Surface versus deep knowledge search through geographically distant advice ties

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Abstract:

Research on the value of personal relationships to distant locations (bridging ties) for innovation has yielded mixed findings. This paper proposes that part of these empirical inconsistencies is due to the ambiguity of the concept of advice tie. Based on knowledge search theories, it draws a distinction between advice ties serving surface knowledge search and those serving deep knowledge search. We theorize that the effect of bridging ties is contingent to the type considered: bridging ties have a positive impact on individual patent performance when they serve deep knowledge search, and negative when they serve surface knowledge search. Data from 140 R&D engineers at a French cluster in nanotechnologies provides evidence for our hypotheses.

Keywords: Bridging ties, Personal networks, Knowledge, Advice ties

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1. INTRODUCTION

If companies need internal knowledge to innovate, they also rely on external knowledge gained through their network to access new knowledge outside their borders (Cohen & Levinthal, 1990; Zaheer & Bell, 2005; Zahra & George, 2002). Indeed, as emphasized by Nahapiet and Ghoshal (1998), generating new knowledge needs shared and exchanged knowledge. Knowledge flows between distant individuals and an opening via the network on new knowledge are therefore key to innovation (open innovation theory, Chesbrough, 2003). Thus, some network structures can be beneficial for innovation performance, each link representing potential access to knowledge and resources (Adler & Kwon, 2002). As a result, previous research has focused on the effects of organizations network structure and interpersonal social networks on innovation (Burt, 2017; McFadyen et al., 2009; Rost, 2011). In addition, a key issue is the transfer of knowledge beyond the boundaries of the company (Argote et al., 2003).

Theoretically, prior research develops two main antagonistic arguments. The closure argument consists in considering as necessary to be very interconnected, to share the same background, to have a common language and culture, and thus to develop trust, in order to be able to transfer these knowledge (Coleman, 1988; Inkpen & Tsang, 2005). Another part of the literature is based on the idea of structural holes and bridging ties (Burt, 2004, 2017). Crossing borders (e.g. geographic, working with individuals from other cities, regions, countries, etc.) provides access to new knowledge that is valuable to innovation activity. Knowledge is considered as sticky and thus hard to transfer (Brown & Duguid, 1998). Therefore, being connected to distant locations provides access to a greater diversity of knowledge, but at the same time create difficulties in effectively transferring such knowledge.

As a result, many studies have sought to understand what network structure promotes better knowledge flow, especially in advice networks, i.e. networks of people consulting each other. However, the results remain ambiguous, and sometimes contradictory, making it unclear whether geographically distant ties have a positive or negative effect on innovation (Bergé, 2017; Feldman in 2003, Chapter 19; Gertler & Levitte, 2005; Hansen, 2015) . We theorize that this ambiguity can be solved by better taking into account the type of knowledge

that is exchanged in advice ties. We differentiate between ties serving what we call surface knowledge search and ties serving deep knowledge search (i.e. the depth of knowledge shared) and argue that whether geographically distant advice ties benefit innovation is dependent on this nature of knowledge search. By drawing a distinction based on the depth of knowledge search, we argue that knowledge workers need both surface and deep knowledge types of ties to innovate, but with a consideration for geographical distance.

2. THEORETICAL DEVELOPMENT

2.1. ADVICE NETWORKS FOR INNOVATION

2.1.1. Contributions of advice networks to innovation

Based on Sparrowe et al. (2001, p. 317), advice network is defined as *"comprised of relations through which individuals share resources such as information, assistance, and guidance that are related to the completion of their work."*. It is an intentionally mobilized network (Nebus, 2006), which is built by individuals, when they need knowledge, through contact with other people. It is therefore a deliberate act, an individual choice, when searching for information. This type of network has different characteristics. First, it is a bi-directional network, where there can be reciprocity (or not). It is thus more beneficial to receive advice than to give advice (Zagenczyk & Murrell, 2009). Indeed, in the advice network, the flow of knowledge goes from the person giving to the person who receives: the giver transfers knowledge to the receiver. If the first person invests time in the relationship, the second gains access to new information. Then, the choice of advisor is not trivial and hazardous, but based on criteria such as status, recognition, or expertise (Lazega et al., 2012). This implies that advice networks are highly centralized. Indeed, it is often the same people, by their individual characteristics, who are asked to give advice (Lazega et al., 2012).

Social ties are a perfect conduit to enable the flow of information and enable knowledge and ideas to circulate. In a systematic review of the literature, Pittaway et al. (2004) thus shows the effect of networks on innovation performance. In particular, advice networks are built by individuals in search of specific information, and can provide access to new knowledge, and thus enhance their ability to innovate. Studying creativity in the workplace, Baer (2010, p. 593) defines the employees' *"idea network"* as their *"ties that provide access and exposure to novel insights and, as such, are instrumental in delivering the informational resources likely to spur the combinatory process underlying the production of creative ideas"*.

2.1.2. Lack of conceptualization to explain the benefits of advice ties

In spite of this proven value of advice ties in knowledge-intensive organizations, their conceptualization in network research has remained surprisingly poor. On the one hand, part of the research focuses on internal advice networks within organizations or in the same professional environment, without considering the links that can cross these boundaries (Di Vincenzo and Mascia, 2017; Sparrowe et al., 2001). Yet, this approach can limit the contributions of the advice network. Restricting the advice network to close contacts can lead to some inefficiency, with redundancy in knowledge possessed (Burt, 1992). Therefore, it may be necessary to expand the network to gain access to advice. In addition, an advice network outside the boundaries of the location and the professional environment can provide access to complementary and different resources from the internal network, and thus be beneficial for performance and innovation. On the other hand, current research does not make it possible to understand which characteristics of the ties in an advice network are beneficial. More specifically, there is opposition between two arguments. First, there is a search for similarities and homophily, to facilitate the transfer of knowledge and reduce transaction cost in increasing mutual understanding. As affirmed by (Lazega et al., 2012), proximity is an important variable, allowing reducing the costs, the time and the energy invested in the relation, and favouring contacts that are more regular. Second, bridging ties were found to influence employees' *"creative successes"* (Fleming et al., 2007), as measured by involvement in innovative projects (Obstfeld, 2005), quality of ideas submitted (Burt, 2004), number of patent applications (Tortoriello & Krackhardt, 2010) or creativity rated by supervisors (Perry-Smith, 2006; Rodan & Galunic, 2004). This argument therefore encourages the creation of geographically distant ties in order to access another network and new knowledge.

In the first case, the argument is built around the cognitive and relational dimensions of the network, while in the second case the central mechanism described is above all structural (Fleming et al., 2007; Nahapiet & Ghoshal, 1998). Therefore, these streams provide only limited understanding of what flows exactly along relationships to result in improved individual production. In particular, they present antagonistic visions of how geographic distance can influence innovation performance. If having a mainly co-localized network (colleagues, friends) may seem easy, it is more complex to develop and maintain a distant network.

2.1.3. Towards an explanation through the breadth and depth of ties

To label what flows through advices ties, authors refer to a variety of concepts such as *"information flows"* (Burt, 2004), *"knowledge transfer"* (Nebus, 2006; Pittaway et al., 2004), *"knowledge sharing"* (Rob Cross et al., 2001), *"diffusion of knowledge"* (Fitjar et al., 2016), without understanding the nature of the knowledge that is shared. In the remainder of this paper, we use the term knowledge transfer, as defined by Wijk et al. (2008, p. 832): *"exchange, receive and influence by the experience and knowledge of others".* The authors also point out that knowledge transfer has three key antecedents: knowledge, organizational characteristics, and network characteristics.

Moreover, the question of what is an advice tie has not received much attention. Advice ties have been considered as a unidimensional, unequivocal conduit for knowledge. However, knowledge search through interpersonal relationships can indeed serve multiple purposes as well as take a variety of forms. A growing evidence suggests that the outcome of a network configuration is in fact contingent to a variety of factors. Some authors identified the nature of the task, exploratory versus exploitative (Hansen et al., 2001). Other contingency factors include the content of the relationship, and most notably its strength. Network research has argued that ties need a certain amount of strength for knowledge transfer to occur (Hansen, 1999).

However, breadth and depth of ties are not really taken into account to explain the difference in performance, even as the literature on open innovation shows the importance of these two dimensions in the information research strategies of organizations to innovate (Ferreras-Méndez et al., 2016; Laursen & Salter, 2006). In the following of this paper, we therefore propose to apply this distinction to advice ties by considering the differences between the close and distant geographical ties (breadth), and between the sharing of surface and deep knowledge (depth). We define *close geographical ties* as relationships allowing frequent contacts, face-to-face, with a small geographic distance. On the opposite, *distant geographical ties* links are long distance relationships that do not allow for daily face to face collaboration. Surface knowledge search consists mainly in taking shortcuts in the flow of information, by asking questions that might be answered. The advice is rather short, precise and specific. On the contrary, deep knowledge entails more specific knowledge co-construction. This advice is based on a succession of intense and extensive interactions that can take place over time. Thus, we define *surface knowledge transfer* as ties mobilized for limited scope, and *deep knowledge transfer* as ties consisting in intense interaction, entailing profound, longer discussions.

2.2. GEOGRAPHICAL DISTANCE, TOWARD A BRIDGING ADVANTAGE

2.2.1. Proximities and knowledge transfer in the network

Proximity in the network has been defined according to several dimensions, such as geographical, organizational, institutional, cultural, cognitive (Bergé, 2017; Hansen, 2015; McPherson et al., 2001). Geographic proximity and networks are related. Collaboration is based on the creation of ties between individuals, and proximity facilitates serendipitous encounters. In addition, it often entails easier access, because interactions can be frequent and embedded in informal social times during a workday. Geographic distance therefore appears as a determinant of collaboration (Katz & Martin, 1997). Thus, the effect of geographic distance and the presence of borders appears at first glance to be negative, making it more challenging to transfer knowledge and adapt it to the local context. Conversely, a close location facilitates the transfer of knowledge. Indeed the proximity favours the frequency of the contacts, the meetings in face-to-face, and thus increase the likelihood of making collaboration fruitful. (Bergé, 2017). Greater geographical proximity also makes it possible, by reducing the distance by which the partitions must be conducted, to facilitate coordination and to improve the transmission of more tacit knowledge (Bergé, 2017; Feldman, 2000), which is inherently difficult to formalize and transfer. To demonstrate this, Gertler & Levitte, (2005) sets the example of knowledge-intensive economic activities. These activities are highly geographically concentrated in order to set up local learning between the actors. Moreover, research found that dispersed research teams tend to underachieve in publications, patents, and commercialization (Cummings & Kiesler, 2005). Altogether, proximity favours higher efficiency in the transfer of knowledge.

Geographical proximity creates a context in which a homophile network is created (McPherson et al., 2001). According to the goldilocks principle, organizational innovation is made optimal by an intermediate distance (neither too close nor too far) concerning the non-geographical dimensions of proximity. Fitjar et al. (2016) thus proves that an average level of cognitive, organizational, social and institutional distance is more beneficial for generating different types of innovation. There is a phenomenon of overlapping between the different dimensions of proximity. Thus, two geographically close people will also tend to be socially and institutionally close (Hansen, 2015). The presence of this common background associated with a geographical proximity allows a better transfer, more communication, a greater confidence, and thus to be more inclined to share knowledge.

In such a geographically close network where people share a common background, the possibility of bringing new knowledge and ideas is more limited in the case of a close tie. In fact, the proximity of the source of knowledge makes it more easily accessible, but this information is often redundant and does not provide openness (McEvily & Zaheer, 1999). Therefore, in the case of deep knowledge transfer, these collaborations may not be fruitful. However, the presence of a close advice network, with the shallow surface ties, can thus make it possible to efficiently address responses to uncomplicated problems requiring rapid resolution. The value of surface ties lies also in their ability to help a focal individual locate relevant knowledge in a larger field or organization. Despite their brief nature, they are crucial by guiding individual in their information search, quickening the process as well as increasing the chances that solutions are found.

Thus, propose the following hypothesis:

Hypothesis 1: *Geographical distance among surface knowledge search advice ties decreases individual innovation performance.*

2.2.2. The problem of knowledge transfer in geographically distant ties

Distant knowledge source have an ambiguous role in knowledge transfer (Howells, 2002). Location of knowledge sources matters because knowledge is often *"sticky"* (Brown & Duguid, 1998), meaning that it is hard to transfer without constant face to face interaction and immersion in the local eco-system's culture. However, by maintaining personal ties to distant others, knowledge workers can access knowledge across boundaries and that is non-redundant with what they have readily access to in their immediate work environment. Indeed, the individuals thus connected by these geographically distant ties present a less important homophily, have a different background, and are source of new knowledge. As a result, they can act as knowledge brokers, translating different pieces combinations into higher chances for innovation (Hargadon, 2002).

Two people connected by geographically distant ties usually share few common features. If this specificity makes the value of this type of tie, because it allows access to new knowledge, it also makes the transfer of knowledge is more difficult. In other words, the very reason why this new knowledge is valuable (stickiness) also raise barriers to its transfer. Geographic proximity facilitates the transfer of knowledge. On the contrary, geographic distance makes it difficult to transfer knowledge (Howells, 2002). Thus, distant surface advice ties might have limited value. In fact, as they consist in superficial exchanges, they are unable to leverage the potential of distance, due to knowledge stickiness. These ties will be improved

if interaction happen on the random basis – serendipity, but you need to know what you are searching to leverage distant ties. Therefore, in the case of surface knowledge transfer, these collaborations may not be fruitful.

However, developing an open network with geographically distant links allows to create links between the internal capabilities and the resources and knowledge of the external network. Therefore, such networks are establishing connections to new sources of information. The effect of distant geographic ties on innovation is therefore improved if they give access to deep sources of knowledge. Indeed, because these links are deep, they allow transfer of knowledge that is sticky and specific to the location (Bell & Zaheer, 2007). The bridging nature of the tie is in that case enhanced. Thus, R&D researchers who seek in-depth knowledge through distant links are more likely to access knowledge that is not redundant to that immediately available in their nearby work environment.

We therefore propose the following hypothesis:

Hypothesis 2: *Geographical distance among deep knowledge search ties increases individual innovation performance.*

3. DATA AND MEASUREMENT

3.1. EXPLORATORY FIELD STUDY AND NETWORK SURVEY

In order to better seize the difference in nature of advice ties according to their serving either surface or deep knowledge search, we conducted 24 interviews with individuals belonging to the target population, in order to understand their advisory relationship. We asked them to report episodes of advice giving and seeking, each time describing the nature of that advice, and the way in which it was exchanged.

Analysis of the interviewees' responses reveals that important differences in nature that were consistently related to the length of the advice exchange episode. Interviewees systematically differentiate between advices taking below or above a certain perceived threshold, the latter ranging from 10 to 45 minutes depending on the interview. Beyond this threshold, advice seems to have a different nature and, often, the type of person is also different. Attached to this notion of time spent is a perceived cost of providing the advice. Surface knowledge search advices are costless in nature for the provider. Deep knowledge search advices, on the contrary, are indeed costly and require a certain amount of commitment to provide the requested advice.

The interview extracts below give illustrations of the two types of advice.

Two examples of surface knowledge search advice ties:

> Interviewer: *"In the first case you described, where you are asked if a deposit will work etc. How long can it take to respond?"*
> Interviewee 3: *"To see if it can work out, let's say the discussion takes usually half an hour, one hour maximum. Realization for something like that can be formalized because we have officials' requests, but often it is more something of half an hour or an hour."*

> Interviewee 18: *"When it takes ten minutes to a quarter of responding through email, people just don't argue at all about doing this little effort. Knowing that when they will come to me with a technical question on components of ours, I will be available just the same. And that's what happens."*

Two examples of deep knowledge search advice ties:

> Interviewer: *"So there, in concrete terms, for you, how long is the answer you give?"*
> Interviewee 23: "*It ranges from half an hour to one hour,.. to more time even, since in the beginning I had even sketched the structures, it took me quite some time. Several days. But it depends."*
> Interviewer: *"Was this accounted for in your planned workload?"*
> Interviewee 23: "*At that time I was busy with a big project but this thing I did that in parallel"*

> Interviewee 24: *"It depends on the scope. I would say 75% of the times a phone call is enough, saying 'what oxide thickness do you need for the next technology", etc. Answers are precise because the cases are known. And then, you have situations when more thinking is needed, maybe sometime even manipulations to be done, experiments. It can take a few days (...)"*

We used these preliminary findings to design the name generators of the network part of our survey (described below). A name generator is a survey question where respondents are asked to recall about their contacts. They elicit names or initials and then further questions may be asked about these contacts. Considering the above-mentioned perceived threshold that we found in the interviews, and the fact that duration was apparently the key to set lines between types of advice, we adapted the traditional name generators used in network surveys to capture networks of advice ties. We asked respondents to elicit two types of advice ties: those typically requiring under roughly 30 minutes and those typically requiring above that limit.

3.2. SAMPLE

The data for this study came from a sample of 140 R&D engineers working in a nanotechnology cluster in France. The data collection was based on a survey emailed to a target population including employees from all three organizations involved in a large consortium of partners joining R&D efforts into a set of common projects in that localized cluster. Reflecting the nature of the target population, most respondents were men (80%), and had long tenures with their company (more than 5 years, 57.9%).

The questionnaire asked respondents to list their contacts (name-generators), and then to answer single-item questions about each contact (name interpreters). The measures used for each respondent are indices calculated by aggregating responses for all the contacts listed in the name-generators.

3.3. OUTCOME MEASURE

Individual innovation performance was measured by the number of patent counts. Respondents were asked how many patents they were referenced on at the date of the survey. Although an external count would certainly have provided more reliability, there is limited reason to doubt that individuals can be accurate about their counts. In addition, even if the relevance of patent to capture innovation performance counts has been debated, patents are an important output of R&D activities in nanotechnologies. As the distribution was positively skewed, we used the log of patent number.

3.4. BRIDGING TIES

For each elicited advice tie, respondents were asked to provide information on location, ranging from: same site (assigned a value of 1), same town (2), further in France (3), out of France (4). The measure bridging ties is the average score on across all cited contacts. It captures the average distance in the network. To test our hypothesis on this variable, it was calculated on the entire advice network, but also separately on the set of surface knowledge search ties and the set of deep knowledge search ties.

3.5. NETWORK CONTROLS

Prior work on advice ties has shown that access to knowledge can also be influenced by other variables such as ties to other organizational or higher hierarchical levels (Cross & Cummings, 2004; Oh, Chung, & Labianca 2004) . Therefore we controlled for the average value - across all contacts - of a scale ranging from “same team” (assigned a value of 1),

"same department" (2), "other department" (3), "external partner organization" (4), "external non-partner organization" (5).

To control for strength of ties we used the measure prevailing in the literature, i.e. emotional closeness (Marsden & Campbell, 1984). For each *alter* cited in the name generators, the respondent was asked to assess the level of perceived emotional closeness (on a 4-point Likert scale from "not close at all" to "very close", based on Burt (1992). The strength of each respondent's ties was the average closeness for all the contacts he/she listed.

Each respondent was asked to assess the hierarchical level of every contact (5-point Likert scale from "no one under his/her responsibility" to "more than 3 levels of responsibility under him/her"). For each respondent we calculated the average hierarchical across contacts.

3.6. OTHER CONTROLS

Not all areas of knowledge are similarly "patentable". Thus it was necessary to control for it. Respondents were asked about their main area among a list derived from ITRS (International Technology Roadmap for Semiconductors, a major standardization documentation for the microelectronics sector). Then these areas were collapsed into two main domains, resulting in two dummy variables: *process* and *design*. Process takes 1 if the respondent works in either Process integration, devices and structures, Front end processes, Lithography or Interconnect (in ITRS parlance). Design takes 1 if they work in either Design or Modelling and simulation. This distinction matches a well-established nomenclature in the field.

Respondents were asked their organization among a list of 47 taking part to the consortium. As the consortium was dominated by one large company and one large government research agency, we created two dummies accordingly (named Consortium Partner 1 and Consortium Partner 2).

We also included demographics such as gender, and most importantly age as regardless of their productivity, senior researchers have obviously higher chances to have strong patent records than juniors. Organizational rank was also controlled for with a 5-point Likert scale similar to the one used for contact (from "no one under my responsibility" to "more than 3 levels of responsibility under my responsibility").

3.7. ANALYSIS

An ordinary least squares (OLS) regression is used to analyse the collected data. In order to test the effect of surface and deep knowledge transfer ties on individual innovation performance, we ran several models. A first model allows to evaluate the effects of the control

variables. In the second model, we add the bridging ties variable, which allows us to take into account in a global way the effect of geographically distant links. The third and fourth models add alternately the variables allowing to measure the effect of surface and deep knowledge transfer bridging ties. Finally, Model 5 allows these two variables to be taken into account simultaneously.

4. RESEARCH FINDINGS

Table 1 shows estimates in different configuration. We can test the hypotheses previously made on the basis of Models 3 to 5. Hypothesis 1 predicts that surface knowledge transfer bridging ties decreases individual innovation performance. Model 3 shows a statistically significant negative effect on individual's number of patents. Hypothesis 2 suggested that deep knowledge transfer bridging ties increases individual innovation performance. As predicted, this variable has a statistically significant and positive effect on individual's number of patents (Model 4). In addition, Model 5, by considering simultaneously bridging ties for surface and deep knowledge transfer, shows a significant and respectively negative and positive effect of these two variables. Thus, these results provide support for both Hypothesis 1 and Hypothesis 2.

Table 1: Results

	Dependent variable:				
	logbrevet				
	(1)	(2)	(3)	(4)	(5)
Type of R&D	-0.013	-0.014	-0.002	-0.015	0.002
	(0.010)	(0.011)	(0.014)	(0.010)	(0.013)
Long term R&D	0.132	0.131	0.084	0.117	0.079
	(0.345)	(0.346)	(0.335)	(0.341)	(0.326)
Area: Process	-0.210	-0.215	-0.168	-0.249	-0.222
	(0.285)	(0.286)	(0.277)	(0.280)	(0.268)
Area: Design	0.083	0.089	0.074	0.130**	0.124**
	(0.064)	(0.065)	(0.062)	(0.065)	(0.062)
Consortium Partner 1	-0.035	-0.026	-0.075	-0.057	-0.120
	(0.175)	(0.177)	(0.171)	(0.174)	(0.167)
Consortium Partner 2	-0.165	-0.150	-0.164	-0.060	-0.055
	(0.177)	(0.180)	(0.172)	(0.180)	(0.173)
Age	0.052***	0.053***	0.047***	0.052***	0.046***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Gender (Male=1)	0.649***	0.628***	0.671***	0.520**	0.527**
	(0.213)	(0.217)	(0.207)	(0.215)	(0.207)
Organizational rank	0.406**	0.394**	0.445***	0.358**	0.387**
	(0.161)	(0.163)	(0.158)	(0.158)	(0.151)
Organizational distance	0.125	0.075	0.297***	-0.020	0.186
	(0.098)	(0.132)	(0.112)	(0.111)	(0.123)
Bridging ties		0.118			
		(0.206)			
Surface KS Bridging Ties			-0.346***		-0.369***
			(0.128)		(0.125)
Deep KS Bridging Ties				0.436***	0.441***
				(0.135)	(0.131)
Constant	-1.543***	-1.625***	-1.291**	-1.813***	-1.567***
	(0.533)	(0.553)	(0.529)	(0.523)	(0.512)
Observations	118	118	117	115	114
R^2	0.406	0.407	0.448	0.451	0.507
Adjusted R^2	0.350	0.346	0.390	0.392	0.448
Residual Std. Error	0.813 (df = 107)	0.815 (df = 106)	0.789 (df = 105)	0.782 (df = 103)	0.747 (df = 101)
F Statistic	7.302*** (df = 10; 107)	6.626*** (df = 11; 106)	7.743*** (df = 11; 105)	7.694*** (df = 11; 103)	8.653*** (df = 12; 101)
Note:					*p<0.1; **p<0.05; ***p<0.01

Notably our results show how differentiating between surface knowledge search and deep knowledge search bridging ties improves the explanatory power of the model. Estimates show that geographical distance influences differently patent performance as a function of the type of ties considered. Bridging ties serving surface knowledge search are detrimental to patent performance, whereas those serving deep knowledge search are beneficial.

5. DISCUSSION

This research shows that the value of bridging ties, *i.e.* ties that connect R&D engineers to distant locations, is contingent to their type. The findings suggest that innovation performance needs two distinct types of ties, surface knowledge search and deep knowledge search advices ties.

Intuitively, the findings could sound unsurprising, as prior research found that tie strength is pre-condition for knowledge transfer (Borgatti & Cross, 2003). However, our data shows that there is no real overlap between the weak/strong and surface/deep knowledge search: the former ties can be strong (some close friend you would keep asking brief hints) and the latter can be weak (some expert you have common interest with, and who deem rewarding to collaborate with you). Thus, our main contribution is to show that studies on knowledge circulation through personal ties should better account for the content and depth of interaction. As such, it is a first step towards better seizing the complexity of knowledge transfer processes in networks.

The current study contains some limitations that further research might address. Although our measurement strategy tried to avoid common method biases, it cannot be completely ruled out. In particular, the data collection instrument relies on self-reported measures, and such perceptual measures can lead to biases, especially when the data collection occurs at a single point in time. To overcome this issue, additional research should collate different measures spread over time or use separate primary and secondary observations. A longitudinal study could investigate path dependencies in the development of the configurations that explain the relationships.

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