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Knowledge, networks and space: connectivity and the problem of non-interactive learning

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Abstract

This paper develops an integrative perspective of network theory and economic geography to attain a more inclusive understanding of the creation and reproduction of knowledge. A sympathetic review of network research in the social sciences conveys that geography is often a marginalized factor and that the empirical evidence about its effect on networks and knowledge has been ambiguous. The paper criticizes network theory for its tendency to overlook processes of collective learning that happen outside networks. By conceptualizing non-interactive learning it posits that an inclusive theory of knowledge has to integrate network accounts of interactions and geographical accounts of non-interactive learning.

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1 Introduction

Economic life is characterized by a deep social division of labour. Firms and the people working within these organizations relate to other people inside and outside their organizations to exchange information, knowledge, goods, services and capital. The myriad of individual and collective actors and the relations that they sustain are the building blocks of social networks. Networks are not merely a representational form of social relations. Instead, research in pursuit of network theory posits that the structure of relationships affects the opportunities and constraints of individual action and their outcomes. Networks affect opportunities for action.

Networks had become popular in geography already in the 1960s when Haggett and Chorley (1969) developed a comprehensive approach to the analysis of networks in and across territory. While their focus was largely on territorial, infrastructural and transport networks, a much broader discourse on social and organizational networks has gained prominence only during the last two decades. The terms of this paper's title "knowledge, network, and space" all belong to the top ten most frequently used terms across the 364 papers presented at the 2012 annual Regional Science Association conference in Delft. Every 6th session and every 8th paper that was presented at the conference, had 'network' in its title[i]. In economic geography, networks have celebrated an exceptional career over many years and they have coined terminology in theories of geographical clusters, global cities, international production systems and globalization.

Uses of the term network refer to at least three distinct levels of scholarly concern: network as an empirical object of knowledge, network as theory, and network analysis as a methodology. The recent history of academic publications in the field illustrates how popular the use of the term has become since the 1980s until recently. Figure 1 displays a frequency count of publications that contain the keywords 'network', 'network theory' and 'social network analysis' in the full-text bodies of all articles published in journals of geography in the respective period.[ii] This analysis suggests that 'network' seems to be used far more often as an object than a theory or methodology. Most research in geography seems to refer to networks as objects of study, e.g. informal networks, project networks, strategic networks or regional networks. Following Grabher's prudent and critical review, however, much of the use of networks in economic geography has been rather selective, often metaphorical and little formalized (Grabher, 2006). Meanwhile, the network discourse has become so broad that between semantic metaphor and formal metrics many uses and perspectives have established.

Network theory and methods of social network analysis are useful to understand the creation and the sharing of knowledge in a topological (network) as well as topographical (geographical) perspective. The fundamental problem of studying the geography of knowledge is that "*knowledge flows are invisible, they leave no paper trail by which they may be measured and tracked*" (Krugman, 1991: 53). However, knowledge is fruit of the circulation and interpretation of information, cumulative experience and cognition. Relationships are important for the acquisition of information (Borgatti and Cross, 2003) and the creation of knowledge has been recognized as a social, interactive process (Lawson and Lorenz, 1999). Because of the interactive nature of knowledge creation, the concept of learning (Lundvall and Johnson, 1994) has become more prominent over the last two

decades and it has replaced the stylized linear model of innovation. Learning has been acknowledged as a reflexive, interactive and continuous process of recombining information and existing knowledge with new insights. The paper aims to engage more fundamentally with approaches of network theory that take a relational perspective not only at the conceptual, but also at the analytical level. The paper also appraises recent achievements and challenges of network theory, and explores conceptual opportunities with respect to the geography of knowledge.

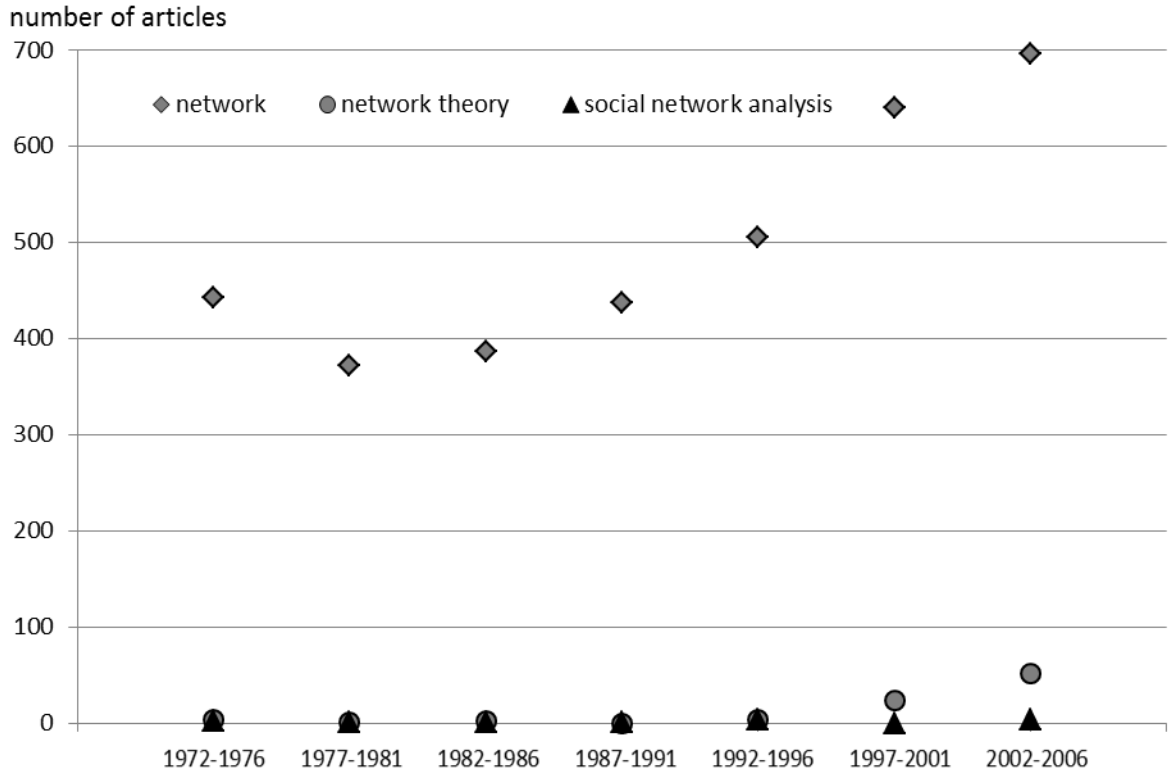

Figure 1: *Number of articles in the 33 journals of geography available through JSTOR with keywords in their full-text body, 1970-2006 (own research based on JSTOR database).*

The analysis starts out by clarifying a concept of formal network theorizing and by distinguishing two different kinds of network theories: the flow and the bond models of knowledge generation (section 2). Section 3 critically reviews flow network models of innovation from the perspective of geography and examines the role of geography for network accounts of innovation. A key finding is the empirical contingency of associations between knowledge, networks and space. Section 4 develops the central argument that different forms of learning require different theoretical treatment with respect to connectivity (networks) and space. Collective learning may occur through interactive as well as non-interactive learning. Interactive learning requires people and firms to build either bilateral strategic alliances or multilateral coalitions in organized networks to exchange and jointly create new knowledge. In contrast, non-interactive learning occurs in situations of co-present observation, reverse engineering or shared mental models to interpret public codified knowledge similarly where people and firms do not need to interact or maintain relations. The consequences of the arguments developed in the paper are discussed in the conclusion.

2 What is network theory?

2.1 Relational geography: from a network perspective to formal network theorizing

The last 20 years have shown a convergence of perspectives towards relational thinking (Bathelt and Glückler, 2003, 2011; Fourcade, 2007). Despite earlier contributions to a theoretical foundation of relational social theory (Emirbayer, 1997), research has begun only in the first decade of the new millennium to reflect more broadly on relational theory (Mische, 2011; Pachucki and Breiger, 2010). The common assumption that all these approaches share is the 'anticategorical imperative' (Emirbayer and Goodwin, 1994) to understand social phenomena such as identity, power, social capital or knowledge as expressions and consequences of the positions and associations that actors enjoy within systems of social relations rather than as substantialist, monadic entities per se (Bathelt and Glückler, 2005). Bad performances of teams are not seen as a consequence of badly qualified or low-skilled employees (i.e. actor attributes), but they are considered as effects of inappropriate interactions and coordination between these actors (i.e. positions and relations). A relational perspective focuses on individual and collective opportunities for action and conceives these opportunities as enabled through the specific context (meaning) and structure (connectivity) of social relations. Such a theoretical perspective necessarily implies an analytical focus on the connectivity of social and economic action.

While some more complex approaches such as actor-network theory, the concept of the rhizome or the theory of publics and network domains (see Grabher, 2006, for a sympathetic critique of theses approaches) are in line with the anticategorical imperative, they do not necessarily employ formal theorizing or quantitative methods of structural analysis, often because the arguments emphasize complexity, multiplexity and contextuality. While economic geography is characterized by a legacy of rich network rhetoric, the analytic treatment of relational structures has been rather scarce until recently (e.g. Glückler, 2007; Ter Wal and Boschma, 2009). Based on 17 journals at the heart of economic geography proper, Figure 2 demonstrates that although the term network has made a high-rising career since the 1990s, it is striking that despite the enormous attention paid to networks there seems so little discussion of network theory and hardly any about network analysis until very recently (Figure 2).[iii]

A network is "*a specific set of linkages among a defined set of persons, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behavior of the persons involved*" (Mitchell, 1969: 2). This definition has two important implications (Glückler, 2007): it implies, first, that relations rather than actors are at the focus of analysis and, second, that the specific structure of relations may be used to draw inferences and expectations on individual and collective action (Gulati, 1998; Mizruchi, 1994). Structure is not conceived as something virtual, but as concrete social interaction where the level of observation is no longer solely the individual relation between two actors, but structures reaching from the triad and other subgroups to the whole network. Social and organizational networks, so the inherent assumption in relational thought, affect diverse economic outcomes in specific ways (Granovetter, 2005).

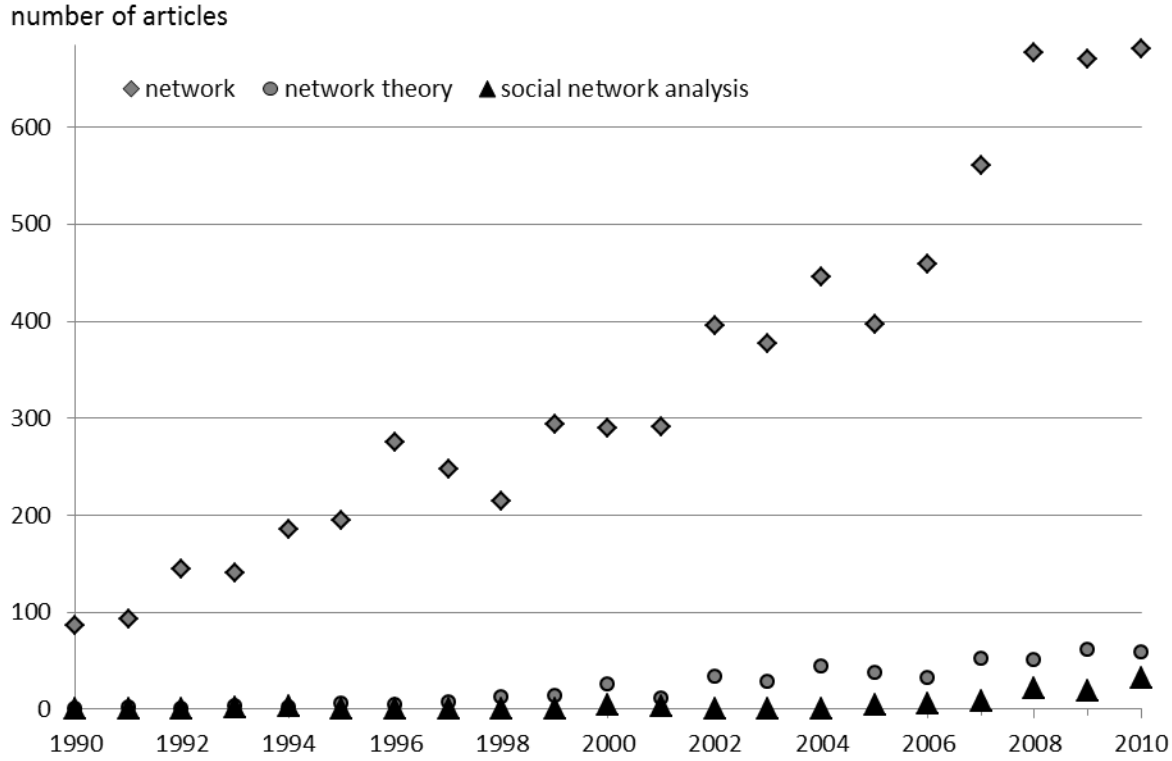

Figure 2: *Number of articles in 17 journals of economic geography with keywords in their full-text body, 1990-2010 (own research based on EBSCO and, when available, individual electronic journal databases).*

Networks can be analytically defined by the researcher or can be consciously built as organizational entities by the network actors themselves, e.g. through concrete membership. Typical examples of analytical researcher-constructed networks are networks of co-inventors (Cantner and Graf, 2006), patent citations (Breschi and Lissoni, 2009), strategic alliances (Owen-Smith and Powell, 2004), inter-firm job mobility (Breschi and Lissoni, 2009), syndicated investments (Sorenson and Stuart, 2001), interlocking boards of directors (Kono et al., 1998) or advisory boards (Glückler and Ries, 2012) etc. The boom in network research has predominantly focused on this kind of researcher-constructed networks where dyadic relations and the strategic opportunities and individual outcomes of firms are center stage. Researcher-constructed networks, however, need neither be constructed by the network actors nor do these actors coordinate or govern the network as a whole. In contrast, organized networks are constructed by the network members themselves as a conscious organizational entity which they coordinate to pursue a shared outcome at the network level. Extant research on networks as organizations has been quite limited and has only recently received theoretical attention within network theory (Glückler et al., 2012; Provan et al., 2007; Provan and Kenis, 2008). An example of a network organization would be a coalition of several legally independent firms into an organization of higher order, e.g. a research consortium or a buying syndicate of retailers or manufacturers where each member is aware of her own membership and of the network as whole. This distinction is crucial since researcher-constructed networks are not governed as a whole while organized networks are subject to at least some degree of explicit coordination (Glückler et al., 2012).

2.2 A framework for formal network theorizing

Despite the exponential growth of research on social and organizational networks (Borgatti and Cross, 2003) there is still no established agreement on a body of network theory. Even the comprehension of what network theory means seems to be contested (Salancik, 1995). Generally, network theories are theories that depart from the crucial assumption that relationality and connectivity between actors of a social system play an important role for social and economic outcomes. The last years have seen a growing literature on the foundations of network theory in various disciplines within the social sciences such as economics, organization theory, sociology, and geography (e.g. Borgatti and Halgin, 2011; Jackson and Watts, 2002; Parkhe et al., 2006; Zaheer et al., 2010). These contributions generally highlight a series of challenges to be solved in further theoretical work, as for instance, the multiplicity of mechanisms and levels of analysis, the dynamics of networks, the interdependence of multiple networks or the trade-offs and negative effects of networks and relationships (Hagedoorn, 2006; Zaheer et al., 2010).

Table 1: *Network mechanisms by model and research tradition (adapted from Borgatti and Halgin, 2011)*

	Social outcomes	
Model	**Success**	**Choice**
Flow (ties as pipes)	Capitalization	Contagion
Coordination (ties as bonds)	Cooperation	Convergence

Borgatti and Halgin (2011) elaborate on the potential of formal network theorizing and offer a concrete conception of network theory. Their framework distinguishes two kinds of outcomes, choices (behavior, attitude, decisions) and success (performance, rewards), as well as two network models: the flow and the bond model (Table 1). While the flow model represents the movement of tangibles or intangibles (e.g. information) along the connecting paths between actors in a network, the bond model reflects the alignment of interests and the coordination of individual and collective action vis-à-vis other actors in the network (e.g. power, division of labour, co-production). By cross-tabulating the two models with the two kinds of outcomes, they define a framework with four network functions (Table 1): *capitalization* entails flow-based explanations of achievement such as innovation or profits. Examples of such network theories are the strength of weak ties theory (Granovetter, 1973) or structural hole theory (Burt, 1992) where both develop hypotheses and explanations for the effects of network characteristics on economic outcomes. The second function of *cooperation* comprises bond-based explanations of success, where resource attainment, control, innovation or any other performance is achieved through alliance strategies that exploit divisions and exclude third parties. The realms of *contagion* and *convergence* refer to flow and bond-based models of choice, such as the adoption of an innovation or equal choices based on direct linkages among actors (e.g. in risk perception, cf. Scherer and Cho, 2003) or the similarity of people and organizations incurred through similar positions in a network (convergence). In the context of innovation, capitalization and cooperation are the functions of interest. As an economic outcome, innovation can either be explained through flows of information or through the coordinated creation of collective novelty.

In addition, Borgatti and Halgin distinguish two related domains of network theorizing: While network theory uses networks as the *explanans* to account for social and economic outcomes, a theory of networks takes the network as *explanandum* and investigates the conditions that cause certain network properties (Table 2). This distinction essentially refers to the role of network variables in a cause-effect research design, where as a cause it forms part of network theory and as an effect it forms part of a theory of networks (Borgatti and Halgin, 2011). Theories of networks are theories that predict network characteristics either with attribute

information or with other network characteristics (Borgatti and Halgin, 2011). Typical network characteristics can be positions (e.g. centrality), group membership (e.g. cliques), roles (e.g. structural equivalence) or dyadic flows between pairs of actors (e.g. knowledge transfers between two firms). In its most complex design, network theories of networks are concepts that use network characteristics to explain other network characteristics (Table 2), e.g. in the context of network evolution (Glückler, 2007; Powell et al., 2005). Network evolution addresses the mechanisms and conditions that affect the emergence of particular relations and forms of networks over time and is considered of increasing relevance to understand the relationship between networks and economic outcomes more fundamentally (Ahuja et al., 2012). Section 3 will discuss capitalization mechanisms of how networks yield innovative outcomes and how geography interacts with these mechanisms.

Table 2: *Three types of network theorizing (Borgatti and Halgin, 2011)*

	Dependent variable	
Independent variable	**Non-network variable as outcome**	**network variable as outcome**
Non-network variable as antecedent	Non-network theory	*(B) Theory of networks*
network variable as antecedent	*(A) Network theory*	*(C) Network theory of networks*

3 Network theories of knowledge and the role of geography

This section reviews network theories of innovation and examines the role of geography in these accounts. It concludes that geography plays a minor part in extant research which is often demonstrated as an apparent but ultimately extraneous factor in performing innovation through networks. This treatment is critically appraised and some arguments are suggested for a more concise theorization of geography in the explanatory triad between knowledge, networks, and space.

3.1 Network theories of innovation

Network theories of innovation conceptualize associations between network characteristics and knowledge outcomes, ranging from information transfer over knowledge creation to innovation. What are the typical network characteristics that are used for these explanations? Without claiming any completeness in my review of the vast body of literature, research in organization theory, sociology and economics has elaborated numerous accounts of the effect of network structure on innovation and knowledge flow. The following 'capitalization mechanisms' (Borgatti and Halgin, 2011) can be concluded from extant research:

First, the mere existence and number of relationships often has a positive effect on the knowledge creation of a firm: collaboration enhances organizational learning. Organizational learning is a function of access to external knowledge sources and of the ability to build the competencies and skills and organizational routines to make use of external knowledge (Powell et al., 1996). Many firms depend on the cooperation with external partners in order to be able to offer competitive services, technologies and commodities (Pfeffer and Salancik, 1978). The cooperation with other firms enables access to new markets, reduces cost through the collective use of infrastructure, builds trust, supports innovation through the recombination of knowledge and yields positive signals to third parties about the quality of partners a firm is already connected with (Podolny, 1993; Zaheer et al., 2010). Related to this argument is the observation that relations create connectivity and mem-

bership with groups of actors that are interconnected (Owen-Smith and Powell, 2004). Strategic alliances may contribute to the development of firm capabilities as well as others' perceptions of its capabilities (Baum et al., 2000).

Second, the quality of these relationships also affects firm performance. Tie strength refers to what Granovetter defined as relational embeddedness (Granovetter, 1985; Uzzi and Lancaster, 2003), i.e. the quality or intensity of a dyadic relation between a pair of actors. The effects of tie strength seem to be contingent on the desired outcome and to environmental conditions. While Granovetter demonstrates that weak ties are a major source of access to new information, referrals, jobs and other resources (Granovetter, 1973), Nelson found strong ties between groups of an organization to be very conducive to the avoidance and resolution of conflict (Nelson, 1989). Further, comparative research found that the effect of tie strength on firm performance is contingent on the evolutionary stage of an industry. While strong ties are conducive to firm performance in early stages of growing markets and technologies (e.g. semiconductor), weak ties are more beneficial for firms in mature stages, e.g. steel industry (Rowley et al., 2000). In addition to tie strength, proximity research in economic geography theorizes the dependence of innovative outcomes on the similarity between actors across different dimensions of cognitive, social, institutional and organizational as well as physical proximity (Boschma and Frenken, 2010; Boschma, 2005).

Third, and at the heart of formal network theorizing, structural positions in a network of relationships may also affect firm innovativeness. Empirical research suggests that the centrality of a firm in a network of inter-firm relations clearly increases the performance and innovativeness of a firm. The tool box of social network analysis offers a range of different measures. The most frequent measures of degree centralityiv, closeness-centrality, betweenness-centrality and power-centrality have been found repeatedly as significant factors of firm innovativeness (Owen-Smith and Powell, 2004; Powell et al., 1996; Whittington et al., 2009). Another structural concept relates to the relative inclination of an actor to establish relations across local group boundaries (e.g. department, division, industry, etc.). Innovation and the adoption of new knowledge from external resources are more likely if actors maintain relatively more relations with actors outside a local domain than within their domain (Krackhardt and Stern, 1988). Another approach found intermediate positions between the core and the periphery of a social network to be most beneficial for the development of creativity, as demonstrated in the context of the Hollywood film industry (Cattani and Ferriani, 2008).

Yet another approach to explain innovative outcomes is the theory of structural holes (Burt, 1992) which argues that actors are innovative to the extent that they enjoy a position of structural autonomy, i.e. a set of non-redundant relations with their alters (Burt, 2004). This approach has sparked much innovative theorizing on the social outcomes of structural positions. In contrast to the strategy of the tertius gaudens promoted by Burt, the rationale of the tertius iungens emphasizes closure of non-redundant relations to be conducive to innovation (Obstfeld, 2005). Another counterpart to structural hole theory is the concept of the structural fold (Vedres and Stark, 2010). By focusing on the generation rather than the adoption of new knowledge the theory of structural folds suggests that new knowledge is fruit of the recombination of diverse knowledge bases residing in distinct cohesive subgroups of a network. Recombination, then, depends crucially on intercohesion at structural folds, i.e. those positions at which diverse cohesive groups overlap and therefore permit "familiar access to diverse resources" (Vedres and Stark, 2010, p. 1151). Contrary to this finding, other findings suggest that the generation of new knowledge is supported by structural autonomy and brokerage whereas cohesion is conducive only to the diffusion or reproduction of new knowledge (Fleming et al., 2007). In summary, the existence and the quality of relations as well as specific structural characteristics of positions, regions (subgroups) and whole networks have been theorized to help or hinder social outcomes such as economic performance or innovativeness.

3.2 The contingent relation between geography, networks and knowledge

Research on knowledge networks has long ignored the geographical dimension (Bell and Zaheer, 2007; Whittington et al., 2009). Only recently have scholars in organization theory discovered geography as a major contingency for organizational change (Freeman and Audia, 2006; Owen-Smith and Powell, 2004; Sydow et al., 2010). From the perspective of network theory, geography is an external variable that forms part of the contextuality of a network. From the perspective of geography, networks are configured and constrained in space. How can these perspectives be reconciled and what roles do geography and networks play in the context of knowledge creation? A traditional combination of these perspectives becomes evident in research designs of regional networks. This type of research is based on a priori designs of regional contexts where networks are studied in full conscience that firms are co-located (e.g. Giuliani and Bell, 2005; Uzzi, 1997). However, much research of this kind focuses on the description of network characteristics and the explanation of a specific kind of performance as an effect of these network characteristics. The problem involved in this design is that although co-location is acknowledged, it does usually not form part of the analysis but remains an external condition either not theorized or filled with a priori assumptions. Geography here, only serves as a pragmatic container for a certain research question.

An important starting point for a theoretical interest in the relation between space, knowledge and networks is the *empirical coincidence of physical proximity and innovation*. Numerous studies have demonstrated what Glaeser expressed as an intuitive expectation: "*intellectual breakthroughs must cross hallways and streets more easily than oceans and continents*" (Glaeser et al., 1992: 1126). Technological development as measured, for instance, by patent citations was repeatedly shown to be sticky to regions (Jaffe et al., 1993; Thompson and Fox-Kean, 2005). How can this coincidence be accounted for when taking both, networks and geography into consideration? Four types of models can be found in the literature that theorize distinct interrelations between networks, space and knowledge: geography as cause, geography as moderator, networks as moderator, and network as mediator.

Geography as a condition for network formation

One dominant approach is based on findings that geographical proximity eases network formation. Physical proximity increases the likelihood for social relations and information exchange to emerge (Allen, 1977; Zipf, 1949). Empirical research on network evolution confirms the plausible expectation that new relations are more likely to emerge in geographical proximity than over large distance (Powell et al., 2005). Recent research in evolutionary economic geography has underscored the association between geographical proximity and tie formation in networks by empirically controlling for other forms of proximity (Balland, 2012). These and other accounts of geographical constraints of network formation and evolution form part of what Borgatti and Halgin would classify as (geographical) theories of networks (Table 2). Apart from the enabling effect of geography on networks, the following sections will analyze different models that theorize the relations of space and networks in their combined effect on knowledge generation.

Geography as a moderator of network effects on knowledge

In an interesting research design, Owen-Smith and Powell (2004) analyzed the joint effects of spatial proximity and network centrality on firm innovativeness. Their study on Boston based biotech firms and their global alliance network found that while network centrality was an important factor of innovativeness in the global network, it was insignificant in the regional cluster. Firms connected to the local alliance network had equal propensities to innovate independently from the centrality of their position in the network. Geographical proximity in a way *moderated* the effect of network centrality on innovation.[v] One explanation of this finding is that proximity allows for knowledge spillovers within the entire network of alliances and beyond the dyadic

alliances. Owen-Smith and Powell (2004) refer to the spread of localized knowledge as 'channels' in contrast to the bounded flows through the 'conduits' of dyadic alliances. In a subsequent analysis of U.S. biotechnology, Whittington et al. demonstrate that the innovativeness of biotech firms benefits from geographical proximity and network centrality in rather contingent ways (Whittington et al., 2009): when firms are not or only scarcely connected to other firms via contractual agreements, close spatial proximity to other firms supports their innovativeness. However, in most other cases, spatial proximity was hardly associated with innovation: firms located in the three leading biotech clusters (Boston, San Diego, San Francisco Bay Area) did not benefit from their spatial proximity to other firms in their clusters because the variance of firm innovation within the cluster was best explained by the centrality of the firms in a network of contractual inter-firm alliances. In turn, the effect of the centrality of firms in the contractual inter-firm network was strongly moderated by proximity: Highly central firms were more likely to innovative in close proximity to other firms than at large distance (Whittington et al., 2009).

Network as a moderator of spatial effects on knowledge

It is usually accepted that information transfer and knowledge spillovers decay with geographical distance. In the context of international technology transfer between units of multinational corporations, Hansen and Lovas (2004) explicitly focused on interaction effects between the major factors of technology transfer. Their analysis conveys that informal and formal networks of relations between distributed organizational units clearly moderate the association between technology transfer and geography. Units are more likely to successfully transfer technology over large distances if they are connected through interpersonal informal ties or through formal organizational linkages. Bell and Zaheer (2007) demonstrate that different levels of relationships – individual, organizational, institutional levels – vary in their dependence on geographical proximity. Empirically they identified rather counter-intuitive evidence for what they call geographic holes, i.e. situations where knowledge flow is more likely between friends when they are geographically distant. In a similar vein, research on contractual alliances (Rosenkopf and Almeida, 2003) as well as informal business relationships (Glückler, 2006) illustrates how relationships substitute for local search and help bridging distance. Moreover, learning-by-hiring can be useful for extending the hiring firm's geographic reach and access to remote knowledge (Song et al., 2003). In all these research designs, the existence and characteristics of networks affect the strength of the association between geography and knowledge.

Network as a mediator of geographical effects on knowledge

Empirically, patents are cited more frequently within the region that they were invented than in other regions (Jaffe et al., 1993; Thompson and Fox-Kean, 2005). This finding supports the argument of spatial stickiness of technological knowledge trajectories. However, new research designs were needed to examine *how* these local spillovers happened. Almeida and Kogut (1999) found that local spillovers did not occur equally across regions and that those regions with the strongest spillovers in technological development were the ones where job mobility was most restricted to intra-regional job moves. Again, more sophisticated research designs used network analysis to demonstrate that local patent citations were strongly affected by the mobility of inventors: when inventors change jobs, they tend to move to employers in great geographical proximity to file similar patents there (Breschi and Lissoni, 2009). One consequence of this research is that the most fundamental reason why geography matters in constraining the diffusion of knowledge is that mobile researchers are not likely to relocate in space, so that their co-invention network is also localized (Breschi and Lissoni, 2009). Other research even demonstrated that inventor mobility increases inter-firm knowledge transfer (patent citations) independent of geography (Rosenkopf and Almeida, 2003). In support of this conclusion, Breschi and Lenzi (2010) offer evidence that proximate and remote job moves occur at equal proportions and Song et al. (2003) demonstrate that proximate as well as distant hiring of inventors both lead to effective transfer in

technological knowledge as measured by patent citations. A second example of how networks mediate the relation between space and knowledge is provided in the context of information search. Borgatti and Cross find that knowing informants and being able to access these sources mediates the relationship between physical proximity and information seeking (Borgatti and Cross, 2003).[vi] In other words, once knowing and accessibility are controlled, proximity has no statistical effect on information transfer. In summary, this line of research suggests that the association between geography and knowledge is not a direct but a mediated effect through inventor mobility, accessibility of other partners and prior knowing.

4 From connectivity to the problem of non-interactive spillovers

4.1 Accounting for ambivalent evidence

Scholars have only recently begun to examine networks and space jointly in their contingent relation with knowledge creation. The evidence of the association between 'knowledge, networks and space' as discussed in the previous section is ambivalent, especially with respect to geography: for some it appears as a force, for others a moderator and again for others only an indirect factor which is mediated by more important factors such as connectivity. A review of this line of network research still leaves many doubts about the real relationship between knowledge, networks and space. In some situations, knowledge creation can be supported by proximity and centrality has no effect, whereas in other situations centrality drives knowledge creation with geography being insignificant. To some extent, these empirical contingencies may be consequences of methodology as well as the kinds of knowledge and the kinds of networks observed. While geography is often observed either as a binary (inside/outside a region) or a measure of geometric distance, network relations, and the types of knowledge and relations vary widely. Relations in networks range from informal to contractual relationships and from individual to organizational levels. New knowledge is usually measured as successful patent applications although innovation occurs in many other forms, too. These different semantics and metrics are likely to produce different effects and may cause large part of the observed contingencies.

Research on information transfer conveys that the mobility and transferability of information depends on other conditions that relate to the quality of knowledge, the actors and the social context (Argote et al., 2003): first, tacitness, stickiness (Von Hippel, 1994), causal ambiguity (Lippman and Rumelt, 1982) and public vs. proprietary knowledge (Uzzi and Lancaster, 2003) strongly affect the availability and transferability of information and interpretability of new knowledge. Proximity enables actors to capture the complexity of knowledge whereas too much of a distance isolates the contextual knowledge necessary to disentangle causal ambiguity (Sorenson et al., 2006). This is mainly because complex knowledge is more difficult to communicate across distance such that proximity can moderate knowledge spillovers by making complex information more accessible (Sorenson, 2005). Second, actor attributes such as absorptive capacity (Cohen and Levinthal, 1990; Zahra and George, 2002), status and qualification affect the ability to absorb new knowledge. Third, relational qualities between the involved actors affect the motivation, intimacy and fertility of a social context of exchange (Gupta and Govindarajan, 2000; Szulanski, 1996).

4.2 The connectivity paradigm at its limits? The spillover phenomenon

A more fundamental problem revealed by the current state of research is to be found in the implicit assumption that all knowledge flow is captured within the logic of networks. Does knowledge flow really respect the paths of connectivity in networks? If we take the ambiguity of empirical findings serious, then proximity and connectivity obviously interfere with each other: while connectivity is a way to bridge distance, proximity is a way to bridge social disconnection and to allow for spillovers were there are no relations at all. Even firms that are fully isolated from an entire contractual industry network were found innovative when located in

close geographical proximity (Whittington et al., 2009). These and other bits of evidence should be appraised more carefully. If knowledge overflows network relations and if proximity eases such overflow, then the role of geography should be reconceptualized and integrated more profoundly in theories of innovation. First, 'being there' increases the likelihood for new relationships to build. Second, however, being there may not be sufficient per se to benefit from local knowledge (Owen-Smith and Powell, 2004) or other local resource endowments (e.g. access to philanthropy, Glückler and Ries, 2012). Third, and at the same time, being there broadens the scope of observation and facilitates access to spillovers beyond the conduits of networks. Proximity creates serendipity and strengthens buzz instead of links (Bathelt et al., 2004). Much in line with the metaphor of a 'channel' (Owen-Smith and Powell, 2004), information can be acquired through non-interactive modes such as observation or reverse engineering etc. Although all these non-interactive forms of knowledge transfer may principally happen in proximity and across distance, geographical proximity often entails a higher density and supposable serendipity that makes non-interactive spillovers more likely. One immediate consequence of this assumption is that networks can only partially account for collective learning because non-interactive learning does not necessarily require relationships or social networks.

4.3 Fortifying geography: non-interactive collective learning

One approach to account for the many contingencies between knowledge, networks and space, is to acknowledge not only interactive but also non-interactive mechanisms of collective learning and the consequences these have for arguments based on connectivity and geography. Collective learning is understood here as a process of learning from and between other actors so to improve an extant state of knowledge within a social context. This includes the collective creation of knowledge as well as its imitation through others. Imitation is a form of learning that refers to the unilateral absorption of existing solutions from one firm by another. Among the many advantages of imitation over experimentation (e.g. Alchian, 1950), imitation absorbs the risk of taking wrong decisions and saves the costs of experimentation by reproducing proven practice. However, imitation may not be limited to the simple copying of external knowledge but may also lead to original innovation, as Alchian emphasizes in a much cited argument: "*While there certainly are those who consciously innovate, there are those who, in their imperfect attempts to imitate others, unconsciously innovate by unwittingly acquiring some unexpected or unsought unique attributes which under the prevailing circumstances prove partly responsible for the success*." (Alchian, 1950: 218). Imitation, therefore is not only an important cornerstone of collective learning but also a potential source of original innovation.

Since imitation can be both collaborative and rival (Hammer et al., 2012), I distinguish two types of imitation: a *friendly imitation* describes the transmission of an existing practice to another firm based on the agreement or active cooperation by the source firm. Friendly imitations, therefore, are interactive and collaborative. In contrast, an *unfriendly imitation* happens when a firm succeeds in absorbing a practice although the source firm is unaware or disapproves the reproduction of its practice by third parties. Hence, unfriendly imitations do not necessarily presuppose interaction. Whether imitation is friendly or unfriendly, then, depends on the attitudes of the actors and the existence (or absence) of interaction between them. Friendly and unfriendly imitations reflect the tension of competition and cooperation between firms. Conventions of friendly imitation are based on the allowance and long-term reciprocity between interacting partners. Joint experimentation as well as friendly imitation, i.e. the active sharing of best practices between partners, has been well understood by network as well as cluster approaches by focusing on the analysis of inter-organizational cooperation and networks of strategic alliances.

Non-interactive forms of imitation, however, seem to be far less understood and almost neglected in empirical research. The process of imitation is found crucial, for instance, in understanding the mimetic behavior of organizations and the convergence toward isomorphic organizational fields without the necessary existence of direct linkages between the organizations for imitation to occur (Dimaggio and Powell, 1983). Quite explicitly,

unfriendly imitation and the collective learning that it facilitates can unfold without trust and cooperation: "*no trust is required as a prerequisite for learning. The sequence of variation, monitoring, comparison, selection and imitation can take place without any close contact or even an arm's-length interaction between the firms*" (Maskell, 2001: 930). Instead, practices of monitoring, observation and comparison enable firms to screen new practices and technologies in close geographical proximity to competitors and to reproduce them in their own organizations (Malmberg and Maskell, 2002). I will briefly sketch three types of non-interactive imitation as practices of collective learning with distinct spatial implications: observability in co-presence; reverse engineering, and public codified knowledge.

When firms pursue similar activities in the same location even minor differences between firms will soon be detected and at some point understood by competitors. The similarity of activities and knowledge as well as the co-presence between firms eases the observability of firms and thus enhances the chances of competitors to detect and imitate a new practice. It is exactly this learning opportunity that Malmberg and Maskell emphasized in their knowledge-based theory of clusters so forcefully (Malmberg and Maskell, 2002: 439): "*business firms often have remarkably good knowledge of the undertakings of nearby firms even if they do not make any dedicated efforts at systematic monitoring. If those neighbouring firms are in a similar business, it is more likely that the observing firm will understand, and learn from, what it observes*." Despite the strong conceptual statement, however, empirical research on non-interactive collective learning has been rather rare in economic geography. It is certainly a pioneering challenge to capture non-interactive learning empirically and to uncover the way in which knowledge overflows networks in concrete geographical contexts.

A second mechanism of non-interactive learning is reverse engineering. This form of imitation describes a legally accepted practice of extracting knowledge from a human-made artifact (Samuelson and Scotchmer, 2002). Almost any participant in the market who has access to a new product or technology can use her own expertise and methods to reconstruct the technological know-why (Lundvall and Johnson, 1994) embodied in a product (Blackler, 1995). Since access to the product is mediated through the market and its supply chain, market participants do neither depend on direct interaction with nor on physical proximity to the innovator to imitate new knowledge. Reverse engineering, therefore is a practice that cuts across both networks of interaction and geographical proximity. A third source of non-interactive collaborative learning is related to localized institutions and domains of public codified knowledge. Whenever certain know-what or know-why is codified, users do primarily depend on their access to the repository of this knowledge rather than individual interactions with actors in that domain. Any kind of broadcasting of codified knowledge (e.g. news, patents, regulations etc.) overflows the effect of network linkages between actors. Whether users are able to absorb and appropriate codified knowledge, however, depends on their prior knowledge and mental models (Bathelt and Glückler, 2005). Codified knowledge requires interpretation and the capabilities to use and recombine that knowledge in proper ways. When people have been trained and living under similar linguistic, educational and further institutional conditions, e.g. in the same region, they are more likely to share a similar understanding of public codified knowledge without necessarily being associated to each other in concrete network relations. In this case, regional knowledge domains may emerge based on geographical contextuality (Gertler, 2003) that enable firms to absorb knowledge from other co-located firms more easily.

Unfriendly imitation is not compensated and may thus be found illegitimate by the source firm. But as long as rival imitation does not infringe upon intellectual property rights or use illegal practice (e.g. industrial espionage) it remains a legal practice. Friendly and unfriendly forms of collective learning are embedded in social expectations and rest on certain institutions such as conventions and agreements. In a competitive situation where firms do not actively cooperate, rival learning does not violate conventions of cooperation, reciprocity or loyalty and firms will have to live up with the risk of undesired knowledge spillover. Unfriendly imitation may also occur, however, in relations of organized cooperation such as multilateral inter-firm networks (Hammer et al., 2012). Existing relations of cooperation and trust may even increase the potential detriment

of rival imitation because information and expertise are shared openly in a belief of mutual responsibility that would otherwise not be shared. Similar to the common saying, that we always hurt the ones we love, Granovetter points to the delicate implication that sometimes only trust offers access to resources otherwise unavailable such that trust creates the opportunity for malfeasance (Granovetter, 1985). Therefore, organized networks of cooperation require compliance to social conventions and thus deter rival learning.

In summary, co-present observability, reverse engineering and regionally shared mental models to interpret public knowledge are examples of collective opportunities for imitation that may work without concrete interactions or linkages between the innovator and its imitators. All these forms are non-interactive forms of learning that potentially violate the connectivity paradigm in that knowledge reproduction can occur without measurable interaction or social relations between firms.

5 Conclusion

Both, geography and networks are important in understanding firm-level innovativeness and inter-firm knowledge reproduction. Though geographers have paid growing attention to networks over the last two decades, research was often restricted to networks as objects whereas network theory and methods of network analysis have been overly neglected. Network theory, however, has seminally contributed to our understanding of the relationality of the information flow and knowledge creation. The existence of relations, membership and positions in networks all make a difference for firm innovativeness and the direction of information flows and knowledge production. Moreover, new research designs in network studies have also contributed to unraveling the diverse and highly contingent associations between knowledge, networks and space. In conclusion of the vast body of network research, geography is recognized as a moderating and sometimes only mediated factor in the causal chain between networks and innovation. The discussion of network research in this paper suggests that geographers should take part in the interdisciplinary endeavor of network theory and go beyond mere descriptions of networks as objects.

Connections and copresence. Innovation is fruit of learning, and learning is a social practice that unfolds in two rather distinct ways. While collaborative learning is based on interactions and active cooperation, this paper has also emphasized the role of non-relational and often rival learning. Rival learning refers to unfriendly imitation by means of observation, reverse engineering and related practices that do not require direct and repeated interaction. While collaborative and interactive learning can be represented within the network logic, non-interactive learning transcends the logic of connectivity. Instead, knowledge overflow may occur in the absence of relationships and interactions may truly benefit from the serendipity, visibility and density of opportunities in geographical proximity. This brief analysis is a plea for a more ambitious integration of connectivity and space in theories of innovation. It leads to the more interesting question of how learning actually happens and how non-interaction is mediated in processes of rival learning.

Beyond this concrete challenge to the network paradigm, I would like to highlight some additional debates about the limits of the formal connectivity paradigm in explaining the creation and the sharing of knowledge. As a way of concluding this sympathetic review and research proposition, the future development of a more inclusive network theory would benefit from resolving three conceptual challenges: the debate on connectivity vs. culture, the problematic conception of knowledge and innovation, and the neglect of organized networks as organizations of multilateral inter-firm collaboration:

Connectivity and Culture. One of the major challenges in current relational social theory focuses on the theoretical relation of culture and connectivity (Pachucki and Breiger, 2010). This debate is an effort to overcome deficiencies in prior approaches, and to integrate structural sociology, which is interested in relationship patterns of social networks, with cultural theories that focus on the construction of meaning in these relations

(Mische, 2011). A more qualitative theorizing focuses less on the associations between structural antecedents and economic effects but on how these things happen. Research that looks at the actors, their interests and the culture of practice aims at putting quality to statistical coincidence by asking how certain effects are socially produced and how social interaction generates network effects on performance (Hallen and Eisenhardt, 2012; Martin and Eisenhardt, 2010). This research provides more grounded theorizing, adds complexity and detail to the emergence and operation of networks and emphasizes agency and strategic action in order to avoid a deterministic understanding of structure on economic outcomes (Ozcan and Eisenhardt, 2009). More qualitative research is needed to really understand the non-relational travels of knowledge in geographical contexts of proximity and distance.

Problematic treatment of knowledge and innovation. Social network analysis tends to have a bias towards stylized facts and 'hard' forms of innovation, i.e. patents. Innovation, however, is not only a patentable outcome or property but also a process involving many diverse actors. Learning does not only lead to new products and technologies but also adds to organization and marketing concepts which have been acknowledged as innovations (OECD, 2005). If innovation is really taken for what it is, a process of learning and of distributing new solutions, it should be conceived as a continuous process of learning rather than sequential market introductions of new inventions. The analysis should focus on the roles and kinds of involvement of different actors in this process, as for examples the distinct roles of innovators (sources), facilitators and carriers of innovation (OECD, 2007). Taking this broader perspective, network theory and analysis would really help to identify roles in social divisions of collective knowledge creation.

Network theories of network organizations. Finally, this paper identifies a research gap in the analysis of organized networks. The network has long been treated as an alternative governance form in comparison with the market and the hierarchy. Organized networks are a relatively young form of organization that – according to Human and Provan (2000) – only began to gain popularity in the 1980s. However, the logics of distinct forms of governance of network organizations has only been discussed very recently (Glückler et al., 2012; Provan et al., 2007; Provan and Kenis, 2008). An organized network is a voluntary and purposive association of members, that aligns the multilateral collaboration between a finite number of independent organizations with a shared economic outcome. A relational concept of the organized network corresponds with the type of theorizing that Borgatti and Halgin (2011) describe as a bond model of innovation in that a set of firms enter a multilateral coalition in order to coordinate the exploitation or exploration of distributed resources and knowledge.

This paper is incomplete in many ways. Its aim has been to appraise two lines of often separate research communities: networks *and* geography of knowledge. Geographers have discovered networks as a powerful source of reasoning, yet they could benefit by running the 'full relational revolution' and also use concepts and methods of structural network theory. In turn, networkers have discovered geography as a relevant interacting force in the relation between network properties and knowledge creation and circulation. Both communities will benefit from sharing their notions. The argument of this paper has been that non-interactive forms of learning such as unfriendly imitation are a key challenge to the connectivity paradigm and justify more detailed research on the integration of topological and topographical concepts of knowledge.

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[i] The 2012 RSA conference in Delft, Netherlands comprised 121 sessions with a total of 364 presented papers. A frequency count of the most popular key words across all papers and sessions conveyed the following ranking of the top ten keywords: region* (256 occurrences), space*/spatial (85), city/cities (79), planning (72), governance (68), development (67), network* (64), innovat* (62), territor* (57), knowledge (48). When key words are truncated (*), it means that any word containing this root was counted, e.g. region* [= region, regions, regional].

[ii] JSTOR (short for Journal Storage) is an online system for archiving academic journals, founded in 1995. As an independent non-profit organization the database contains more than 1,200 journal titles in more than 50 disciplines. In geography, a total of 33 academic journals are listed, of which 13 are covered back to the 1970s and before. Access to the database was granted through the Heidelberg University license agreement in April 2012.

[iii] The journals include: The Annals of Regional Science, Annals of the Association of American Geographers, Antipode, Economic Geography, Entrepreneurship & Regional Development, European Planning Studies, European Urban and Regional Studies, Environment and Planning A, Geoforum, Geografiska Annaler, Journal of Economic Geography, Papers in Regional Science, Progress in Human Geography, Regional Studies, Tijdschrift voor Economische en Sociale Geografie, Transactions of the Institute of British Geographers, Urban Studies.

[iv] In contrast to other measures of centrality, degree is usually not considered as a real structural measure of centrality. It is defined as the number of direct contacts of an actor in a network and does therefore not say anything about her relative position in the overall network. It can be called a local measure of centrality as opposed to global measures of closeness or betweenness.

[v] A moderator variable influences the strength of a relationship between two other variables, whereas a mediator variable explains the relationship between two other variables (Baron and Kenny, 1986)

[vi] Mediation implies that the mediated variable (proximity) predicts the mediating variables as well as the dependent variable (e.g. innovation, information exchange), and that the coefficient for the mediated variable becomes insignificant when the mediators are included in the model (Baron and Kenny, 1986).