Substituting face-to-face contacts in academics' collaborations modern communication tools, proximity, and brokerage

Werker, Claudia; Ooms, Ward

DOI
10.1080/03075079.2019.1655723

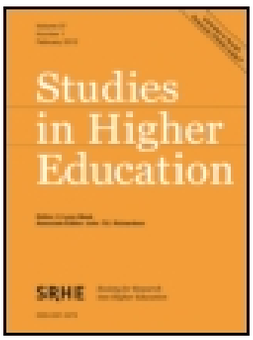
Publication date
2019

Document Version
Final published version

Published in
Studies in Higher Education

Citation (APA)
Werker, C., & Ooms, W. (2019). Substituting face-to-face contacts in academics' collaborations: modern communication tools, proximity, and brokerage. *Studies in Higher Education*, *45*(7), 1431-1447. https://doi.org/10.1080/03075079.2019.1655723

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.



Studies in Higher Education

ISSN: 0307-5079 (Print) 1470-174X (Online) Journal homepage: https://www.tandfonline.com/loi/cshe20

Substituting face-to-face contacts in academics' collaborations: modern communication tools, proximity, and brokerage

Claudia Werker & Ward Ooms

To cite this article: Claudia Werker & Ward Ooms (2019): Substituting face-to-face contacts in academics' collaborations: modern communication tools, proximity, and brokerage, Studies in Higher Education, DOI: 10.1080/03075079.2019.1655723

To link to this article: https://doi.org/10.1080/03075079.2019.1655723

Published online: 26 Aug 2019.

STUDIES IN HIGHER EDUCATION
https://doi.org/10.1080/03075079.2019.1655723

Routledge
Taylor & Francis Group

Substituting face-to-face contacts in academics' collaborations: modern communication tools, proximity, and brokerage

Claudia Werker [a,b] and Ward Ooms [c]

[a]Department of Technology, Policy and Management, VTI Economics of Technology and Innovation, Delft University of Technology, Delft, Netherlands; [b]Research Area TIME, RWTH Aachen University, Aachen, Germany; [c]Faculty of Management, Science, and Technology, Open University of the Netherlands, Heerlen, Netherlands

ABSTRACT

Prior analyses of face-to-face contacts in collaborations have focused on one substitute only. Instead, we analyse various potential substitutes for face-to-face contacts in collaborations. Based on 45 interviews with academics from five leading European universities of technology our findings show that face-to-face contacts are closely intertwined with other mechanisms of coordination and communication for collaboration, particularly modern communication tools, proximity, and brokerage. Generally, to add personal and social proximity to their collaborations academics in our sample rely on face-to-face contacts. In their relationships with industrial partners, face-to-face contacts remain crucial to overcome cognitive and organizational distance. Yet when working with their peers, a number of partial substitutes for face-to-face contacts exist, knowingly combinations of temporary geographical proximity and modern communication tools. Moreover, PhD students can play a crucial role as junior brokers, overcoming a lack of face-to-face contacts between partners jointly supervising them while working in different locations.

KEYWORDS

Modern communication tools; face-to-face contacts; proximity; junior brokers; academia

1. Introduction

The question of whether and how face-to-face contacts between collaboration partners can be substituted has not been conclusively answered yet. This question has, however, become increasingly important in the era of modern communication. Face-to-face contacts involve at least two different persons communicating in each other's presence. Its advantage over modern communication lies in the mutual visual and physical contact when transferring, interpreting, and co-developing knowledge (Asheim, Coenen, and Vang 2007). Face-to-face contacts support learning by social information and psychological motivation (Storper and Venables 2004), thereby overcoming a lack of personal, organizational or cognitive proximity (Werker, Ooms, and Caniëls 2016). They allow for knowledge transfer in complex environments (Bozeman, Fay, and Slade 2013; Cummings and Kiesler 2005; Storper and Venables 2004) and particularly support the transfer and understanding of tacit knowledge (Asheim, Coenen, and Vang 2007; Venkitachalam and Busch 2012).

In the era of modern communication, tools such as e-mail have changed the way collaboration partners organize and maintain ties (Genoni, Merrick, and Willson 2005; Haythornthewait 2002; Rychen and Zimmermann 2008). Prior to their introduction, collaboration at a distance was more

CONTACT Claudia Werker c.werker@tudelft.nl

costly and potentially of lower quality, as compared to collaborations in close geographical proximity and with face-to-face contacts (Kraut, Galegher, and Egido 1990). Modern communication tools open new opportunities for collaborating at a distance, because they are essential means to coordinate research projects in a way that it resembles the coordination that was previously only possible in close proximity (Cummings and Kiesler 2005).

In the following, we shed light on potential substitutes of face-to-face contacts by focusing on the individual relationships between academics and their partners. Academics collaborate to produce knowledge (Bozeman, Fay, and Slade 2013). In doing so, they aim at increasing their research productivity, at gaining access to labs and instruments, or at simply having more fun (Van Rijnsoever and Hessels 2011). Because research collaborations between academics and their (non-)academic partners thrive on the successful transfer, interpretation, and co-development of (tacit) knowledge between them, these collaborations serve as a particularly suitable context in which to examine the (partial) substitution of face-to-face contacts.

While former investigations on substitutes for face-to-face contacts have concentrated on one of the following potential substitutes only, we investigate all three of them including the relationships between them. First, we look into proximity. Whereas face-to-face contacts are usually enabled by permanent geographical proximity, recent empirical research has suggested *temporary geographical proximity* as an important enabler of face-to-face contacts (Bathelt and Henn 2014; Edler, Fier, and Grimpe 2011; Torre 2008; Werker, Ooms, and Caniëls 2016). Here, we also look into the question of whether, when, and how cognitive and organizational proximity may enable or enhance the positive effects of temporary geographical proximity. The reason is that cognitive and organizational proximity have gone hand in hand with permanent geographical proximity in positively affecting collaborative output (Boschma 2005; Broekel and Boschma 2012; Cunningham and Werker 2012; Huber 2012). Yet little is known about how temporary geographical, cognitive and organizational proximity interact (for some first indications see Werker, Ooms, and Caniëls 2016). Second, we analyse *modern communication tools* as potential (partial) substitutes of face-to-face contacts. Since their emergence, modern communication tools have been suggested and discussed as potential replacements of face-to-face contacts (Kraut, Galegher, and Egido 1990). These tools can help potential partners to get in touch, as well as help to maintain and intensify ties with existing partners (Cummings and Kiesler 2005; Genoni, Merrick, and Willson 2005; Haythornthewait 2002), because these tools may mimic essential coordination activities enabled by face-to-face interaction, thereby allowing for efficient interactions at a distance that are of high quality without requiring extensive travel. Third, we investigate *brokers* as potential (partial) substitutes of face-to-face contacts. Brokers have been known to transfer knowledge between different knowledge communities because of their position in networks (Heinze and Bauer 2007). Often, academics in a brokerage role are particularly strong as regards their research output in terms of patents and publications (Lissoni 2010). Here, we also consider brokerage roles for academics other than the top scholars, e.g. PhD students as more or less 'junior' brokers between collaboration partners who jointly supervise them while working in different locations.

Our study is a multiple-case study based on interviews with forty-five academics at leading European universities of technology about their collaborations with different kinds of partners (e.g. industry partners, academic partners). This rich data allows to analyse how academics use face-to-face contacts during collaborations, to analyse whether, when, and how (i.e. by what means) they substitute these contacts (e.g. modern communication tools), and to understand relevant variations across types of collaborators.

In our study, we investigate whether and how academics substitute face-to-face contacts either by temporary geographical proximity, modern communication tools, or junior brokers. In Section 2, we look into former findings on substitutes of face-to-face contacts. Subsequently, we introduce the research design (Section 3.1) and the qualitative data analysis based on forty-five interviews with academics working at five leading European universities of technology data analysis (Section 3.2). In Section 4, we summarize our results in four propositions. Based on these propositions, we discuss the theoretical implications of our results (Section 5). Finally, we round our paper with a

short summary of our main findings, suggestions for future research, and managerial implications (Section 6).

2. Academics' collaborations: the role of face-to-face contacts

2.1. The nature of academics' collaborations and the role of face-to-face contacts

The nature of academics' research, as well as the nature of their collaborations, differs substantially. In their research academics either enhance the fundamental understanding of their own or related disciplines, try to put their findings to practical use, or do both at the same time (Gulbrandsen and Kyvik 2010). Accordingly, the goals of academics' research range from advancing the scientific knowledge base to solving socio-economic problems (Bentley, Gulbrandsen, and Kyvik 2015; Ylijoki, Lyytinen, and Marttila 2011). Thus, academics either carry out basic research or applied research, or do a mixture of both. Often research is conducted in collaborative ties with others (Banal-Estañol, Jofre-Bonet, and Lawson 2015; Bozeman, Fay, and Slade 2013; Cunningham and Werker 2012; Werker, Ooms, and Caniëls 2016). Yet depending on the nature of their research, academics collaborate with dissimilar partners. The typical partners for academics focusing on the quest for fundamental understanding, i.e. doing mainly basic research, are other academics (Nowotny, Scott, and Gibbons 2003). In contrast, academics focusing on solving socio-economic problems, i.e. doing mainly applied research, collaborate with industrial partners (Lam 2010; Porac et al. 2004). Academics focusing on fundamental understanding and searching for solutions to socio-economic problems at the same time, deal with both academic and industrial partners (Lam 2010).

The nature of academics' ties mirrors the goals of their research. Academics working with only other academics carry out research of a similar nature, and particularly pursue the same kinds of goals, i.e. their goal is broadly to add to the fundamental advancement of their field and publish research results in academic journals (Lam 2010). Other academics work – at least partly – with industrial partners. This means that they need to work together with partners who pursue goals that differ from their own, particularly goals directed towards earning profits from doing research. This generally requires the partners to keep research outcomes secret or to protect them via patent applications (Perkmann et al. 2013), as not to harm any potential resultant value capture from innovation.

Forming and maintaining collaborations via face-to-face contacts comes with two substantial advantages for the partners involved. First, collaborative academic research requires the exchange of substantial tacit knowledge (Storper and Venables 2004). Tacit knowledge is embodied in persons, and much more difficult to transfer and use in collaborations than codified knowledge (Venkitachalam and Busch 2012). In the earlier stages of research projects partners typically exchange substantial tacit knowledge. Tacit knowledge is exchanged when they discuss research problems and questions, as well as compare and design potential approaches (Storper and Venables 2004). Second, face-to-face contacts enable collaboration partners to do their research in an inherently uncertain and fluid environment, i.e. environments 'where information is imperfect, rapidly changing, and not easily codified' (Storper and Venables 2004, 351). For such creative collaborative projects, including those in academic research, face-to-face contacts help partners to build trust between them, and to jointly better understand the ambiguity of their ever-changing environment. To sum up, collaboration partners can utilize face-to-face contacts to exchange tacit knowledge, to create novel ideas, and to generate new knowledge in an inherently uncertain environment.

While face-to-face contacts come with these obvious advantages, academics still seem to form and maintain ties with little or no face-to-face contacts. In later stages of research projects, partners seem to rely less on face-to-face contacts, because results are codified and available for reporting and analysis (Storper and Venables 2004). Moreover, academics carry out research in non-local, often even global, networks of knowledge ties (Bozeman, Fay, and Slade 2013; Cunningham and Werker 2012; Werker, Ooms, and Caniëls 2016). Academics have an important reason to do so. If they would only rely on local ties, academics would limit their access to other knowledge and research potential

(Bathelt, Malmberg, and Maskell 2004). Yet we witness an increasingly international nature of successful collaborative knowledge production in academia (Jacob and Meek 2013). When exchanging codified knowledge and when collaborating nationally and internationally academics need (partial) substitutes for face-to-face contacts.

2.2. Potential substitutes of face-to-face contacts

There are a number of potential substitutes for face-to-face contacts, which we proceed to illustrate below. First, in recent years, the notion of temporary geographical proximity was introduced, and we are particularly interested in how it relates to, and is supported by, cognitive and organizational proximity. Second, another potential substitute is a variety of modern communication tools. Their effects have been controversially discussed in the past though, as we illustrate below. Third, a less obvious and less discussed substitute for face-to-face contacts in academic ties is the broker, i.e. a third person bridging between the others. In this study, we will consider brokerage particularly between persons not located in the same place.

2.2.1. Temporary geographical proximity as substitute for face-to-face contacts

While face-to-face contacts have traditionally been associated with geographical proximity, the link between geographical proximity and face-to-face contacts is less straight-forward than usually suggested. Geographical proximity usually does not suffice to successfully collaborate, because face-to-face contacts require partners to do more than just stay in each other's close geographical proximity. They need to actively use the geographical proximity by meeting in person in order to benefit from a face-to-face exchange of knowledge (Aguilera, Lethiais, and Rallet 2014). Moreover, while geographical proximity shows positive effects on collaborative output of academics, these positive effects are usually due to combinations of geographical proximity with other kinds of proximity, e.g. organizational and cognitive proximity (Boschma 2005; Boschma, Marrocu, and Paci 2015; Werker, Ooms, and Caniëls 2016). While partners may benefit from geographical proximity when collaborating, they still need relevant synergies between their knowledge in order to understand one another and to have learning opportunities, i.e. cognitive proximity (Werker, Ooms, and Caniëls 2016). Moreover, they need to get along on a personal level, i.e. personal proximity, as well as pursue joint goals and use similar routines, i.e. organizational proximity (Werker, Ooms, and Caniëls 2016). To sum up, academics have to activate the geographical proximity by using other kinds of proximity in order to effectively collaborate, rather than merely be collocated.

In this study, we look into face-to-face contacts enabled by temporary geographical proximity because of two reasons. First, in previous studies geographical proximity is interpreted as permanent geographical proximity, and empirical research suggests that geographical proximity directly affects the output of ties, because it seems to ease knowledge transfer between partners not sharing similar goals and knowledge bases (Hussler and Ronde 2007). Yet the more other factors, such as cognitive and organizational proximity, have been included in empirical research, the more these factors seem to capture the positive effects on the output of collaborations (Broekel and Boschma 2012; Cunningham and Werker 2012). Second, recent empirical research has suggested that temporary geographical proximity is an important enabler of face-to-face contacts (Bathelt and Henn 2014; e.g. Edler, Fier, and Grimpe 2011; Torre 2008; Werker, Ooms, and Caniëls 2016). In particular, research shows that spatiality plays a crucial role in trust building (Nilsson and Mattes 2015).

Temporary geographical proximity is defined as spending time in the same spatial location, i.e. in geographical proximity to one's partner(s), for a limited amount of time. In fact, while called temporary geographical proximity, the term actually catches the fact that partners temporarily interact face-to-face in the same spatial area. Temporary geographical proximity can take place when visiting the same conferences or spending time together at the same research organization, e.g. as post-doctoral researchers. These temporary face-to-face contacts can be very important for the formation and maintenance of collaborations (Rychen and Zimmermann 2008; Torre 2008). Temporary face-to-face

contacts between partners kindle trust building and enable knowledge transfer (Bathelt and Henn 2014; Torre 2008). Empirical evidence suggests that temporary international mobility helps academics to form and maintain non-local collaborations (Edler, Fier, and Grimpe 2011; Jacob and Meek 2013).

2.2.2. Modern communication tools as substitutes for face-to-face contacts

Over time, academics have gained access to a wide variety of modern communication tools, that are used to aid communication in general, ranging from the use of e-mail, to (video)conference calls, and to online project management tools – to name only a few. They can contribute to the formation and maintenance of ties in three ways (Haythornthewait 2002). First, modern communication tools can open means and opportunities to communicate with (potential) partners previously unconnected. Second, they can help to develop and strengthen ties. Third, they can add additional means of communication that may prove useful. Academics collaborating with their peers benefit from using modern communication tools (Cummings and Kiesler 2005). The same holds for academics getting in touch with unknown other academics (Genoni, Merrick, and Willson 2005). From this point-of-view, modern communication tools, and more specifically those tools that can be regarded as collaboration technology (Venkatesh, Dennis, and Brown 2010), hold plenty of potential to be useful in collaborations of academics. These tools are specifically designed 'to assist two or more people to work together (…) at different places or different times' (Venkatesh, Dennis, and Brown 2010, 11).

2.2.3. Brokers as substitute for face-to-face contacts

Individual academics have been known to transfer knowledge between others. These brokers are individuals strategically located in networks who serve as a bridge between others who want to share knowledge. Their brokerage ties are diverse and spanning the network (Burt 2000; Whittington 2018). In particular, knowledge brokers connect different knowledge communities simply because of their network position (Heinze and Bauer 2007), or they are (put) in charge of an interface entrusted with the collection and distribution of knowledge through their network (Rychen and Zimmermann 2008).

In an academic context, brokers are usually considered to hold a position of power, as they connect diverse knowledge areas of otherwise unrelated networks (Lissoni 2010), and therefore, they may be expected to be more senior academics.

Here, we propose that when it comes to more discretionary, individual-level ties between senior partners, brokers could also be more junior academics, and bridge between the senior academics. Typically, PhD students would help to substitute face-to-face contacts between senior academics jointly supervising them, but working in different locations. External ties in the personal knowledge networks of academic scholars are strong, and are rooted in mutual experience and common history (Grabher and Ibert 2006).

3. Research design and data analysis

3.1. Research design, sample, and data collection

We conduct a multiple-case study of the collaborations of academics working at five European universities of technology, i.e. Delft University of Technology (The Netherlands), the Imperial College London (United Kingdom), Paris Institute of Technology (France), RWTH Aachen University (Germany), and the Swiss Federal Institute of Technology (Switzerland). Thereby, we study different (in terms of location) yet comparable (in terms of a focus on science and technology) universities in order to enhance the external validity of this study (Gibbert, Ruigrok, and Wicki 2008).

3.1.1. Theoretical sampling and matched-pairs approach

As we want to derive propositions on potential substitutes for face-to-face contacts in academics' collaborations, we sampled the cases for our study theoretically (Charmaz 2014; Eisenhardt 1989;

Eisenhardt and Graebner 2007; Siggelkow 2007). We pick the cases in such a way that helps us to clarify whether, when, and how academics employ substitutes of face-to-face contacts, i.e. we sample interviewees from very different research fields. Particularly, we used a matched-pairs approach to sample forty-five academics working at the aforementioned five European universities of technology. When compared to other studies based on interviews (e.g. Fritsch and Aamoucke 2015 with twelve interviews; or Pataraia et al. 2014 with eleven interviews), our sample is rather large with 45 interviewees. We chose this approach in order to provide a solid empirical base for our findings, from which we can develop theory about substitution of face-to-face contacts in academics' collaborations in the form of propositions that may subsequently inform hypotheses in future research.

Accordingly, we selected nine interviewees at each of the five universities. In each university, three interviewees were selected who conducted mainly pure basic research, another three academics were selected who conducted mainly use-inspired research (i.e. doing both basic and applied research), and a final set of three academics were selected who conducted mainly pure applied research. This distinction and pairing was based on Stokes' (1997) conceptual framework, which distinguishes academics focusing on pure basic research from those focusing on pure applied research, and those combining basic and applied research interests (for details see Section 2.1). Academics were matched and classified according the information on academics' professional websites, as well as information provided during their interviews, including their own assessment of their research activities based on the conceptual framework by Stokes (1997). Throughout Section 4 we present illustrative segments from the interview data in the text and in Tables 1–3. After each illustrative segment we report an anonymized interviewee identifier, from which one may read the research orientation of the corresponding interviewee, as follows: an interviewee whose identifier starts with A is sampled as pure applied researcher, an interviewee whose identifier starts with B is sampled as pure basic researcher, and an interviewee whose identifier starts with U is sampled as use-inspired researcher.

The scholars in our final sample obtained their PhD degree between 1969 and 2010. The interviewees started their positions at their current university in different years, ranging from 1975 to 2011. Thirty-three out of forty-five interviewees in the final sample were full professors, twelve interviewees held junior, assistant, and associate professorship positions, or were lecturers or readers. Although the sample contains both male and female academics, due to the overall limited number of female academics at these universities it was not possible to match pairs considering gender.

3.1.2. Data collection: interviews

We conducted semi-structured interviews to collect data. At the start of each interview, we verified pre-collected information, i.e. academics' age, year of doctoral defence, and employment history. Next, we asked the interviewees detailed questions about their research orientation, i.e. the nature of their research interests and outputs. We presented them with a visualization of the Stokes' (1997) model, and asked them to indicate the percentages of their research time spent on pure basic research, pure applied research, or use-inspired research. We also asked them to describe their research activities in detail, as to double-check whether these matched the distribution indicated on the Stokes' model. Then we turned to the core of the interview, focussing on the interviewee's most important collaboration partners, which we asked interviewees to list for us. For each listed partner, we constructed a chronological account during the interview, giving us detailed information about the collaboration's start, process, and outcomes. We asked interviewees to provide details about geographical distance to each partner (regional, national or international collaborations), the kind of partner (academic or industrial), the history of the tie (particularly who had initiated it and in what way collaborators had been in touch during the collaboration), the expected future evolution of the tie (to find out how the collaboration had evolved and whether interviewees were satisfied with the results), and the output of the tie (e.g. product and process innovations, publications, joint supervision of PhD theses, etc.). In that way, we collected in-depth information and background for all collaborations reported. We specifically avoided an interview set-up where we would be directly asking questions about, for example, the substitution of face-to-face contact

Table 1. Face-to-face, modern communication, or both?

Proposition	Illustrative data			
Proposition 1	*[In EU-funded research projects:]* 'I think that is relevant. Say, on European projects, these are helped by travelling and meeting them in project meetings and so on.' (B7)	*[In general about all long-standing contacts:]* 'It is important that you meet every now and then with the people. Well, I mean, you can do a lot of Skype and e-mails internationally, but I think it is important in a network that you meet every now and then, and have dinner with people, and have a beer … I think it is important to keep it together.' (U8)	*[When comparing several projects at different geographical distance, and discussing the one closest to the interviewee's university and considering the possibility to use modern communication for those projects at greater distance:]* 'And even more stark is the difference when I compare those projects with all the meetings we have in *[city/region where university is located]*, it is just because of the proximity. We can go out for lunch, and we discuss things. Otherwise, I have to drive extra to *[city at a distance]*, because then I do not have so much time, because I go back on the same day, there is already a difference there. Sure, you could work with videoconferencing these days, but I am not that far. So I think it is easier to talk over the phone.' (A3)	'*[on face-to-face contact in temporary geographical proximity:]* I mean it's definitely desirable. Video conferences and *[video conferencing software]* are absolutely not even close to a personal meeting. So I've been known to fly out for a night to Singapore and back.' (U7)
Proposition 2	*[When interviewee compares his approach to collaboration with academics to his approach to collaboration with industry partners, he explains physical visits and face-to-face contact are much more often used:]* 'Actually for the implementation of your research projects *[in industry]*, industries I work with are Holland-based, like *[large health technology firm]* for instance – yes, that's an international company, but many of their scientists sit here.' (U5) 'Yea, every now and then. We have regular appointments with them. Well, that PhD student wants that company to do certain things: And then you better have good communications and talk regular with each other, because otherwise nothing will happen.' (A4)	'For collaborations with hospitals it is also very important that they are close, because I want to talk to a surgeon.' (U4)	'With industry it is a bit different, actually. E-mail only does not always work, because I find myself meeting with them *[industry]* more often than I do with my colleagues and other professors, for instance. […] Perhaps because on that level maybe there has to be more of an official try. I find this is how it works: Usually you have to physically actually go to the company and meet there, rather than just sending an e-mail, which would be enough for an academic partner.' (A12)	'Well, it's more in case of them commissioning us to do the work, and then obviously strategically they have an input into the direction of the work. So we'd have meetings every 6 months or something, that in terms of the day-to-day running of the project, you know that we'd be responsible for that.' (A9)

Table 2. Academics prefer face-to-face contacts.

Pattern	Illustrative data			
Proposition 3	'[…] if I got into the car now, I'll be in Grenoble in 5 h, if need be, and if it's within Europe, for example, if I want to go to Marseille, I'll drive out to the airport, get on a plane, and fly there. When you have a lot to talk about, you meet personally, you meet once every year somewhere. And if there really is something urgent, then you could sit there together or if you wanted to discuss more specific, then you could say: "Now we go to Zürich and sit down together for 2 days and we discuss something." We already had that. So when it is in Europe, then you get on the plane, and then you are there.' (B10)	'When the contacts are established, videoconferencing works. But, I strongly stick to my view that you must meet each other twice a year, sit at a table together, grab a bite of dinner, drink a beer together, and truly stay in touch like this. So, as soon as contact exist, then videoconferencing can help you to work together more effectively. But, as I said, you cannot use videoconferencing to establish or maintain ties with partners, that works only face-to-face.' (U2)	'[…] the face-to-face, sometimes it's not even efficient, because then you finally get to meet, and then you also talk about other things, but it's more the creative one, it's where you discuss a new project, it's where we work together with students.' (B12)	'No, of course I mean it is more efficient if we can have direct contact. For instance, the people in Rome when they go and they come. The amount of work which is done in a small amount of time is bigger. But if we cannot, then we use the other ways. It is efficient and it works.' (U14)
	'I spend a lot of time *[videoconferencing]* with all of these *[partners]*, especially these three I mentioned now, so *Person A*, *Person B,* and *Person C*. Plenty of my time is spent really on e-mails and *[video conferencing software]*. *[Video conferencing software]*is a key thing, because that is the quick and efficient flow of information that has to go and come back when we need answer.' (B12)	'I think it is usually helpful to maintain a good exchange of information and collaboration to have regular *[video conferencing software]* or conference calls. We complement that with meetings *[in temporary geographical proximity]* … at least every 6 months.' (A15)	'Well, in the academic world it is not a necessity that you see someone face-to-face, because there is a lot of e-mail exchange going on and you might see someone at a conference once a year, which is still enough to maintain a collaboration.' (A12)	'So, I hope it *[i.e. usefulness of the tie]* maintains the same level, but in reality I expect it to be weakened because of the distance. I mean … it's quite different I guess if you are able to see the other person. I think that still helps, you know, just sit down and have coffee and just talk things out, brainstorm ideas, still, even with the availability of *[video conferencing software]*. The time difference also matters, right, and it's just not the same. I try to go back and forth, but I think that's just a little bit difficult physically and timewise.' (U10)
	'I visited them once after that at the launch of the project, and since then we have maintained contact by means of conference calls. I think that has been the case for past almost 2 years. We have a location [at our disposal] for visits	*[Talking about projects in basic research:]* 'Some things are of course easier to discuss, if you really sit in the same room, but you can also discuss many things very well via videoconference. […] makes up for the lack of	'Mostly audio-conferences. So we get on Skype and talk to each other, within the European project we do one teleconference every month. So yes, it is important. We exchange e-mail, we	

(*Continued*)

Table 2. Continued.

Pattern	Illustrative data		
	and so on, but we are trying to save this for when they are doing the experiments, so that we go there for a particular purpose. But I mean, it works perfectly fine. And they [other project partners] actually communicate from different places in the US as well. We don't even use video, it's just a conference call. But we do exchange documents.' (B7)	spatial proximity. […] That contributes to or that is advantageous if really projects ideas or projects are running.' (B3)	send papers around and modifications of the papers through electronic means. So it's extremely important.' (A6)

Table 3. Other substitutes for (temporary) geographical proximity.

Pattern	Illustrative data			
Proposition 4	'The expertise that we do not have here, but other colleagues elsewhere, that you can initiate this relatively straightforward and the doctoral students go over there and then get the info. *[When asked if the interviewee is referring to face-to-face contact in temporary geographical proximity to the collaborator:]* Exactly.' (B11)	'But, for example the people from Finland or Sweden, I have not been there, their PhD was here, but the supervisors were never here for a long period of time.' (A6)	'… Professor *[Name]*, who is older than me, but we have been working together closely for several years. We have two joint PhD students and we work intensively […] I have a student now, who is about to go out to *[university where this professor works, at geographical distance]*.' (A8)	'And then, there is a PhD student they want to send from there to here, and I have master students, whom I send from here to *[country in another continent]*.' (A4)

(e.g. with modern communication tools), as discussing these themes explicitly would be problematic for reliability and potentially cause participant bias (Silverman 2013a, 2017).

3.2. Qualitative data analysis

In our data analysis, we followed a three-step approach, departing from a starting list of codes, but maintaining the necessary openness to alternative theoretical concepts and causal relationships (Siggelkow 2007). In this way, we were able to ensure the validity and reliability of our coding process. In all steps of the data analysis, we used the MAXQDA 11 software package to aid our qualitative data analysis, i.e. to perform coding and analysis, as well as to assist interpretation, and in order to create and maintain a database for our case studies. This software aids researchers in establishing a clear chain of evidence for case study results, and thereby enhances construct validity (Gibbert, Ruigrok, and Wicki 2008).

In a first step, we departed from theoretical concepts and former findings on causal relationships in our theoretical framework which had been the basis for our research project. Hence, we started with a first round of deductive coding of the interview transcripts. In particular, we assigned codes from a predefined starting list of codes to segments of the transcripts of the interviews. Accordingly, we coded:

- the type of partner (industrial, academic, or other)
- relevant proximity dimensions (e.g. geographical or cognitive proximity)

- output(s) (e.g. publications, patents, innovations, PhD dissertations)
- the use of face-to-face communication and/or modern information and communication tools
- 'other', to categorize any relevant information that we could not otherwise code based on the starting list

In a second step, we assigned inductive (sub-)codes to the data, in order to enable more detailed analysis and to aid interpretation of the data. Here, we assigned new codes to some of the segments labeled 'other' during the first round, but also refined coding for other codes from the starting list. For example, all segments dealing with 'geographical proximity' were redistributed to new sub-codes in order to identify the degree of geographical proximity (differentiating segments referring to partners at the local, regional, national, European Union, and global level), and all segments pointing to the use of modern communication tools were assigned additional labels to keep track of what kind of modern communication tools had been used (e-mail, videoconferencing, audio-only conference calls).

In a third step, we conducted various analyses using the coded data, in order to identify clear patterns in this data, based on (counting and analyzing) code (co-)occurrence. Data related to the identified patterns was then compiled and reported in separate files, for further inspection and interpretation. In developing propositions from our data in Section 4, we choose to develop only propositions that can be supported with clear patterns in our data based on coding, analysis of our coded data, and interpretation of the qualitative data linked to the potential patterns identified. We provide illustrative data, both in the text as well as in additional tables, with all propositions. Our approach to coding data, analyzing data, interpreting data, and reporting the results is a well-established procedure, safeguarding the internal validity of findings against problems such as 'anecdotalism' (Gibbert and Ruigrok 2010; Silverman 2013b).

4. Academics' collaborations: face-to-face contacts and (partial) substitutes

4.1. Face-to-face contacts add personal and social proximity to academics' ties

In order to form and maintain their collaborations, the academics in our sample prefer to have face-to-face contacts with their partners as they want to add a social and personal dimension to their relationships in order to build trust and capture the tacit elements of the knowledge transferred and created. As *Interviewee U8* puts it:

> … you can do a lot of Skype and e-mails internationally, but I think it is important in a network that you meet every now and then, and have dinner with people, and have a beer … I think it is important to keep it [the tie] together.

Trust building depends a lot on whether or not partners get along personally, i.e. on the personal proximity between them. Some academics feel very strongly about this:

> I am quite happy to travel to the far-east to get something done with somebody agreeable, rather than walk across campus and deal with some miserable guy. I would rather fly sixteen hours to avoid that and work with somebody who is fun to work with. Yeah, if you don't have the personal chemistry it just isn't going to happen. You won't be able to trust each other or to get things done. (*Interviewee U7*)

We provide additional illustrative data of the proposition postulated below in Table 1.

> Proposition 1: In order to add personal and social proximity to their professional relationship, European academics at universities of technology rather use face-to-face contacts than modern communication tools in their collaborations with both academic and industrial partners.

4.2. University-industry ties call for face-to-face contacts

In contrast to ties with other academics, university-industry ties call for face-to-face contacts (e.g. *Interviewee U5*), both to form these ties, as well as during the collaboration:

- ' … because he had to join one of our programs as a student to learn about the production of [*a product used in road construction*], he was with us for half a year […] This all went well, and from these contacts a long tradition of collaboration emerged' (*Interviewee A1* about the formation of a tie with an industry partner)
- 'Usually you have to physically actually go to the company and meet there, rather than just sending an e-mail, which would be enough for an academic partner.' (*Interviewee A12* about ongoing projects with industry partners)

With their industrial partners academics in our sample only use modern communication tools for minor practical matters, such as setting up meetings or exchanging documents. Yet they are usually uncomfortable in dealing with research content with their industrial partners by using modern communication tools. Hence, the academics organize major constituents of their research (e.g. reporting and discussing progress, experimentation) with their industry partners almost exclusively face-to-face. They find it very important to meet frequently and face-to-face with their industrial partners. This becomes very clear in the example of *Interviewee U4* who stresses that s/he wants to 'talk to the surgeon' in person. Many others also report this approach to their collaborations with industry partners, e.g.: *B10* that he seeks face-to-face contact when developing applications for citizens using his research; *A13* goes on location to record technical data for industry partners; for *A4* the most important industry partner has chosen to locate right next door to the university to have more face-to-face contact; and *U5* describes how his collaborations with industry tend to alternate between brief periods of frequent face-to-face contact to start-up research and report on research findings and other, more lengthy periods of no contact at all when (contracted) research is being conducted. Given this need for face-to-face contacts, the academics usually choose their industrial partners in rather close geographical proximity; if for some reason they cannot, we find that they travel in order to meet face-to-face or, in one case, collaborate at a distance assisted by local intermediaries on-site of the industry partner.

Hence, it appears academics in our sample need more face-to-face contacts with their industrial than with their academic partners in order to overcome the cognitive and organizational distance described in the above. Indeed, our analyses surface three reasons why here academics rely more on face-to-face communication with their industrial partners than with their academic partners, all of which are related to organizational and/or cognitive distance. First, the task at hand is different in nature, as it is more applied. Face-to-face meetings enable partners to see, hear, and even touch experimental outcomes (*Interviewee B10* and *Interviewee U11*). Second, ties with industry, and specific projects with industry partners, are more formalized than ties with other academics. With industrial partners 'there has to be more of an official try' (*Interviewee B12*). This means that face-to-face meetings are at times a requirement, particularly when a funding institution is involved, or at least academic partners feel that industrial partners expect them to report about the project in face-to-face meetings (*Interviewee A9*). Third, the division of labor between partners is clear-cut and requires regular exchange, certainly when industry partners commission work to the university (i.e. contract research), as in the case of the collaboration discussed by *Interviewee A9*. Therefore, partners need to update one another on a regular basis.

Proposition 2: To overcome cognitive and organizational distance European academics at universities of technology regard their face-to-face contacts as crucial when collaborating with industrial partners.

4.3. Academic collaborations: modern communication tools and proximity as substitutes

In general, being geographically close means that partners have more time, and time they can use to not only talk business (i.e. discuss the particular research project at hand), but also to discuss and exchange other information over lunch or dinner (see *Interviewee U8*, and *Interviewee A3*,

Interviewee U2). From the data we can derive that academics in our sample use temporary or occasional face-to-face contacts (i.e. via temporary geographical proximity) to form ties with other academics:

- 'the more creative one, it is where you discuss a new project' (*Interviewee B12* about the nature and the use of face-to-face contacts)
- 'because of talks when we met at a workshop' (*Interviewee U2* about the formation of a tie)

Often, collaboration partners have spent time together before, e.g. when one partner was a visiting scholar at the other partner's institute (e.g. *Interviewees B7 and A8*), when they shared employers for a brief or longer period of time (e.g. as post-docs, *Interviewee A7*), or when they met at conferences regularly organized by their community (e.g. *Interviewees U5 and U6*). After initially forming collaborations, academic partners keep making use of temporary or occasional face-to-face contacts, but also rely heavily on modern communication tools. However, yet again, interviewees prefer face-to-face contacts over modern communication to work with academic partners as well. The interviewees report three reasons why temporary face-to-face contacts remain important (see Table 2):

- to make considerable progress in research projects in a limited amount of time (e.g. *Interviewee U14)*
- to deal with, and to resolve, complex problems arising in joint research (e.g. *Interviewees B10 and B12*)
- to 'maintain' (the strength of) existing ties (e.g. *Interviewee U2*)

In Table 2 we provide additional illustrative segments from the data, in which academics explain why they prefer to have regular face-to-face contacts. Yet despite their clear preference for face-to-face contacts, and without exception, the interviewees do use modern communication tools to stay in touch at times when face-to-face contact is neither necessary nor efficient. This applies to all kinds of academics in our sample, because there are no clear differences in the use of modern communication tools related to, for example, age, tenure, and research orientation. Only three out of forty-five academics in our sample indicate that they do not like to use modern communication tools in their collaborations with other academics. Yet the same three interviewees do report regular use of these modern communication tools nonetheless, indicating that although they prefer temporary face-to-face contacts, distance and efficiency forces them to use modern communication tools. All other academics use these tools to substitute permanent geographical proximity, in most cases quite extensively (they use the tools frequently and across many or all of their collaborations with other academics), and in a small number of cases almost exclusively, albeit always in specific projects or with specific collaborators (e.g. U11 report three collaborations with other academics in which research projects were conducted and published without any face-to-face interaction between the collaborators). Our results suggest that modern communication tools are used at a large scale to coordinate projects, to exchange information on routine and urgent tasks, and to work on specific parts of research projects consecutively. Hence, the day-to-day collaboration between academics in our sample takes place largely by communicating via e-mail, videoconferencing, and conference calls (audio only). Based on further analysis of the data segments coded as referring to the use of modern communication tools (often times combinations thereof), we can identify that the vast majority of academics who use modern communication tools use e-mail (70%), followed by considerable use of videoconferencing (52%), as well as conference calls with audio only (33%).

Proposition 3: In order to substitute permanent geographical proximity, European academics at universities of technology successfully use a combination of temporary face-to-face contacts and modern communication tools in their collaborations with their peers in academia.

4.4. PhD students as substitutes for face-to-face contacts between academics

There are quite a number of senior academics in our sample who work in different locations and choose to collaborate via PhD students. We find seventeen interviewees who report about the role of PhD student as substitutes to face-to-face contacts between the collaborating academics, in four cases these PhD students also serve as a broker between the academics and industry partners, and in one case even graduate students take on this brokerage role. As *interviewee A6* puts it:

> … , for example the people from Finland or Sweden, I have not been there, their PhD was here, but the supervisors were never here for a long period of time.

For these senior academics the regular exchange of students who successfully carry out their research projects by working in both locations seem to be trust building. Interviewee A4 describes it as follows:

> And then, there is a PhD student they want to send from there to here, and I have master students, whom I send from here to [country in another continent].

Please find additional segments from our interviews supporting this pattern in Table 3. It is mostly through joint PhD students or via each other's PhD students that these academics interact with their collaborators (e.g. *Interviewee A6*). The PhD students serve as junior brokers between the academics jointly supervising them. Therefore, the academics themselves have a decreasing need to meet face-to-face with their peers in such cases.

In one case an academic even published several times with another academic s/he has never met because of the brokerage of a PhD student. a single and, hence, exceptional case in our sample, an academic from ETH Zürich doing use-inspired research had published several times with someone s/he never met before or after. Prior to this joint work, the collaboration partner had had conducted experiments in his/her lab for the academic in our sample, and had also had one of his/her PhD students visiting for a period of time. Both of these events seem to instil sufficient confidence in mutual research interest, and sufficient trust between the partners, in order for them to publish together in this case.

> Proposition 4: When supervisors are situated in different locations and/or organizations, PhD students can serve as junior brokers, and replace face-to-face contacts between the supervisors themselves.

5. Discussion: face-to-face contacts still important in the era of modern communication

Our results contribute to shedding light on whether, when, and how academics use face-to-face contacts, as well as whether, when, and how (i.e. by what means) they substitute them. Our results confirm that face-to-face contacts remain important in the era of modern communication. In general, academics in our sample prefer face-to-face contacts when forming and maintaining their research collaborations (see Proposition 1 in Section 4.1). This result is in line with former findings (e.g. Hoekman, Frenken, and Tijssen 2010; Morgan 2004). More particularly, our results indicate that combining cognitive proximity with personal proximity enables and accelerates academics' collaborations. With this we support former findings indicating that face-to-face contacts help to establish personal proximity (Werker, Ooms, and Caniëls 2016), adding social information and psychological motivation to the professional tie (Grabher and Ibert 2006; Storper and Venables 2004).

The role of face-to-face contacts depends on the kind of partner academics collaborate with. In particular, academics in our sample heavily use face-to-face contacts with their industrial partners (see Proposition 2 in Section 4.2). The interviewees stress that face-to-face contacts help them to overcome cognitive and organizational distance between their industrial partners and themselves. Academics have a greater cognitive distance to their industrial partners compared to their academic partners, because industrial partners focus on their practical problems at hand (cf. this and the following Ambos et al. 2008; Lam 2010). In contrast, academics want to build up an area of expertise and

contribute to scientific advances in their area of expertise, even when doing pure applied research. Academics have a greater organizational distance to their industrial partners compared to their academic partners, because although academics may value the practical outcomes of research, they will generally also aim at generating publications from their research. In contrast, industrial partners may rather keep research outcomes secret for a while, in order to be able to capture value from innovation. Industrial partners are certainly much less interested in publications anyway. Hence, in university-industry collaborations partners do not pursue the same goals. This even means that their time horizons differ, i.e. academics tend to be more interested in long-run contributions and industrial partners in short-run solutions. So, frequent face-to-face contacts are crucial to help academics to overcome the cognitive and organizational distance with their industrial partners. Furthermore, as was pointed out in Section 2.2.1, temporary geographical proximity may enable the repeated face-to-face interaction that is necessary to build trust with the industry partners. Trust was identified as important mechanism by which firms coordinate their collaborations with external partners (e.g. Filippetti and D'Ippolito 2017).

While academics in our sample prefer face-to-face contacts when collaborating with their peers (see Proposition 1 in Section 4.1), also in this type of collaboration, they (partly) substitute face-to-face contacts on a regular basis. These academics do so because they need to connect to and exchange knowledge with, partners who are nationally and internationally dispersed. If they are unable to connect to these partners they would considerably limit their knowledge base and, hence, their research potential (Bathelt, Malmberg, and Maskell 2004). Our results point at three (partial) substitutes of face-to-face contacts: (1) temporary face-to-face contacts, (2) modern communication tools, and (3) junior brokers. With their peers, academics are cognitively and organizationally much closer than with their industry partners. Therefore, they can more easily form and maintain ties with them without relying on permanent geographical proximity, which they would otherwise use to enable frequent and considerable face-to-face contact with their partners. To successfully collaborate on research projects with other academics they often use a combination of two substitutes of face-to-face contacts: temporary geographically proximity enabling temporary face-to-face contacts (e.g. occasional meeting at conferences and workshops or occasional joint stays at one research organization), and modern communication tools in order to interact at geographical distance (proposition 3 in Section 4.3). This is line with findings suggesting temporary geographical proximity including face-to-face contacts can already go a long way to build trust between partners (e.g. Rychen and Zimmermann 2008; Torre 2008; Werker, Ooms, and Caniëls 2016).

Our results point at junior brokers who help to substitute face-to-face contacts between academics. PhD students can act as junior brokers when their supervisors work in different locations. As such, they are substituting regular face-to-face contacts between their supervisors. In doing so, they limit both the need for permanent as well as temporary geographical proximity between their supervisors (see proposition 4 in Section 4.4). This brokerage role for PhD students is one that is not much considered in the literature to date, as studies of brokerage in academic networks point mostly at roles for senior academics who manoeuvred gradually into a brokerage position in the network through patenting and publishing (Forti, Franzoni, and Sobrero 2013; Lissoni 2010). These typical brokerage roles are held by academics in what could be considered 'strategic positions' in the overall network. Yet our findings point to junior brokers that the quantitative measures used to analyse social networks' structure (e.g. patent and publication data) have not revealed. Our qualitative study puts forward the idea that although more senior academics may hold strategic brokerage positions in the overall collaborartion networks of academics, the 'actual' brokerage on a micro-level is via more junior brokers, such as PhD students.

6. Conclusions

Our results add to the theory about face-to-face contacts in collaborations by analyzing the use of potential substitutes and their relationships in detail, instead of only focusing on a single potential

substitute. We show that face-to-face contacts are closely intertwined with and complemented by other mechanisms of coordination and communication, particularly modern communication tools, junior brokerage, as well as personal, social, cognitive and organizational proximity. By analyzing 45 interviews with academics at five leading European universities of technology, we answer to earlier calls for the identification of intangible and tangible factors underlying tie formation and maintenance, i.e. those factors that go beyond the information obtainable from publication data and other quantitative measures (Bozeman, Fay, and Slade 2013).

Our findings offer some hints for academics, university managers, and policy makers. Academics themselves may be more confident in using substitutes for face-to-face contacts when collaborating with their peers in other locations, because we provide evidence that others have been doing this successfully on a regular basis. The same holds for using PhD students as junior brokers. Moreover, university managers and policy makers who want to stimulate university-industry collaborations may wish to support face-to-face contacts between (potential) partners.

Several open and new research questions emerge from our results. Our finding that academics use temporary geographical proximity together with modern communication tools to substitute for face-to-face contacts when collaborating with their peers deserves further elaboration. So does our result on PhD students as junior brokers bridging between their supervisors who work in different locations. First, these results raise questions such as whether these substitutes may lead to trade-offs in terms of quality and quantity of collaborative research output, and if so, to what extent the benefits of using these substitutes exceed the cost? Second, PhD students as junior brokers indicate that senior academics may depend on junior academics to secure and hold their strategic positions in academics' networks. Particularly, it may be valuable to further investigate our understanding of academics networks beyond quantitative measures that visualize network structure. Our results stress the need for further research into questions about how academics can attain and keep strategic positions in their networks. That is, to what extent does having PhD students in the form of junior brokers aid academics in this respect? Could there be yet other ways to attain and keep these positions? Third, our results reaffirm prior findings (e.g. Werker, Ooms, and Caniëls 2016), in illustrating that a combination of personal, social, cognitive, organizational and geographical proximity is important for the formation and maintenance of ties. It would be interesting to find out whether this also the case when studying quality, quantity, or impact of collaborative research output. Fourth, our data reveals that often e-mail or only audio solutions suffice to substitute face-to-face contacts. In this context, a systematic investigation of what modern communication tools are used by whom for which purposes during collaboration would be welcome. Finally, although the European academics at universities of technology in our sample were interviewed about their collaborations with other academics from around the globe, the dynamics of collaborations of academics at other types of universities or in other continents may still vary (e.g. cultural customs may affect the perceived value of face-to-face interactions). Future research could aim to investigate collaborations by academics in other types of universities or in other continents.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding

Claudia Werker gratefully acknowledges the funding by the European Commission as part of the Seventh Framework Programme [grant number 275357] for this project.

ORCID

Claudia Werker http://orcid.org/0000-0002-1922-7235
Ward Ooms http://orcid.org/0000-0003-4293-906X

References

Aguilera, A., V. Lethiais, and A. Rallet. 2014. "Spatial Proximity and Intercompany Communication: Myths and Realities." *European Planning Studies* 23 (4): 798–810. doi:10.1080/09654313.2014.979137.

Ambos, T. C., K. Mäkelä, J. Birkinshaw, and P. D'Este. 2008. "When Does University Research Get Commercialized? Creating Ambidexterity in Research Institutions." *Journal of Management Studies* 45 (8): 1424–1447.

Asheim, B., L. Coenen, and J. Vang. 2007. "Face-to-face, Buzz, and Knowledge Bases: Sociospatial Implications for Learning, Innovation, and Innovation Policy." *Environment and Planning C: Government and Policy* 25: 655–670.

Banal-Estañol, A., M. Jofre-Bonet, and C. Lawson. 2015. "The Double-Edged Sword of Industry Collaboration: Evidence from Engineering Academics in the UK." *Research Policy* 44 (6): 1160–1175. doi:10.1016/j.respol.2015.02.006.

Bathelt, H., and S. Henn. 2014. "The Geographies of Knowledge Transfers Over Distance: Toward a Typology." *Environment and Planning A* 46 (6): 1403–1424. doi:10.1068/a46115.

Bathelt, H., A. Malmberg, and P. Maskell. 2004. "Clusters and Knowledge: Local Buzz, Global Pipelines and the Process of Knowledge Creation." *Progress in Human Geography* 28 (1): 31–56. doi:10.1191/0309132504ph469oa.

Bentley, P. J., M. Gulbrandsen, and S. Kyvik. 2015. "The Relationship Between Basic and Applied Research in Universities." *Higher Education* 70: 689–709. doi:10.1007/s10734-015-9861-2.

Boschma, R. 2005. "Proximity and Innovation: A Critical Assessment." *Regional Studies* 39 (1): 61–74. doi:10.1080/0034340052000320887.

Boschma, R., E. Marrocu, and R. Paci. 2015. "Symmetric and Asymmetric Effects of Proximities. The Case of M&A Deals in Italy." *Journal of Economic Geography* 16: 505–535. doi:10.1093/jeg/lbv005.

Bozeman, B., D. Fay, and C. P. Slade. 2013. "Research Collaboration in Universities and Academic Entrepreneurship: The-State-of-the-art." *The Journal of Technology Transfer* 38 (1): 1–67. doi:10.1007/s10961-012-9281-8.

Broekel, T., and R. Boschma. 2012. "Knowledge Networks in the Dutch Aviation Industry: The Proximity Paradox." *Journal of Economic Geography* 12 (2): 409–433. doi:10.1093/jeg/lbr010.

Burt, R. S. 2000. "The Network Structure of Social Capital." *Research in Organizational Behaviour* 22: 345–423.

Charmaz, K. 2014. *Constructing Grounded Theory*. London: Sage Publications.

Cummings, J. N., and S. Kiesler. 2005. "Collaborative Research Across Disciplinary and Organizational Boundaries." *Social Studies of Science* 35 (5): 703–722. doi:10.1177/0306312705055535.

Cunningham, S. W., and C. Werker. 2012. "Proximity and Collaboration in European Nanotechnology." *Papers in Regional Science* 91 (4): 723–743. doi:10.1111/j.1435-5957.2012.00416.x.

Edler, J., H. Fier, and C. Grimpe. 2011. "International Scientist Mobility and the Locus of Knowledge and Technology Transfer." *Research Policy* 40: 791–805. doi:10.1016/j.respol.2011.03.003.

Eisenhardt, K. M. 1989. "Building Theories from Case Study Research." *Academy of Management Review* 14 (4): 532–550.

Eisenhardt, K. M., and M. E. Graebner. 2007. "Theory Building from Cases: Opportunities and Challenges." *Academy of Management Journal* 50 (1): 25–32.

Filippetti, A., and B. D'Ippolito. 2017. "Appropriability of Design Innovation Across Organisational Boundaries: Exploring Collaborative Relationships Between Manufacturing Firms and Designers in Italy." *Industry and Innovation* 24 (6): 613–632. doi:10.1080/13662716.2016.1263888.

Forti, E., C. Franzoni, and M. Sobrero. 2013. "Bridges or Isolates? Investigating the Social Networks of Academic Inventors." *Research Policy* 42: 1378–1388. doi:10.1016/j.respol.2013.05.003.

Fritsch, M., and R. Aamoucke. 2015. "Fields of Knowledge in Higher Education Institutions, and Innovative Start-ups: An Empirical Investigation." *Papers in Regional Science* 96: S1–S27. doi:10.1111/pirs.12175.

Genoni, P., H. Merrick, and M. Willson. 2005. "The Use of the Internet to Activate Latent Ties in Scholarly Communities." *First Monday* 10 (12), doi:10.5210/fm.v10i12.1301.

Gibbert, M., and W. Ruigrok. 2010. "The "What" and "How" of Case Study Rigor: Three Strategies Based on Published Work." *Organizational Research Methods* 13 (4): 710–737.

Gibbert, M., W. Ruigrok, and B. Wicki. 2008. "What Passes as a Rigorous Case Study?" *Strategic Management Journal* 29 (13): 1465–1474. doi:10.1002/Smj.722.

Grabher, G., and O. Ibert. 2006. "Bad Company? The Ambiguity of Personal Knowledge Networks." *Journal of Economic Geography* 6 (3): 251–271. doi:10.1093/jeg/lbi014.

Gulbrandsen, M., and S. Kyvik. 2010. "Are the Concepts Basic Research, Applied Research and Experimental Development Still Useful? An Empirical Investigation among Norwegian Academics." *Science and Public Policy* 37 (5): 343–353. doi:10.3152/030234210x501171.

Haythornthewait, C. 2002. "Strong, Weak, and Latent Ties and the Impact of New Media." *The Information Society* 18: 385–401. doi:10.1080/0197224029010819.

Heinze, T., and G. Bauer. 2007. "Characterizing Creative Scientists in Nano-S&T: Productivity, Multidisciplinarity, and Network Brokerage in a Longitudinal Perspective." *Scientometrics* 70 (3): 811–830. doi:10.1007/s11192-007-0313-3.

Hoekman, J., K. Frenken, and R. J. W. Tijssen. 2010. "Research Collaboration at a Distance: Changing Spatial Patterns of Scientific Collaboration Within Europe." *Research Policy* 39 (5): 662–673. doi:10.1016/j.respol.2010.01.012.

Huber, F. 2012. "On the Role and Interrelationship of Spatial, Social and Cognitive Proximity: Personal Knowledge Relationships of R&D Workers in the Cambridge Information Technology Cluster." *Regional Studies* 46 (9): 1169–1182. doi:10.1080/00343404.2011.569539.

Hussler, C., and P. Ronde. 2007. "The Impact of Cognitive Communities on the Diffusion of Academic Knowledge: Evidence from the Networks of Inventors of a French University." *Research Policy* 36 (2): 288–302. doi:10.1016/j.respol.2006.11.006.

Jacob, M., and V. L. Meek. 2013. "Scientific Mobility and International Research Networks: Trends and Policy Tools for Promoting Research Excellence and Capacity Building." *Studies in Higher Education* 38 (3): 331–344. doi:10.1080/03075079.2013.773789.

Kraut, R. E., J. Galegher, and C. Egido. 1990. "Patterns of Contact and Communication in Scientific Research Collaborations." *Intellectual Teamwork: Social and Technological Foundations of Cooperative Work*, edited by J. Galegher, C. Egido, and R. E. Kraut, 163–186. New York: Psychology Press. doi:10.4324/9781315807645.

Lam, A. 2010. "From 'Ivory Tower Traditionalists' to 'Entrepreneurial Scientists'?: Academic Scientists in Fuzzy University–Industry Boundaries." *Social Studies of Science* 40 (2): 307–340. doi:10.1177/0306312709349963.

Lissoni, F. 2010. "Academic Inventors as Brokers." *Research Policy* 39 (7): 843–857. doi:10.1016/j.respol.2010.04.005.

Morgan, K. 2004. "The Exaggerated Death of Geography: Learning, Proximity and Territorial Innovation Systems." *Journal of Economic Geography* 4: 3–21.

Nilsson, M., and J. Mattes. 2015. "The Spatiality of Trust: Factors Influencing the Creation of Trust and the Role of Face-to-Face Contacts." *European Management Journal* 33 (4): 230–244. doi:10.1016/j.emj.2015.01.002.

Nowotny, H., P. Scott, and M. Gibbons. 2003. "Introduction 'Mode 2' Revisited: The New Production of Knowledge." *Minerva* 41: 179–194.

Pataraia, N., A. Margaryan, I. Falconer, A. Littlejohn, and J. Falconer. 2014. "Discovering Academics' key Learning Connections." *Journal of Workplace Learning* 26 (1): 56–72. doi:10.1108/jwl-03-2013-0012.

Perkmann, M., V. Tartari, M. McKelvey, E. Autio, A. Broström, P. D'Este, R. Fini, et al. 2013. "Academic Engagement and Commercialisation: A Review of the Literature on University–Industry Relations." *Research Policy* 42: 423–442. doi:10.1016/j.respol.2012.09.007.

Porac, J. F., J. B. Wade, H. M. Fischer, J. Brown, A. Kanfer, and G. Bowker. 2004. "Human Capital Heterogeneity, Collaborative Relationships, and Publication Patterns in a Multidisciplinary Scientific Alliance: a Comparative Case Study of two Scientific Teams." *Research Policy* 33 (4): 661–678. doi:10.1016/j.respol.2004.01.007.

Rychen, F., and J.-B. Zimmermann. 2008. "Clusters in the Global Knowledge-Based Economy: Knowledge Gatekeepers and Temporary Proximity." *Regional Studies* 42 (6): 767–776. doi:10.1080/00343400802088300.

Siggelkow, N. 2007. "Persuasion with Case Studies." *Academy of Management Journal* 50 (1): 20–24. http://www-management.wharton.upenn.edu/siggelkow/pdfs/AMJ_Persuasion.pdf

Silverman, D. 2013a. "What Counts as Qualitative Research? Some Cautionary Comments." *Qualitative Sociology Review* 9 (2): 48–55.

Silverman, D. 2013b. *Doing Qualitative Research: A Practical Handbook*. London: SAGE Publications Limited.

Silverman, D. 2017. "How was it for You? The Interview Society and the Irresistible Rise of the (Poorly Analyzed) Interview." *Qualitative Research* 17 (2): 144–158.

Stokes, D. E. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC: Brookings Institution Press.

Storper, M., and A. J. Venables. 2004. "Buzz: Face-to-Face Contact and the Urban Economy." *Journal of Economic Geography* 4 (4): 351–370. doi:10.1093/jnlecg/lbh027.

Torre, A. 2008. "On the Role Played by Temporary Geographical Proximity in Knowledge Transmission." *Regional Studies* 42 (6): 869–889. doi:10.1080/00343400801922814.

Van Rijnsoever, F. J., and L. K. Hessels. 2011. "Factors Associated with Disciplinary and Interdisciplinary Research Collaboration." *Research Policy* 40 (3): 463–472. doi:10.1016/j.respol.2010.11.001.

Venkatesh, V., A. R. Dennis, and S. A. Brown. 2010. "Predicting Collaboration Technology Use: Integrating Technology Adoption and Collaboration Research." *Journal of Management Information Systems* 27 (2): 9–54. doi:10.2753/mis0742-1222270201.

Venkitachalam, K., and P. Busch. 2012. "Tacit Knowledge: Review and Possible Research Directions." *Journal of Knowledge Management* 16 (2): 357–372. doi:10.1108/13673271211218915.

Werker, C., W. Ooms, and M. C. J. Caniëls. 2016. "Personal and Related Kinds of Proximity Driving Collaborations: A Multi-Case Study of Dutch Nanotechnology Researchers." *SpringerPlus* 5 (1), doi:10.1186/s40064-016-3445-1.

Whittington, K. B. 2018. "A Tie is a Tie? Gender and Network Positioning in Life Science Inventor Collaboration." *Research Policy* 47 (2): 511–526. doi:10.1016/j.respol.2017.12.006.

Ylijoki, O.-H., A. Lyytinen, and L. Marttila. 2011. "Different Research Markets: A Disciplinary Perspective." *Higher Education* 62 (6): 721–740. doi:10.1007/s10734-011-9414-2.