in cognitive frameworks which necessitate frequent interaction. In other words, geographical proximity can compensate and allow for the lack of cognitive proximity in the collaborations (Boschma 2005; Hansen 2012). As interdisciplinary research is characterised by, firstly, high cognitive distance as collaborators come from different scientific fields and, secondly, high institutional distance as interdisciplinary research often involves collaboration with practitioners, which operate under different incentive structures, we may suggest that geographical and social proximity are highly valuable in this context. Thus, it is likely that the two-community problem in interdisciplinary research due to the heterogeneity of the involved actors can be partly overcome through frequent interaction facilitated by geographical proximity.

Secondly, as research highlights the difficulties of overcoming cognitive and particularly institutional distance in distanced collaborations (Lam 1997; Gertler 2003; Hansen 2014), it follows that the local composition of research and non-research (e.g. clinical) activities is

central to interdisciplinary research. As noted above, geographical proximity is important to allow cross-fertilisation between actors with a high degree of cognitive distance. Thus, in relation to interdisciplinary research, we would expect that the presence of excellent research groups within different scientific fields in the same region would promote interdisciplinary research between these fields and limit the extent of the two-community problem.

Thirdly, the positive influence of geographical proximity to policymakers on the ability to influence policy priorities is well-established. For instance, the importance of presence in Brussels is crucial for actors seeking to influence EU regulation (Mitchell 1995; Ferguson 1998; Van Criekingen, *et al.* 2005). As noted by Van Criekingen, *et al.* (2005), geographical presence in Brussels is absolutely required as it provides access to strategic unofficial information and networking with relevant EU officials. This reflects the general importance of informal relations, which have been found to provide access to influencing decisions by policymakers (Furlong 1997). The economic geography literature highlights the significance of interaction at the local and regional scales for the development of such informal relations (Storper 1997; Henry and Pinch 2000; Maskell 2001; Dahl and Pedersen 2004). Further, it is suggested that temporary proximity in the form of regular face-to-face meetings may allow the establishment of similar relations (Torre and Rallett 2005). In summary, these insights suggest that at least temporary geographical proximity to decision-makers is likely to contribute to overcoming the problem of inadequate institutional support to interdisciplinary research.

A last observation of central importance for our analytical framework is that the importance of geographical proximity may vary between different stages of the collaboration process. Dettmann and Brenner (2010) suggest that while high geographical proximity is generally conducive to collaboration, it is particularly important in the formation phase. Although the specificities of interdisciplinary research imply that geographical proximity will generally be of greater importance here than in non-interdisciplinary research, we follow Dettmann and Brenner (2010) in suggesting that the importance of geographical proximity for overcoming the two key challenges to interdisciplinary research – the two-community problem and inadequate institutional support – may vary between the formation phase and the initial collaboration phase.

In the *formation phase*, we would expect that geographical proximity allows potential partners to frequently meet, talk and establish a common framework for the collaboration. This is likely to be particularly important for interdisciplinary research where the two-community problem makes the alignment of expectations to the collaboration difficult and time demanding. Thus, meetings, seminars and social events facilitate the formation of interdisciplinary collaborations, and a sufficient number of such encounters is much more likely to take place if the partners are located close to each other. Concerning inadequate institutional support, close interaction with policymakers and funders is central in the formation phase, in order to ensure sufficient institutional support. Again, this is expected to be of particular importance to interdisciplinary research as funding structures are generally focused on disciplinary research.

In the *initial collaboration phase*, we would expect an even higher degree of geographical proximity to be beneficial in order to overcome the two-community problem, when compared to the formation phase. In the initial collaboration phase, collaboration partners have to go from planning the collaboration, to making the actual collaboration work. It can be expected that many issues arising from cognitive and institutional differences between partners only become evident through the actual collaboration. Overcoming such challenges is likely to require extensive periods of direct collaboration between the partners to establish mutual understanding, thus, necessitating geographical co-location. Regarding inadequate institutional support, geographical proximity to decision-makers is of less importance in this phase, although it makes it possible to stay up-to-date and potentially influence developments in funding priorities, which might become beneficial at a later stage.

Figure 1. Suggested effects of geographical proximity in overcoming challenges to interdisciplinary research

	Formation phase	Initial collaboration phase
Two-community problem	Geographical proximity allows frequent interaction between potential partners and, thus, establishment of a common framework for collaboration	Geographical proximity necessary to establish mutual understanding which makes actual interdisciplinary research possible
Inadequate institutional support	Geographical proximity allows frequent interaction between interdisciplinary researchers and decision-makers, which can ensure funding for interdisciplinary research	Geographical proximity to decision-makers is of limited importance

4. Research design

In this paper, we analyse the importance of geographical proximity in the formation phase and initial collaboration phase of Create Health, a strategic centre for clinical cancer research. This interdisciplinary research centre was established in 2006 and brings together researchers from three different faculties at Lund University in an effort to develop, validate and implement new cancer diagnostic technologies. These researchers, while sharing a scientific mind-set, come from different cognitive backgrounds: the centre builds on the competence developed in multiple scientific fields, including bioinformatics, nanotechnology and proteomics as well as clinical oncology, cancer genetics and tumour cell biology. Furthermore, the centre has a mandate to carry out translational research that connects the laboratory bench to the patient's bedside and back again, thereby bringing together scientists from the university and clinicians from the university hospital. These two fields, as will become evident in the paragraphs below, are institutionally different; they do not share the same priorities, standards of value or language of communication. The interdisciplinary

research centre therefore represents a collaborative forum that bridges the cognitive and institutional differences between multiple scientific disciplines, as well as between scientific and clinical fields. During the course of our research, it became clear that this new organisational form of research is not merely a reaction or adaptation to the official guidelines set out by the funding agency in 2004. Rather, antecedents can be identified over a longer time-period, going back to previous collaborative arrangements. We collected original data from 15 semi-structured interviews with key individuals inside and outside the research centre to clarify, triangulate, challenge and uncover the processes that led to the formation of this new organisational form. Additionally, we collected publicly available information from the organisations' webpages, funding program guidelines and press materials, as well as the organisations' internal archives such as funding proposals, program evaluations and minutes of board meetings. This research design allows us to identify triggering events and critical incidents in the formation and initial collaboration of the centre.

Interviews were carried out with key informants at the research centre, the university and the funding agency that supported the establishment of the strategic research centre. These interviews took place between November 2010 and February 2011 in Lund and Stockholm, lasted 52 minutes on average and as long as 70 minutes, and all were digitally recorded and transcribed. We carried out our first round of interviews with the principal investigators at the centre, and used these to identify individuals for subsequent interviews. We wanted to capture the process of establishing an interdisciplinary research centre from the point of view of individual actors, in order to identify the perceived barriers to interdisciplinary research and their motivations for participating in this organisational form. In addition to the principal investigators, we conducted a second round of interviews with supporting staff and graduate students at the centre, as well as so-called 'moral and scientific supporters' at the university. Finally, we spoke to current and former directors and staff at the main funding body supporting the centre, because it became clear in our first round of interviews that without the specifics of the call for proposals for interdisciplinary and collaborative strategic research centres, the centre would not have taken the form it has today. As the funding requirements had an explicit impact on the organisational structure of the centre, it was important to situate this particular scientific field as well as funding scheme in a broader and long-term perspective.

5. Formation phase

5.1 Technological antecedents

Technologically speaking, antecedents to the formation of the centre can be found in the emergence of functional genomics in the 1990s. This is a field of molecular biology that attempts to describe gene and protein functions and interactions, making use of data produced by genome sequencing projects. Because of its genome-wide approach, this field requires the use of high-throughput technologies capable of assaying many functions or relationships simultaneously (informant 5). In the late 1990s, scientists in molecular biology and other life sciences in Sweden saw an opportunity to build up significant strength in the emerging field of functional genomics. They observed scientific activities in the US, UK and Germany, and

noted that if Sweden wanted to compete, substantial investments in new equipment, instruments and technologies were necessary. Several research funding programs in Sweden requested additional funding from the government to support the emerging field of functional genomics, but with little success. This led to a mass of uncoordinated efforts by Swedish universities to secure alternative sources of funding. The Knut and Alice Wallenberg Foundation (the largest private funder in Sweden that supports scientific research, equipment and infrastructure in science, engineering and medicine) received several very similar requests for financial support to purchase equipment. It was impossible to fund all these proposals, totalling several billion SEK, and instead the foundation proposed to finance two bigger consortia in different parts of Sweden within functional genomics, thereby constructing social proximity from geographical proximity: “They hinted that one would be for the Stockholm-Uppsala region and one maybe for Lund-Gothenburg” (informant 8).

In Southern Sweden, researchers from the cities of Lund and Gothenburg (2,5 hours of travel distance apart) had several meetings about joining forces, which took place in a so-called “neutral place, an inn just between Lund and Gothenburg” (informant 8). The groups started from competitive and sceptical positions, where people from Gothenburg thought that Gothenburg should have it all and people from Lund thought that Lund should have it all: “First meetings, nobody wanted to show all their cards” (Informant 8). Gradually, through continued dialogue and several meetings, they developed a consensus and set up task forces in different scientific fields. This Gothenburg-Lund-Malmö consortium applied for, and was granted, SEK 600 million (€68 million) for five years in 2000. The resulting consortium, called Swegene, funded shared instruments, heavy technologies and resource centres, rather than supporting individual scientists or research groups. The aim of this consortium was to offer a new generation of scientists access to new technologies and large-scale analyses as well as new bioinformatics tools. After 2005, when the Wallenberg foundation funding ended and the individual universities took over the responsibility for funding technical personnel and the cost for infrastructure, the coherence and collaboration between researchers at Gothenburg and Lund-Malmö, gradually eroded: “Money was a fantastic carrot as long as it was there, but when the carrot was gone, was eaten up, the motivation for collaboration was not that strong anymore” (Informant 8).

In this very early phase of technological development, the geographical context clearly had an impact. Geographical proximity was necessary in the process of developing a collaborative application between the universities in Southern Sweden, but even this relative proximity was insufficient to secure continued collaboration between the partners after the funding period came to an end: “It was Gothenburg for themselves again and Lund-Malmö for themselves... People say that even two floors within the building can be an ocean. So imagine what 300km between the cities is, it is more than an ocean, it is half a world” (Informant 8). To further develop the interdisciplinary research opportunities that opened up with technological advancements, even greater geographical proximity was needed. In order to support communication across different research fields, overcoming cognitive distances, required the co-location of partners in Lund, where the researchers had created strong, trustful

relations: “even between Lund and Malmö there has always been a gap, it is old rivalry. I think Malmö feels outside Lund University” (Informant 8).

5.2 Organisational antecedents

Organisationally speaking, the formation of the centre can be traced to at least two sources: a network of early collaborators that stems from the Swegene consortium, and an opportunity to acquire funding for a new interdisciplinary research centre. We discuss each in turn. Although Create Health is not considered a direct continuation of the development work at Swegene, this period did prepare the base for Create Health, most obviously seen in technological terms: “Swegene laid the ground for the research results that we later built on in Create Health” (Informant 4). During the Swegene period, it became clear that the techniques that were being developed had potential to improve clinical practices and patient care, which gave the incentive for Create Health’s focus on translational medicine: “from bench to bedside and back”. However, a second and possibly more essential ingredient to the formation of Create Health, was the network of collaboration that began to emerge during Swegene, where several of the principal investigators had worked together or interacted in some way: “Swegene encouraged us to cross disciplinary boundaries, to set up joint projects and target similar questions... at the end of the day they all add to the understanding of cancer, by providing better technology, or more rapid and cheaper analysis, more sensitive analysis” (Informant 5). Such previous collaborations laid the groundwork for knowledge flows between different research groups: “some of the students from one group moved into our department. So in that respect we already had some interactions” (Informant 9). Previous collaborations also established a basis for trust and so-called ‘chemistry’ to develop, also due in large part to geographical proximity: “Chemistry in a group is important. Create Health is smaller than Swegene and more target-oriented. Scale is important, and the fact that all the people were in Lund. It was not Lund-Malmö-Gothenburg” (informant 8). One informant even went on to illustrate the importance of geographical proximity as follows: “I am pretty sure that if a person sits next door, is an inspiring person, sooner or later I would have a collaboration. We scientists are like that, it is because we are next door or met on a flight” (Informant 2). When the time came to secure new sources of funding for research and development, and bring together a core group of diverse people for a new strategic research centre as outlined by the call for proposals from the Swedish Foundation for Strategic Research, these previous collaborations between partners located in geographical proximity were therefore critically important.

This new opportunity for funding was itself a manifestation of developments that had taken place over a much longer period. Traditionally, Swedish funding agencies were, like academic disciplines, structured around more homogeneous research fields. This allowed for smoother evaluation processes and more clearly targeted deliverables. Over time, these priorities of Swedish funding agencies have changed. Whereas it used to be “difficult to get money for research that went across borders” (informant 8), this gradually changed and borders between sub-disciplines such as biochemistry and physical chemistry eroded. However, as one of our

informants cautioned, “this does not mean you abandon disciplines, it is good to have someone who knows a lot about basic biochemistry, but they need to be open-minded towards others” (informant 8). These changes in Swedish funding priorities reflected developments in the field of science more generally, where the number and range of skills needed to conduct scientific research increases with technological advancement and it becomes difficult for any one scientist to embody all these capabilities. Furthermore, our informants argued, scientific research has in recent years become more problem focused and question-driven (informant 10), and “if you define the problems, you see that you need people from different areas” (informant 4).

The events leading up to the formation of this new interdisciplinary team were, in other words, two-fold. First, sharing technical resources under the Swegene consortium left a legacy of collaborative experiences between some researchers. Second, developments in the funding environment created a new opportunity to organise research in interdisciplinary forms. When the principal investigators sat down to decide on the group composition for what would later become Create Health under this new funding opportunity, this composition was therefore shaped in large part by previous local collaborations, and by the range of areas in which localized expertise had been built up in Lund. In order to meet their ambitions of conducting interdisciplinary research that translated science from the laboratory bench to the patient’s bedside, they needed to bring in more people: “The players that came to Create Health had complementary technology backgrounds that could at different levels of implementation add knowledge and development power to Create Health. If you look from a technology point of view, what entry points can we provide and how can that actually make the difference at the end in the clinic. Based on that, we formulated a strategy in our initial application in 2004 and that included [new participants] clinical people” (Informant 5). When it came to choosing new members to supplement the group, this was therefore determined in large part by the scope of the research program and existing social networks: “We needed a biologist and a clinical oncologist. I picked the best people from the field. I did not need ratings, I knew all of them because I am old, I have been around for a while. We have been collaborating, you meet now and then, it is your network” (Informant 4). Eventually, after a number of meetings about the call for proposals and the group’s expertise, they created a project map: “this is why we have to be who we are [in the project team] and this is what we are going to do” (Informant 4).

What does this tell us about the factors that shape the formation of interdisciplinary research programs? Firstly, this highlights the importance to look beyond the individual project and take into account previous projects and established relations. Secondly, it highlights the benefits of taking a geographical perspective in order to understand the creation of networks that make projects possible and applications successful. Geographical proximity played an important role in supporting interactions across technological and scientific boundaries: “I think many groups could do this, but sometimes it is not possible because they are situated in many different places in a large city like Stockholm. Lund is quite small in comparison to many others. That’s the benefit of working in a small town” (Informant 9). This is particularly the case for informal interactions and learning: “informal meetings are key to me. Just being able to say ‘hey, I saw your lecture, I have a question’. That question might come two months

later when I meet you in the corridor. If I don't see them in the corridor two months later, the questions will never come" (informant 5). Lund's small size was seen as significant by our informants, and so was the range of localized expertise that was available: Lund has a full-range university including a medical as well as technical school, and with world-class expertise in multiple disciplines and research areas.

Furthermore, it is at this stage of organisational development that proximity to decision-makers plays an important role. Individuals in or close to the group had social networks that, now and/or in the past, brought them in dialogue with authority figures at funding agencies (which often operate on a national level and are found in Stockholm) and university leadership. The centre's leader, for example, is considered by the others as a true connector, also playing key roles within the central university administration. "I was myself a part of the research council for many years and we were always trying to get interdisciplinary research going... I was part of the same process, I evaluated hundreds of these proposals" (Informant 4). His networking activities over the span of his career, generated social proximity that enabled the group to obtain institutional support from universities and funding agencies. Similarly, our informants repeatedly mentioned the importance of "mental supporters" of the centre. These senior scientists still play important roles behind the scenes, as "puppet-masters", "visionaries" and "discussion partners". Their connections to research councils, are particularly illustrative: "They are the big guys that meet other big guys, they have a drink together and they talk. So they can stimulate. They paint the big picture" (informant 9). Although many (national) research councils and funding agencies are found in Stockholm, social networks are able to support (at least temporary) proximity to decision-makers.

In sum, geographical proximity in the formation phase has had a facilitating effect on social proximity between researchers, allowing for the establishment of a common framework for collaboration between fields separated by some degree of cognitive distance, and it had a positive impact on the ability of actors to influence funding priorities and decision-making.

6. Initial collaboration phase

In the initial collaboration phase, activities progressed from planning and knowledge exchange to actual collaboration. Create Health was officially founded in 2006, and funded with SEK 55 million over 5 years. Their interdisciplinary organisation and translational research is fairly new to Sweden and Scandinavia, and is considered to have been successful at putting the right people together with a focused program as described above, which has led to "wonderful things" (informant 4).

This case of valuable interdisciplinary collaboration and knowledge exchange is, according to our informants, underpinned by two learning mechanisms: the ability to easily seek advice from people with complementary competencies, where the individual learns from this research environment; and the serendipitous knowledge spillovers between people in different fields, where the quality of the research environment itself is enhanced by an individual's contributions. One of the most oft-cited advantages was the ability to ask your collaborators questions: "Being in that environment, I can ask lots of questions, I can be specially educated

by the best people in the field, it is very stimulating” (informant 5). Additionally, informants highlighted that Create Health gave them the opportunity to engage in activities where they would be likely to be exposed to stimulating impulses: “I get a broader view, I think we learn a lot, not just by meeting and talking, but also from the types of things that different applicants write in a common application. You learn how to understand the other type of approach and take it into your own, modify your approach and make it better. That is valuable” (informant 9). The co-location of different areas of expertise is instrumental in generating such learning opportunities.

Further, in addition to intentional learning, our informants stressed that unintentional learning is highly important in order to break down the ‘conventional wisdom’ of any one discipline. This is particularly relevant where it concerns technological advancement in science: “you do what you can do. If you cannot do something from the technology point of view, you are hampered. But then if suddenly you can do it, it is a complete change of mind set” (informant 4). What is considered standard practice in one field can be a revolutionary advancement in another, but such knowledge transfers are only possible when disparate fields intersect. However, this cross-fertilisation requires trustful relations between individuals that allow them to comment on issues which they find surprising or even strange: “By learning I understand questions better. If I know the questions better, I can start thinking about what we can do about those questions. Some of those questions I never even thought about, as I did not know that it is a problem. Once you are in that environment of all those questions, you see answers to the things that others even did not identify as being a problem. That is the environment I want to be in. Many times you see that being ignorant is good in a sense that you ask seemingly stupid questions. I am a stupid engineer so I am allowed to ask these questions. I ask ‘why do you do that?’ ‘Well, that’s how we do that’. ‘So, it does not seem very convenient’, ‘no, it is a bloody hell, we have to do that every day!’ ‘Why don’t you optimise that, isn’t there anyone doing that?’ ‘Well, this is standard, a golden standard’. And you start thinking about that” (Informant 5). The value of interdisciplinary research, transcending the conventions and limitations in any one discipline, thereby manifests itself.

According to our informants, scale and geography mattered a great deal in the case of Create Health to overcome cognitive as well as institutional distance. Some of the respondents highlighted not only the benefits of being located in the same city, but the importance of being ‘under one roof’ for the development of joint projects and to create opportunities for unintended knowledge exchange: “P can do things for S, that S could not even think about” (Informant 4). The opportunity for cross-fertilisation is of particular relevance to interdisciplinary and translational research, where partners are not intimately familiar with the language, culture and institutions of each other’s fields: “When you go and listen to the head of oncology, on the hospital side, their visions on future cancer treatment, you realise that they have a totally different world than we live in at the research. They have to take care of patients; they have to take care of the personnel working with patients. And then we come in and say ‘you should take this biomarker into consideration’” (Informant 9). Although respondents highlighted the importance of geographical proximity and the ‘under one roof’ form of the centre, for these very reasons, one member of the group retained his office a short

distance away from the 'home' of the centre in order to retain a feeling of embeddedness in his own field while participating in the collaborative forum. He felt this space helped to preserve the cognitive 'distance' that was "essential" (informant 1) to his performance as a collaborator.

Being geographically proximate especially helped to overcome the institutional distance that is inherent to the two-community gap. While cognitive distance formed the main challenge, but also asset, within the research group, we find an even greater barrier to interdisciplinary and translational research success in the form of the institutional distance between the technological and the clinical fields. Informants most commonly referred to this as a 'language' problem: "talking to surgeons, there's zero overlap...Here [at Create Health] we are all scientists, you think in a scientific way.... the experiment and control approach: you define the question, the question then defines the type of experiment, the experiment defines the controls; that's how it's done. Whereas it's not quite as simple if you're dealing with a patient. You're dealing with a whole pile of variables that by definition a scientist can't control" (informant 7). Acknowledging, accepting and ultimately respecting the institutional differences between these communities is difficult and takes time: "That is one problem: that you don't understand what the others are talking about. But it also a problem of understanding the big question, bringing it to the clinics where it is useful for the patient...that kind of language is a learning curve for the more technology oriented people" (informant 9). In order to overcome such institutional distances, scientists have been actively trying to learn this other 'language'. These practices are made possible by the range of expertise available in Lund in medical and technological fields, and the opportunity for frequent and long-term interaction due to the geographical co-location of the collaborators: "for the last six months there has been a dialogue with the surgeons, with the pathologists. That's one of those difficult dialogues to have because we speak entirely different languages. The surgeons tend to be very mechanically minded: 'there's a tumor, cut it out. What do we need technology for?' So X and I actually went on a clinical course, so back to school, we actually went on courses"(informant 7). Overcoming the institutional distance by learning together is also taking place in a more systematic manner at the organizational level: "we started these prospective sessions to really work with clinicians for a long time to get them to understand what we are doing and vice versa, to see how it works in the clinic. Understanding bioinformatics it might be difficult for older peers to understand, but young students coming up directly from education, have an easier time learning new things when they work together in a multidisciplinary field" (informant 9).

Create Health has since entered a new phase. The centre secured five years of financing, and during the interview period it was announced that a large Cancer Centre would be established at Lund University, bringing together all cancer related research under one roof. Moreover, this new centre will increase the potential for collaboration between scientists, clinicians and private companies. This new environment will undoubtedly shape the future organisational structure of Create Health.

Figure 2: Observed effects of geographical proximity in overcoming challenges to interdisciplinary research

	Formation phase	Initial collaboration phase
Two-community problem	<p>Importance of geographical proximity is high: facilitates social proximity at the local level (Lund) but not at the regional level (Gothenburg-Lund-Malmö)</p> <p>Supports development of “trust” and “chemistry”</p> <p>Importance of local context: Lund’s small scale and expertise in multiple fields supports the establishment of collaboration with cognitively distant partners</p>	<p>Importance of geographical proximity is very high: Overcoming the two-community problem is supported by frequent opportunities for (formal and informal) interaction between collaborators from multiple areas of expertise.</p> <p>Exploit cognitive distance within research centre: seek advice from collaboration partners, question conventional knowledge held by collaboration partners.</p> <p>Overcome institutional distance between technological and clinical fields: learn each other’s ‘language’ by working together and taking formal courses.</p>
Inadequate institutional support	<p>Geographical proximity (at least at some point in time) resulted in social proximity to decision-makers in funding agencies and university administration at national and local levels</p>	<p>Geographical proximity facilitates continued support from different university faculties and hospital</p>

These findings illustrate the valuable insights on interdisciplinarity generated by a geographical perspective. They suggest that geographical proximity is not only important, but also that the impact of geographical proximity may vary between different stages of the collaboration process. In the formation phase, the two-community problem can be overcome due to the social proximity generated by partners being in close geographical proximity. Frequent interactions and knowledge exchange supported the development of trust relationships. In the initial collaboration phase, geographical proximity was of even greater importance as these relationships then allowed researchers to exploit their cognitive distance and contribute to a common learning environment. At the same time, institutional distance between technological and clinical fields could be bridged through reciprocal learning, which benefited from frequent interaction due to geographical proximity.

7. Discussion

This paper contributes to a growing body of research on interdisciplinary collaboration and the ways in which projects overcome two fundamental challenges: the two-community problem and obtaining support from universities and funding agencies. Past research has identified a range of practices, organisational features and management strategies that can help to promote and support interdisciplinary research. However, building on the lessons learned from this case study, we suggest that a geographical perspective can offer additional insights to the conditions that lead to successful collaborations. In this section we will elaborate on each of the two challenges as they were manifested in the case study of Create Health, and suggest lessons we can learn from a geographical perspective to inform where policy intervention may stimulate fruitful interdisciplinary research.

The two-community problem implies that collaborators do not share a common language, corpus of knowledge or evaluation standard. This cultural or behavioural gap results in an opportunity to learn from each other on the one hand, but a struggle to communicate on the other. In order to overcome this gap, collaborators must establish and rely on trust: to trust that collaboration partners in other fields know what they are talking about; to trust that listening and learning from the partners is worthwhile; and to trust them in order to follow their advice when they suggest ways of doing things differently. Two aspects of the geographical context help to overcome this two-community problem. First, as suggested earlier, there is ample evidence in the literature on economic geography that shows how geographical proximity, or spatial co-location, increases the opportunity for frequent face-to-face interactions between partners, which is fundamental for the establishment of trust. Second, geographical proximity increases the likelihood of encounters between potential collaborators in the first place, and reduces communication costs. The case of Create Health illustrates these advantages derived from geographical proximity: the collaborators' co-location in Lund allows for frequent opportunities to interact in planned and unplanned settings, and it supports the development of trustful relationships. Partners learn from sharing apparatus, samples and data analyses; they learn from observing each other; and they learn by asking questions in the corridor two weeks following a seminar, and from being asked such questions. These observations contribute to our understanding of the role played by geographical proximity. Taking the longer collaboration history of Swegene into account, we see this may be different in different stages of collaboration. We suggest that the more advanced the subject matter of collaboration becomes, the greater appears the need for geographical proximity. In other words, the more tacit and specialised the knowledge that is being exchanged becomes, the more need there is for interaction and trustful relationships. The collaboration based on sharing resources under Swegene was able to stretch from Gothenburg to Malmö, but when it came to knowledge exchange and knowledge creation, much greater proximity was required.

A second and related aspect of the geographical context that helps to overcome the two-community problem is the localised presence of strengths in different fields. The process of cross-fertilisation between cognitively distant fields requires firstly, the identification of possible synergies, and secondly, a high degree of expertise in each of the respective fields in

order to successfully transfer solutions across boundaries. The presence of multiple excellent research groups meant that each had been successful in securing research funding in the past and had been able to build up physical and human resources. These resources could be pooled, shared and combined in new ways, which supported the establishment of relationships between the collaborating partners as well as their post-docs and doctoral students. Considering the emphasis in the economic geography literature on the benefits of interaction at the regional scale, it is important to note that our case also questions whether cross-fertilisation takes place at this scale. When considering advanced processes of interdisciplinary knowledge creation, the regional level may not stimulate cross-fertilisation. Our case points to the importance of the micro-scale for scientific collaboration, thereby echoing the point recently made by Catalini (2012) and Owen-Smith, *et al.* (2012).

The second challenge faced by interdisciplinary research – obtaining support from university and funding agencies – also has a distinctly geographical character. Such organisations are perceived as inherently inert and resistant to change, and they represent and protect the interests of established research fields traditionally organised as disciplines. Thus, as illustrated by our case, the likelihood of achieving support depends on the charisma, status and social network of the researchers. As pointed to by the economic geography literature, the presence and informal relationships in Brussels are of vital importance to being able to influence EU regulations. We observe a similar story in our case, where senior figures in and around the research centre have close formal as well as informal relationships with funding agencies and university administration. This is articulated in comments such as being able to interpret what the funding agency “hinted at” (informant 8) when they would not be able to finance eight but only two consortia in 2000; and when “the big guys... have drinks together and they talk” (informant 9). Such social proximity to decision-makers has been crucial during the formation of the centre by securing support from university administration. Moreover, this form of proximity has a large temporal dimension to it: the researchers are, as they put it, “old” and “have been around” (informant 4). These senior researchers have served on the boards of national funding agencies, have acted as evaluators of research proposals, and they have held a variety of administrative positions within the university. This long-term and longitudinal perspective on an individual’s social network highlights the place-specificity of such networks. These individuals have overlapped in their trajectories over the span of careers in the Swedish science system, building up informal and trustful relationships over time. This highlights that social proximity to decision-makers is likely to also have a historical dimension, where relationships are built up over long periods of time as individuals spend their careers in any one place.

In terms of policy implications, these findings suggest a number of considerations on the role of funding in supporting interdisciplinary research environments. If funding is of a limited and relatively short duration, as was the case in Swegene, and the research environment stretches over large distances, then this is likely to not result in lasting collaborative relationships. It takes time and frequent face-to-face interaction in order to develop trust between collaboration partners. This is especially the case for interdisciplinary (as opposed to intra-disciplinary) research, where the cognitive and institutional distances between partners is

large by design, and where the usual foundations for trust that are embedded in a community, are therefore missing. Partners are embedded in different communities, with different standards, ambitions and indicators of value, which make assessing each other's competence and contribution more difficult. In the absence of such established indicators of value, partners must rely on developing inter-personal trust, which is greatly facilitated by geographical proximity that allows for frequent face-to-face interaction. Furthermore, to move from sharing resources to knowledge exchange and ultimately knowledge creation, takes time. Individuals need to absorb and learn from their environment, before they are able to contribute to this environment themselves, and before the others in the research environment accept the individual's contributions. This indicates that financial support intended to encourage lasting interdisciplinary collaborations therefore need to be of a longer duration than what we see in intra-disciplinary research fields, and/or limited to groups where collaborators are in close geographical proximity to each other. Thus, while agreeing with Rosenberg (2009) that establishment of interdisciplinary research is a highly complex process, our analysis highlights that there are ways in which policy intervention may be likely to stimulate fruitful interdisciplinary research.

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