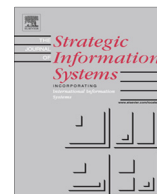




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## Open source project success: Resource access, flow, and integration

Sherae Daniel <sup>a,\*</sup>, Katherine Stewart <sup>b</sup>

<sup>a</sup> University of Cincinnati, 2925 Campus Green Dr, Cincinnati, OH 45221, United States

<sup>b</sup> University of Maryland, 7621 Mowatt Ln, College Park, MD 20740, United States

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### ABSTRACT

Open source software projects share key resources including knowledge and developer attention. Developers who participate on multiple projects create ties among projects and facilitate access to those projects' resources. However, projects also compete for developer attention, and they vary in their ability to integrate knowledge. This paper explores how factors that facilitate knowledge integration (low software coupling and high interactive discussion) impact project success and how developers' attention to external projects may dampen a focal project's success. Further, we explore how these factors may moderate the positive impact of a project's network degree centrality to develop a more nuanced model of their influences on project success. Using data from 175 OSS projects we find that software coupling, interactive discussion and externally focused developer attention directly impact completed code commits. Interactive discussion also amplifies the benefit of high network degree centrality, while developers' external attention weakens the positive impact of high network degree centrality. Results add to theory by providing a more nuanced view of how key strategic resources (knowledge and attention) drive OSS success. In particular it describes how knowledge integration ability, developer attention, and network degree centrality interact to influence project outcomes.

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### Introduction

Open source software (OSS) development has emerged as a viable model for creating and distributing software, transforming the software industry (Kogut and Metiu, 2001; Morgan and Finnegan, 2014; West, 2003) and serving as inspiration for adoption of more open practices in other domains (Von Krogh and Hippel, 2006). As such, OSS has had and continues to have significant impact on the strategy of firms in the software industry (Casadesus-Masanell and Ghemawat, 2006; Morgan and Finnegan, 2014; Von Krogh and Spaeth, 2007), and effectively managing the use and development of OSS is critical to success for many such firms (Dahlander and Magnusson, 2005; Gulati et al., 2012). Important strategic resources for organizations include knowledge (Grant, 1996) and attention (Ocasio, 1997); similarly, key resources that have been identified in the OSS setting are knowledge (Singh et al., 2011) and developers (Ke and Zhang, 2009). Recent work focuses on an OSS project's network as a crucial source of resources facilitating project success (Grewal et al., 2006; Mallapragada et al., 2012; Singh et al., 2011). Several studies have shown positive effects of network degree centrality and argued that these result from access to knowledge (Singh et al., 2011). Other work has shown that increasing numbers of developers and developer effort

\* Corresponding author.

E-mail addresses: [sherae.daniel@uc.edu](mailto:sherae.daniel@uc.edu) (S. Daniel), [kstewart@rhsmith.umd.edu](mailto:kstewart@rhsmith.umd.edu) (K. Stewart).

has a positive effect on OSS project outcomes (Chengalur-Smith et al., 2010; Crowston and Scozzi, 2002) and that developers' attention may be attracted through network connections (Hahn et al., 2008).

While research has established the importance of knowledge and developers as key resources, and the potential benefits of attaining these resources through network connections, little work examines the factors that allow an OSS project to effectively leverage those resources, or the possibility of losing resources to other projects in the network. Past work makes the implicit assumption that access to network knowledge equates to use of that knowledge (Grewal et al., 2006; Singh et al., 2011). However, research in the broader management literature establishes that individuals and groups vary in their ability to integrate and use new knowledge (Gulati et al., 2011; Lee et al., 2001; Pil and Leana, 2009; Reinholt et al., 2011). Knowledge integration refers to the combination of multiple sources of knowledge in a meaningful way (Alavi and Tiwana, 2002; Grant, 1996). A highly connected OSS project may fail to benefit from network knowledge access if the project developers experience difficulty integrating that knowledge. We argue that software structure and interaction among project participants are critical to knowledge integration capabilities, and ask how do these factors affect the extent to which a project benefits from its network connections?

Integrating knowledge into an OSS product requires effort from developers. Past work has shown that developers may be accessed via network connections without considering that, unlike knowledge, their attention is a limited (Ocasio, 2011) and a rival resource (Ocasio, 1997). While developers may contribute to multiple projects, the time they spend on one project cannot be spent on another, implying that while some projects may gain developer resources via network connections, others may lose those resources. We argue that developer engagement in project discussions indicates the level of attention a developer is devoting to a project and ask how does the proportion of developer engagement in external projects (vs. the focal project) influences project technical success?

The main contribution of this work is extending prior research to consider conditions under which projects may benefit more or less from resources available in the network, or may suffer detrimental consequences from resource flows away from a project. We draw on the literature that points to knowledge (Grant, 1996) and attention (Ocasio, 1997) as key strategic resources as well as recent work on consequences related to network participation (Trkman and Desouza, 2012). We highlight the importance of knowledge integration to enhance the benefit from knowledge access, and we explore the implications of developers' attention shifting away from a focal project to other projects in the network.

The following sections describe OSS projects in general, explain why developers' external attention, knowledge access and knowledge integration are important factors influencing the success of an OSS project, and describe the nature of OSS project network connections. We then hypothesize how technical success in the form of completed code modifications is influenced by network degree centrality, knowledge integration factors (software coupling and the level of interaction among project participants in a focal project), and the proportion of their attention developers devote to a focal project versus other projects. Section 'Methodology' describes the empirical study, and results suggest that projects benefit more from network degree centrality (knowledge access) when they have higher levels of interactive discussion, and less when developers' external attention is higher.

## Resources for success in OSS: knowledge and attention

### *What is "success" in OSS?*

OSS projects focus on creating software applications. As such, outcomes related to the code created by a project have been viewed as crucial indicators of project success (Singh et al., 2011). Researchers have typically measured outcome variables that tap how much code an open source project generates, how many additions are made to the code, or how many bugs are fixed (Giuri et al., 2010; Grewal et al., 2006; Midha and Palvia, 2012; Singh et al., 2011). More broadly, completing individual code modifications, which may represent additions, changes, or deletions, has frequently been viewed as a key indicator of the progress of an OSS project (Giuri et al., 2010; Grewal et al., 2006; Singh et al., 2011; Yang et al., 2013). Completing modifications related to building the application precedes a project reaching other goals, such as achieving quality and gaining market share (Méndez-Durón and García, 2009; Setia et al., 2012; Subramaniam et al., 2009). As such, completing code modifications is of significant strategic importance for OSS projects. Thus we concentrate our theorizing around a project's ability to achieve "technical success" in terms of completed code modifications, and focus on two key resources needed to develop code: knowledge and developer attention.

### *Knowledge in OSS*

Creating a software product requires significant knowledge resources (Patnayakuni et al., 2007; Sandhwalia and Dalcher, 2010; von Krogh et al., 2003) including "know-what," such as a knowledge of functional requirements, and "know-how," such as an understanding of programming principles (Rogers, 1995; Tornatzky and Fleischer, 1990). To attain technical success software projects must gain access to this knowledge. For this reason, past work explores how access to knowledge impacts OSS technical success and how knowledge enters OSS projects (Haefliger et al., 2008; Singh et al., 2011).

While traditional software development projects are housed within organizations that may provide a base of knowledge and a structure for drawing the needed knowledge into a project, many OSS projects exist outside traditional organizations.

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