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SHORT COMMUNICATION

The Future of Supply Chain Information Systems: The Open Source Ecosystem

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Abstract *The open source phenomenon has made a significant impression, not only on the software industry, but also on software-intensive organizations in both the public and private sectors. The collaborative model offered by the open source ecosystem can potentially change the collective nature of organizations and is claimed to increase innovation and technology adoption while reducing costs. These potential advantages are influencing how organizations acquire software and are leading to significant adoption of open source products across several domains. In fact, a recent Forrester Research report found that 78% of companies surveyed are running part or all of their operations on open source and 66% use open source to create software applications for their customers. Unfortunately, limited research exists regarding the implications and boundaries of open source technologies employed for supply chain management. For a firm to decide whether or not to pursue open source strategies, the field needs more research that helps us to understand how a firm's use of open source information systems relate to flexibility, agility, operational performance, and the triple bottom line. In this brief thought piece, we describe the potential for open source software to change the nature of supply chain information systems.*

Keywords Open source · Open innovation · Flexibility · Technology · Supply chain management · Information systems management

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Introduction

Open source software has emerged as a major cultural and economic phenomenon (Lerner and Tirole 2002) and serves as an exemplar of the recent trend toward developing user innovation to increase a firm's performance (Von Hippel 2009). User innovation integrates the user, whether an individual or organization, into the development of products (Morrison et al. 2000). In other words, it places the user in the role of innovator. Open source software is a means of user innovation applied to information products (Von Hippel 2001). It is software that is voluntarily developed and extended by users specific to their organization's needs and made freely available to all (O'Mahony 2003). The collaborative model offered by the open source ecosystem can potentially change the collective nature of organizations and is claimed to increase innovation and technology adoption while reducing costs (Huizingh 2011).

The open source concept continues to diffuse throughout organizations due to continuing advances in computing and communication technologies (Roberts et al. 2006). Moreover, with the growing demand on firms to become more mobile and application friendly, open source provides the ability to create new applications quickly, reliably, and economically (Fang and Neufeld 2009). Consequently, adoption of open source products is increasing across several domains (Deshpande and Riehle 2008). In fact, a recent Forrester Research report found that 78% of companies surveyed are running part or all of their operations on open source and 66% use open source to create software applications for their customers; however, this same report found that significant gaps exist in managing open source adoption across organizations and supply chains (Forrester Research 2016).

Unfortunately, limited research exists regarding the implications and boundaries of open source technologies employed for supply chain management. The purpose of this short communication paper is to start the discourse on the future of supply chain information systems in the emerging open source environment. We lay out the case for open source to provide a common backbone for global supply chain information sharing and provide ideas for timely and relevant research in this area.

Background

The emergence and benefits of open source in regard to software development and delivery within the software industry is well documented (i.e., Feller et al. 2006; Scacchi et al. 2006; Østerlie and Jaccheri 2007). In fact, over the past two decades an impressive body of research on open source software has emerged. This research has focused primarily on (1) individual incentives and the motivations for contributing to open source projects (i.e., Berquist and Ljungberg 2001; Von Krogh et al. 2003; Zeitlyn 2003), (2) governance, organization, and innovation processes established in open source software firms (Kogut and Metiu 2001; Shah 2006; O'Mahony and Ferraro 2007), and (3) the impact of open source software on competition in the software industry (Bonaccorsi et al. 2006; Economides and Katsamakas 2006). Yet, much of this research focuses on how open source software impacts firms within the software development and delivery industry.

However, open source capabilities are quickly expanding outside the software industry. The US Federal Government recently implemented a policy (Office of Mgmt. and Budget 2016) emphasizing open source to "promote innovation and collaboration across Federal agencies" by promoting sharing of, and public access to, Federal source code.[1] As another example, academic journals are sharing open source code to allow for quicker dissemination of scholarly knowledge to practitioners.[2] In addition, non-software firms are adopting open source for developing their own applications, reducing software licensing costs, and enhancing business agility (Forrester Research 2016). Specific examples include Cendant Travel Distribution Services replacing a $100 million mainframe system with a $2.5 million system running on 144 Linux servers; Amazon.com cutting its technology expenditure from $71 million to $54 million by switching to open source applications; and Sabre Holdings saving tens of millions of dollars by adopting MySQL, an open source database product (Nagy et al. 2010). Moreover, a recent O'Reilly survey (King and Magoulas 2013) revealed that analysts knowledgeable in open source technologies employed by non-software firms make more money than those dealing in proprietary technologies, suggesting that non-software firms are placing greater value on open source capabilities. Put bluntly, open source software is having a significant impact not only on the software industry, but also on non-software industry organizations in both the public and private sector (Hauge et al. 2010).

Unfortunately, limited conceptual and empirical research exists regarding the implications and barriers of open source technologies across the supply chain, especially for non-software industry firms. For a firm to decide whether or not to pursue open source strategies, the field needs more research that helps us to understand how a firm's use of open source information systems relate to flexibility, agility, operational performance, and the bottom line. Such flexible systems maximize utility of a firm's strategy, structure, systems, people, and culture. Recognizing and leveraging internal information systems capabilities provide firms with an opportunity to realize a sort of strategic renewal (Bell et al. 2014) in that firms realize, enhance, and appreciate their own information technology capabilities and how they can be used to improve process–technology fit, both internally and externally.

The sections that follow discuss opportunities that open source capabilities provide for the supply chain along with highlighting research areas that need to be addressed if tomorrow's supply chain is going to keep pace with today's open source adoption rates.

The Case for Open Source as the Foundation for Supply Chain Information Systems

Through open source, firms can acquire the basic software or code structure for free and then spend more of their time and resources customizing to their own needs. Costly enterprise resource planning (ERP) software provides a great example of the problems presented by current business practices. Historically, firms dedicate significant resources in highly customized ERP projects outsourced to proprietary software firms, only to receive inflexible software that requires additional resources to manage and upgrade whenever corporate structure or market demands change. An open source approach to ERP systems would provide the fundamental "Lego blocks" but allow the firm to develop and customize as necessary. So, rather than having an outside vendor try to envelope the firm's entire ERP needs at once (which often ends in catastrophe, as

[1] https://code.gov/.

[2] Examples include Journal of Statistical Software, R Journal, Bioinformatics, Open Physics, The Journal of Open Source Software, etc.

evidenced by the US Air Force's failed program),[3] an open source approach would allow the firm to add-on to the basic ERP building blocks specific to their own needs.

Moreover, open software has the opportunity to create greater fluidity with supply chain partners, which is of increasing importance in our fast-changing marketplace. By supply chain trading partners becoming their own user-innovators of software products, there is potential for these partner firms to customize software tools more specific to their operating environments, creating greater inter-organizational efficiency and effectiveness.

Modularity has been recognized as a key success factor of open source software projects (Langlois and Garzarelli 2008). A benefit of modularity is that it lessens dependencies throughout the software product. Consequently, multiple suppliers across all tiers of the supply chain could leverage a firm's open source software to build and customize their software components specific to their needs. Thus, the principal organization now allows each supplier to innovate their interacting software applications in their own way. This creates a less restrictive environment and has the opportunity to spur innovative, joint capabilities. Plus, if new and unique innovations are developed that other suppliers could benefit from, by its nature the source code can be shared, thus echoing the cliché "a rising tide lifts all boats." Consequently, the end result is a dynamic software application that allows suppliers, customers, and the principal firm to change quickly to market demands and to harness energies to compete against other dominant supply chains in the industry.

The idea of using and sharing source code among business partners is likely concerning to many. This might be especially true in the case of a firm with multiple suppliers, where each supplier is expected to use the same source code. Why would two suppliers to the same firm willingly share code? First, user-innovator-driven approaches such as open source tend to have a higher appeal in the general marketplace and minimize information asymmetries (Hippel and Krogh 2003). Thus, an open source approach is likely to lead to greater demand for the suppliers' products or services and also for the principal firm's products or services, which will drive stronger demand back down at the supplier level. Moreover, the reduced information asymmetries minimize risk. So by participating in an open source construct, a firm is likely to reduce external risks. Participating in the open source community also signals that the company is actively involved in the modern data and technology-driven economy (Lerner and Tirole 2002). This signal of technologically savvy can benefit firms in two ways. First, it can be a means for attracting greater talent as workers involved in open source technologies will want to go where the greatest advancements are being made. It also acts as a signal to partner firms by illustrating the talent and capabilities the firm has, which can increase demand for the firm's services. Consequently, although sharing source code may have its drawbacks, the added benefits it garners via increased demand, reduced risk, and improved signaling may outweigh the costs.

An Open Source Ecosystem

So what could an open source supply chain ecosystem look like? An organization that embraces an open source ecosystem engages participative communities both inside and out. Starting with the focal firm, open source can be leveraged to create more internal collaboration and innovation. This can include creating new applications to connect the many disparate databases across an enterprise; sharing code behind the internal data analysis processes that drive key business decisions; streamlining reporting and training processes that all employees take part in but only a few design; and even opening hardware design beyond the R&D department by sharing source files underlying physical devices. The idea is to leverage the full power and ingenuity of all employees to improve internal information products.

External to the focal firm, open source can be leveraged to engage collaboration and innovation across all flows of supply chain information. By opening up the underlying source code to the interfacing applications between partner firms and customers, firms can allow these agents to fully customize products and processes to their needs. This may include allowing customers to partake in the development of mobile applications so they better align to user needs or improve quality and are more secure since more users have the ability to verify and validate the code; develop better interagency workflows such as billing, routing, and inventory insight; and even opening hardware design by sharing source files underlying physical devices with customers and suppliers.

There is also the potential for the open access revolution to change the way industry firms leverage expertise provided by software development companies. Writing software code is becoming an ordinary job function within organizations. As this trend continues, there will be much less need for individual companies to require the typical services of today's software companies (i.e., Microsoft, Oracle). This is because each firm will retain its own coding and software development capabilities, which it will then share with their own trading partners as they work on

[3] The US Air force spent $1.03 billion over seven years to attempt to produce a single integrated ERP system that replaced approximately 240 outdated disparate systems. The program was terminated in 2012 and failed to produce an operable product. Full details behind the calamity are outlined in the US Senate's investigative report (Levin and McCain 2014).

mutually beneficial collaborations (both technological and operational). Today's software companies can begin to think of themselves as architects and integrators of open source software between and within companies. These companies will provide more value in terms of developing and managing enterprise and inter-organizational technology architectures than they will develop and sell commercial off-the-shelf or proprietary software. Consequently, firms will need to develop a relationship with open source suppliers to aid in the integration of this ecosystem across the entire supply chain.

Thus, a true open source ecosystem is holistic in nature and encompasses the entire value chain of an organization.

Concluding Remarks and Call for Research

A new stream of research is needed to address this area of how firms adopt and employ collaborative, open-source-based supply chain information systems. Although frameworks to posit open source supply chain research questions are numerous, here we consider the SCOR model (APICS Supply Chain Council 2006) to pose critical questions that need to be answered in future research to expand our understanding of open source's role in supply chain management. By no means do we consider the SCOR model to be the only framework to position these research questions, nor are these questions all-inclusive.

Plan

Supply chain planning processes use information from external and internal operations to balance aggregate demand and supply (Zhou et al. 2011). Thus, the ability to get real-time information and rebalance supply chains using updated information has proven to improve supply chain integration and performance (Narasimhan and Kim 2001; Fawcett et al. 2011). With this perspective, questions abound regarding how open source capabilities can influence:

1. Insight into supply resources.
2. Execution of resource assignment.
3. Aggregation of procurement, production, and distribution requirements.
4. Capacity planning across products and supply chain channels.

Make

The Make process includes the practices that efficiently transform raw materials into finished goods to meet supply chain demand in a timely manner (Zhou et al. 2011). Historical research regarding the Make process has generally focused on just in time production (JIT), total preventative maintenance (TPM), total quality management (TQM), and human resource management (HRM) (Shah and Ward 2003; Benton 2011). Hence, important questions exist regarding how an open source ecosystem can improve or otherwise affect:

1. Lean and six sigma implementations.
2. Demand forecasting.
3. Production planning and control.
4. Shop scheduling and sequencing.
5. Location and facility planning decisions?

Source

Sourcing practices connect the focal firm with suppliers, and significant literature has shown that improving supplier relationships through information systems improves performance (i.e., Tan et al. 1998; Carr and Kaynak 2007; Hsu et al. 2008). Consequently, research must seek to understand:

1. How can open source affect supplier relationship management?
2. What is the process for initiating financial transactions via these networks?
3. What kinds of open source information sharing agreements should be established between supply chain partners?
4. Does a body need to be formed to regulate the ecosystem? Perhaps a constitution?
5. Who manages the open source ecosystem?

Delivery

Extant literature has shown delivery to be a critical link in supply chain management (Ha et al. 2003). Moreover, information systems have proven to increase delivery performance and agility (Zhou et al. 2011). Thus, research should consider:

1. If a standardized open-source infrastructure can enable faster, more accurate, more responsive, and/or more collaborative data and product transfer across trading networks?
2. How open source affects customer relationship management?
3. Can open source improve order management–warehousing–transportation integration?

Return

The return process is associated with returning or receiving returned products and has become a critical requirement in

today's eco-friendly supply chains (Hazen et al. 2011). As the demand for sustainable operations grows, research may help us understand:

1. How can an open source ecosystem increase efficacy of return networks and/or reverse logistics?
2. Can an open source ecosystem help to facilitate the transition toward a circular economy? A sharing economy?
3. How can an open source ecosystem increase the customer involvement in improving the return process?

Additional Questions

In addition to the above questions centered around the SCOR model, additional open source ecosystem questions demanding research includes:

1. What will motivate firms to adopt an open-source supply chain information system strategy?
2. How can firms overcome barriers to adoption of an open-source construct? Barriers might include:
   a. Security concerns
   b. Fear that trading partners won't adopt.
   c. Sunk costs of existing information systems.
   d. Risks associated with moving to a new architecture (downtime, lost data, etc.)
   e. Setting and monitoring baseline criteria and standards.
   f. Constraining version proliferation.
3. Does using an open source ecosystem increase supply chain information system flexibility, agility, and robustness at the intra- and/or inter-firm levels?
   a. Do any enhancements in supply chain information system flexibility realized via use of open source architecture translate into any tangible measures of operational or supply chain performance?
   b. How can firms incorporate measures of health and performance to gauge open source systems' influence on intra- and inter-firm activities?
4. How can firms be assured that their proprietary data will not be compromised?
5. Does developing an open-source partnership with a trading partner increase levels of trust, coordination, and collaboration between parties?
6. How can performance be measured?

This paper contributes to the literature by beginning the discourse on the future of supply chain information systems in the emerging open source environment and by motivating timely and relevant area to fill this large knowledge gap. The above listing of topics is certainly not all-inclusive. Instead, these represent just a few ideas for research in this new area. To that end, each of the many topics that embody the extant supply chain information systems literature will need to be addressed in consideration of a new paradigm. We look forward to seeing new and exciting research that will help to develop knowledge within this new field of inquiry.

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Key Questions

1. Can open-source information systems be used to increase collaboration, security, and performance amongst supply chain partners?
2. Can companies transition to open-source solutions in a manner that would ultimately provide significant savings in costs, efficiencies, and effectiveness?
3. Could an open-source ecosystem facilitate a new way of looking at supply chain relationships?
4. Is it possible to enable large-scale diffusion of open-source information systems for supply chain management?