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The firm's knowledge network and the transfer of advice among corporate inventors—A multilevel network study

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ABSTRACT

Knowledge networks consisting of links between knowledge elements and social networks composed of interactions between inventors both play a critical role for innovation. Taking a multilevel network approach, this study integrates research on the two types of networks and investigates how the knowledge network of a firm influences work-related interactions among its inventors. To this end, we associate inventors with specific knowledge elements in the firm's knowledge network and examine how this association affects the inventors' popularity and activity in a work-related advice network. Empirically, we combine survey data on 135 inventors working in a German high-tech firm with information derived from the firm's 1031 patents. Results from multilevel exponential random graph models (ERGM) show that different dimensions of knowledge derived from the firm's knowledge network shape the transfer of advice among inventors in unique ways. Thus, our study demonstrates how structural features of the firm's knowledge stock influence interpersonal interactions among its inventors thereby affecting the intra-organizational diffusion of knowledge and the recombinant possibilities of the firm.

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1. Introduction

While traditionally, researchers have represented organizational knowledge as an aggregation of knowledge elements used by firms for inventive activities (e.g., Ahuja and Katila, 2001; Fleming, 2001; Quintana-García and Benavides-Velasco, 2008), recent studies have drawn attention to the structure of the firm's knowledge stock as a determinant of innovation (Dibiaggio et al., 2014; Guan and Liu, 2016; Wang et al., 2014; Yayavaram and Ahuja, 2008). In its structural representation, firm knowledge is a collection of links between knowledge elements (Dibiaggio et al., 2014) that can be conceptualized as a network (Guan and Liu, 2016; Wang et al., 2014). In this “knowledge network”,¹ knowledge elements embody discrete pieces of knowledge and links between them indi-

cate whether and how the firm has combined these elements in the process of knowledge creation and invention. Knowledge networks hence capture commonalities in the subject matters of different knowledge elements (Carnabuci and Bruggeman, 2009; Yayavaram and Ahuja, 2008).

The properties of knowledge networks have been shown to influence the usefulness of innovations that firms generate (Yayavaram and Ahuja, 2008) and affect firms' and inventors' tendency to engage in exploitative and exploratory innovation (Guan and Liu, 2016; Wang et al., 2014). While these findings confirm that knowledge networks matter for innovation outcomes, scholars have been at odds concerning their relationship with social networks as an important component of the innovation process (e.g., Carnabuci and Operti, 2013; Singh, 2005). Yayavaram and Ahuja (2008) have suggested that the structure of a firm's knowledge network is reflected in the social ties among its employees – that is, the two networks are supposed to be isomorphic. In contrast, Guan and Liu (2016) and Wang et al. (2014) have demonstrated that a firm's knowledge network and its social network possess dis-

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¹ In line with Guan and Liu (2016) and Wang et al. (2014) our use of the term “knowledge network” differs from its use in other studies (e.g., Hansen, 2002; Owen-Smith and Powell, 2004) that investigate social knowledge networks. Whereas social knowledge networks capture knowledge transfer among individuals or collectives, the knowledge networks focused upon in this study represent “the combination

and consequent affiliation of knowledge elements in the process of creating new knowledge” (Phelps et al., 2012; 1156).

tinct structural features and influence innovation differently. They have concluded that knowledge networks and social networks are not isomorphic but rather decoupled. Aiming to dissolve this tension and provide a more detailed understanding of the different networks that determine innovation in organizations, this study addresses the question of how a firm's knowledge network relates to the social network among its inventors and thereby affects the social process of innovation generation in corporate R&D.

We argue that while the knowledge network and the social network may be decoupled in the sense that they have unique structural features (Guan and Liu, 2016; Wang et al., 2014), they are not independent from each other. Corporate inventors creating the social network are embedded in their firm's knowledge network by possessing specific knowledge elements that reflect their individual knowledge (Wang et al., 2014). We assume that this embeddedness in the knowledge network affects the inventors' work-related social ties, particularly the transfer of advice as part of their day-to-day work. In other words, inventors' knowledge relative to the overall knowledge of the firm is supposed to drive their popularity as advisors, that is, the extent to which they get addressed for advice by their colleagues, as well as their activity as advice seekers, that is, the extent to which they ask colleagues for advice. We follow Wang et al. (2014) and conceptualize knowledge as a multidimensional, complex structure reflected by the firm's knowledge network and the inventors' embeddedness in it. We investigate (1) inventors' knowledge diversity, (2) uniqueness of knowledge, (3) combinatorial potential and (4) combinatorial opportunities offered by knowledge elements, as well as (5) knowledge proximity among inventors as distinct knowledge dimensions determining the transfer of work-related advice.

To analyze the influence of the firm's knowledge network on the inventors' social network we follow a multilevel network approach (Zappa and Lomi, 2015) integrating three distinct networks into one multilevel framework. Drawing on data collected in a German high-tech firm in the electrics and electronics industry, we examine the structure of the firm's knowledge network at the macro level determining the structure of the social network among its inventors as the outcome variable at the micro level. We link the social network to the knowledge network using an affiliation network that connects each inventor to single knowledge elements within the knowledge network, thereby reflecting the inventors' embeddedness in the knowledge network of the firm. To empirically construct the multilevel network, we combine data from different sources. While the social network is derived from survey data on 135 corporate inventors, we draw on all of the firm's patents – more precisely the co-assignment of technology classes to these patents – to construct its knowledge network and to derive information on the technological knowledge elements that the inventors possess. Analytically, we apply newly developed exponential random graph models (ERGMs) for multilevel networks (Wang et al., 2013) that allow accounting for cross-level influences of network structure at one level on the emergence of ties at another level. ERGMs thus enable us to investigate how properties of the firm's knowledge network affect the presence or absence of work-related advice ties in the social network, explicitly taking into account that ties in a (multilevel) network do not occur independent of each other.

Our study contributes to existing research first, by extending our understanding of the firm's knowledge network as a factor influencing the social process of innovation generation in corporate R&D. Most prior studies have treated firm knowledge as an aggregation of knowledge elements (e.g., Ahuja and Katila, 2001). By taking into account the structural properties of firm knowledge and embedding corporate inventors within this knowledge network, we are able to provide a more precise understanding of the role it plays for innovation. In addition, to the best of our knowl-

edge there are only two studies that have integrated knowledge networks and social networks into a single analytical framework (Guan and Liu, 2016; Wang et al., 2014). Both studies have examined the separate influence of the two networks on innovation outcomes and call for future research investigating the influence of the knowledge network on the innovation process. Following their call, we demonstrate that the knowledge network and the social network are closely related as the structure of firm knowledge influences patterns of informal interactions among inventors thereby affecting intra-organizational knowledge diffusion and the overall innovation process (Singh, 2005).

Second, we add to research on the determinants of social networks as a central component of corporate R&D's function to generate new knowledge by recombining existing knowledge (Fleming, 2001; Kogut and Zander, 1992; Nerkar and Paruchuri, 2005). Social networks are the main channels for inventors to transfer recombination-related knowledge (Allen, 1977; Hansen, 1999; Singh, 2005). They influence inventors' productivity (Harhoff et al., 2013; Tortoriello, 2015; Tortoriello and Krackhardt, 2010) as well as the way that firms innovate (Carnabuci and Operti, 2013). In short, effective social networks are crucial in corporate R&D and understanding the drivers of tie creation in these networks is essential to reach this effectiveness. While scholars have demonstrated that factors such as formal organizational structure (Brennecke and Rank, 2016; Caimo and Lomi, 2015), status (Agneessens and Wittek, 2012; Lazega et al., 2012), spatial proximity (Kabo et al., 2014), as well as network endogenous processes (Rank et al., 2010) determine the structure of social networks, knowledge has attracted limited attention as a driver of interpersonal exchange. This seems surprising because one of the main goals of seeking advice from colleagues is complementing what one knows with other knowledge elements. To fill this gap, we investigate how different knowledge dimensions that account for the relation of individual to firm knowledge influence the work-related transfer of advice among corporate inventors.

2. Theoretical framework

2.1. The firm's knowledge network and the inventors' embeddedness in it

The knowledge network of a firm is a structural representation of its cumulative stock of rules, routines, practices, or documents and as such is the result of collective efforts of past and present employees (Wang et al., 2014). Reflecting the firm's inventive history, it is more than the sum of its current inventors' individual knowledge stocks. The basic building blocks or "nodes" of a knowledge network are knowledge elements, in our study pieces of technological knowledge that are the fundamental components of an invention (Fleming and Sorenson, 2004). Knowledge elements are often embodied in discrete artifacts such as patents, products, or scientific publications (Phelps et al., 2012). Connections or "ties" between knowledge elements result from their combination in the process of knowledge creation and invention (Carnabuci and Bruggeman, 2009; Fleming and Sorenson, 2004). The printing press, for instance, can be seen as a combination of knowledge elements from areas such as press, metallurgy, ink and others (Diamond, 1997). Ties in the knowledge network thus indicate the degree of relatedness in the subject matters of single knowledge elements, with elements that have been combined in inventions more often being more closely related (Fleming, 2001). The position of each knowledge element in the knowledge network reflects its combinatorial history within the firm (Carnabuci and Bruggeman, 2009). It mirrors the firm's idiosyncratic beliefs about which knowledge elements should be considered jointly and, conversely, which

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