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Research Note

Knowledge management in OSS communities: Relationship between dense and sparse network structures

Stefan Kambiz Behfar[a,*], Ekaterina Turkina[b,1], Thierry Burger-Helmchen[a,2]

[a] BETA-CNRS 7522, Bureau d'Economie Théorique et Appliquée, Université de Strasbourg, 61, Avenue de la Forêt Noire, F-67085 Strasbourg Cedex, France

[b] Department of International Business, HEC Montreal, 3000, chemin de la Côte-Sainte-Catherine, Montréal, Québec, H3T 2A7 Canada

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ABSTRACT

Some authors in the literature have addressed knowledge transfer via weak ties between organization's units which are themselves strongly tied inside (e.g. Hansen, 1999). Some others have investigated knowledge management among open-source-software (OSS) developers and discussed factors influencing knowledge transfer within development teams (e.g. Joshi and Sarker, 2006). In the domain of open source software (OSS) communities, more companies are now attempting to establish relationships to benefit from these potential value-creating communities; and project managers could in fact target different goals within software development teams including knowledge transfer within and between teams. We step forward to distinguish knowledge transfer within groups as opposed to knowledge transfer between groups; where relevant projects are bundled into separate strongly intra-connected groups. In knowledge management literature there is a trade-off between sparse network structures (Burt, 2000, 2002) versus dense network structures (Walker et al., 1997; Coleman, 1988). It is argued that the former facilitates the diffusion and generation of ideas among groups, while the latter affects the implementation of idea within each dense group. To our best knowledge, there has been no study to investigate the relationship between dense and sparse network structures. We propose that *knowledge transfer within dense groups has a positive influence on knowledge transfer between sparse groups*, in that intragroup density, group size, developers centrality and betweenness could impact intergroup coupling. To prove our hypothesis, we use a complex network of open source software (OSS) as the domain of interest, where developers represent nodes and two developers contributing to a project task represent a network tie. Developers contributing to tasks in groups other than their own can *explore* novel ideas via sharing knowledge, whereas developers contributing to tasks inside groups *exploit* ideas to improve those projects. We investigate the idea both analytically and empirically within 4 months, 8 months and 1 year lagged time, and finally show that intragroup density has a positive whereas developers' centrality has a negative influence on intergroup coupling.

1. Introduction

Inside organizations, units can learn from each other and knowledge transfer can provide new mutual opportunities for units as well as for the whole organization. New ideas diffuse rapidly when they benefit organizations adopting them, and they vanish, if otherwise (Abrahamson, 1991). Huber (1991) suggested that organizational units transfer knowledge and learn from other units, but not all units have access and capacity to learn knowledge and apply it; they require external access and internal capacity. Internal capacity can be achieved by R & D ability increase, while external access to new knowledge can be improved by networking. In this regard, Hansen (1999) introduced modelling an organization as a complex network with inter-unit links, where knowledge transfer is investigated by analyzing inter-organizational network.

In regards to usage of social network analysis (SNA) in organizations, different authors focused on a wide range of network characteristics from relational (e.g. tie strength) and nodal (e.g. functional background) to positional (e.g. betweenness centrality) and structural (e.g. density), e.g. impact of size of network on innovation (Baer, 2010), relationship strength (Rost, 2011), or weak and strong tie (Nelson, 1989; Tsai, 2000, 2001). Baer, Evan, Oldham, and Boasso (2015) carried out a *meta*-analysis of studies on innovation and social networks and presented insights into the various trade-offs between strength of

* Corresponding author.
E-mail address: kambiz.behfar@gmail.com (S.K. Behfar).
[1] http://www.hec.ca/en/profs/ekaterina.turkina.html.
[2] http://www.beta-umr7522.fr/-BURGER-HELMCHEN-Thierry?lang=fr.

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ties and bridging ties among other things. Tsai (2000) suggested that social networks facilitate the creation of new knowledge within organizations. In another study, Tsai (2001) focused on the question "How can an organizational unit gain useful knowledge from other units to enhance its innovation and performance?", and emphasized the role of strong ties in intra-corporate and strategic alliances. Moreover, Ahuja (2000) discussed firm's network relationship impacting the rate of innovation, where network allows for knowledge sharing and information flow. Others have studied the role of networks within the topic of knowledge sharing and innovation adoption where importance was given to the number of firm linkages and geographical proximity (Florida, 1995; Van Oort & Atzema, 2004) impacting rate of adoption.

Apart from the discussion about knowledge management within and between organizations and the discussion about social network analysis in organizations on the topic of innovation, within topic of open source software (OSS) development, researchers have used social network theories to investigate the OSS phenomenon including communication among developers. The positions and relationships among developers in a social network are significant in the efficiency of the network (Jackson, 2004) using different techniques and tools such as social network analysis (SNA). Success of many OSS projects is closely related with the communication structure (see Grewal, Lilien, & Mallapragada, 2006; Singh, Tan, & Youn, 2011). One distinguished feature of the OSS development model is the cooperation and collaboration among the members, which will cause various social networks to emerge (Grewal et al., 2006). To some extent, the OSS community is a more networked world than the traditional organizational communities; where programmers can join, participate, and leave a project at any time and developers collaborate not only within the same project team but also across teams. It has also been shown that the structure of an interproject network affects knowledge sharing within and across open source projects. Montazemi, Siam, and Esfahanipour (2008) demonstrated that the market structure of embedded interpersonal ties enables participants to take advantage of information asymmetry for profit taking Singh, 2011. Hinds and Lee, (2008) discussed costs and benefits of community ties, and concluded that social network structure of open source software has no important effect on community structure. On the other hand, Antwerp and Madey (2010) investigated social network structure of open source software, and used long term popularity as the metric developer–developer tie and concluded that previous ties are generally an indicator of past success and usually lead to future success. Crowston, Annabi, and Howison (2003) also discussed social structure of open source software development teams based on the analysis of interactions represented in bug reports from 122 large and active projects, and found out that some projects are highly centralized, and others are not.

As above-mentioned, several authors have previously discussed the significance of positions and relationships among developers or so-called community ties in the efficiency of OSS network. In addition, knowledge management among open-source-software (OSS) has been investigated (Joshi and Sarker, 2006), where they discussed factors influencing knowledge transfer within development teams. Ojha (2005) also discussed knowledge sharing between team members based on similarity-attraction paradigm; where he proposed that knowledge sharing more likely happen between same demographic team members. However, developers collaborate not only within the same project group but also across groups, therefore knowledge transfer should be also investigated across groups within sparse network structure. In this regard, there are conflicting explanations concerning the impact of sparse and dense network structure for the purpose of innovation. Walker et al. (1997) and Coleman (1988) stressed that dense network structure impacts on implementation of idea within each group, and argued that strong ties are required for exchange of complex knowledge, whereas Burt (2000, 2002) emphasized that a sparse network structure facilitates diffusion of ideas and argued that strong ties within dense network are inefficient for acquiring external knowledge as they do not promote diversity in resources. To our best knowledge, there has been no study to investigate relationship between dense and sparse network structures, i.e. impact of dense network on sparse network structure in regards to knowledge transfer. In other words, intragroup density, group size, developers' centrality and betweenness within dense groups could have a positive influence on intergroup coupling between sparse groups. In the theoretical development section, we discuss why we have chosen these independent variables in this causal relationship.

In order to develop our hypotheses, we use a complex network of open source software (OSS) as the domain of interest. In this network, developers represent the nodes and two developers contributing to a project task represent a network tie. Developers contributing to tasks in groups other than their own can *explore* novel ideas for new project creation, whereas developers contributing to project tasks inside their own group *exploit* ideas to improve those existing projects with better inside-group search possibility.

In the theoretical development section, we provide hypotheses and discuss logical and analytical reasoning to prove our hypothesis; then in the empirical section, we alternatively examine the relationship between intragroup density, group size, developers' centrality and betweenness with intergroup coupling, using 4 months, 8 months and 1 year lagged time (to examine robustness), via examining OSS data collected from SourceForge repository.

2. Theory development

In the introduction section, we provided literature and motivation for this paper; here we render the hypotheses and model design to give logic and reasoning to prove the hypothesis.

2.1. Network group structure

As discussed by Burt (2000), groups are inter-connected via both strong and weak ties, where weak ties are far more numerous. Groups are also intra-connected via both strong and weak ties, where strong ties are far more numerous, while intergroup coupling is used between groups, as shown in Table 1. We use the word "coupling" between

Table 1
Terminology.

term	definitions	measure
Network tie	two developer working on same project task	frequency of developer contribution in project tasks
Network structure		
	Dense intragroup structure	Densely intraconnected groups, where developers work on relevant project tasks
	Sparse intergroup structure	Sparsely interconnected groups, where developers work on irrelevant project tasks
Intragroup density		Sum of intragroup ties over total possible ties within a group
Intergroup coupling		Sum of intergroup ties (sum of intergroup project tasks)
OSS group	$group\_project_{id}$, including project relevant members	Assigned by sourceforge administration for any new project; moreover new members/developers are added by the group administrator based on relevancy and of course his or her interest