Information Systems Research
Vol. 19, No. 4, December 2008, pp. 475–493
ISSN 1047-7047 | EISSN 1526-5536 | 08 | 1904 | 0475

informs®

DOI 10.1287/isre.1080.0207

From Peer Production to Productization: A Study of Socially Enabled Business Exchanges in Open Source Service Networks

Joseph Feller, Patrick Finnegan
University College Cork, Cork, Ireland {jfeller@afis.ucc.ie, p.finnegan@ucc.ie}

Brian Fitzgerald
LERO, University of Limerick, Limerick, Ireland, brian.fitzgerald@ul.ie

Jeremy Hayes
University College Cork, Cork, Ireland, j.hayes@ucc.ie

Peer production phenomena such as open source software (OSS) have been posited as a viable alternative to traditional production models. However, community-based development often falls short of creating software "products" in the sense that consumers understand. Our research identifies an emerging business network archetype in the OSS sector, the open source service network (OSSN), which seeks to address the "productization" challenge. To do so, OSSNs must overcome the problems associated with exchanging resources between firms. We demonstrate that OSSNs overcome exchange problems by primarily relying on social, rather than legal, mechanisms; similar to the OSS communities from which they emerged. This is made possible because OSSNs use IT infrastructures that provide high visibility for primary value-creating activities. The research utilizes a multimethod theory-building approach, deriving a model from extant research, refining the model through qualitative case study analysis, and further refining the model through quantitative analysis of survey data. The paper reveals the manifestation of social mechanisms in OSSNs and how these are used for coordinating and safeguarding exchanges between firms. Specifically, we illustrate the primary importance of a shared macroculture (goals and norms) and collective sanctions for punishing firms who violate these goals/norms. Furthermore, our research highlights the interplay between digital and social networks within OSSNs, demonstrating that the use of social mechanisms is inherently dependent upon the underlying IT infrastructure.

Key words: business networks; exchange problems; open source service network; open source software; peer production; social mechanisms; multimethod research
History: Ritu agarwal, Senior Editor. This paper was received July 15, 2006, and was with the authors $8\frac{1}{2}$ months for 3 revisions.

1. Introduction

> . . .Whenever you have a commons, somebody is going to be the shark and try to hijack the commons, and have a winner take all mentality. And you can fight back in the courts, but that takes a lot of time; companies are dead before you get remedied and it's a lot of money. So we're trying to introduce [a different approach], if you get kicked out of the network, that's just as bad as getting sued, as word will get around to your potential customers . . . This is an opt-in kind of system—social mechanisms are what really underpin that. Getting into the network is only the first part. If you want to do transactions with other people in the network or on a network bid, then you need to show yourself to be competent and professional.
>
> —Paul Everitt, Founder of the Zea Partners network, speaking to the authors after the network won a contract (against 10 other bidders) for the development of a multilingual Content Management System for a multinational organization with over 3,000 partners in more than 100 countries.

Peer production has been posited as an alternative model for organizing production without reliance on markets, managerial hierarchies, property, and contracts (Benkler 2002, 2006). Peer production is characterized by the decentralized accumulation and exchange of information (Benkler 2002, 2006), and is seen as potentially superior to traditional hierarchy

and market-based models (cf. Coase 1937, Hayek 1945) as a mechanism for discovering/applying human skill and knowledge to the creation of information resources. Peer production is manifested in a number of ways; collaborative authorship (e.g. Wikipedia.org), user-generated content and metacontent (e.g. YouTube.com, Del.icio.us), and various forms of "open innovation" (cf. Chesbrough 2003). However, the most well-established example of peer production is open source software (Benkler 2002, 2006).

The collaborative creation of open source software is enabled by (1) licensing terms that allow the software to be freely used, modified and redistributed; (2) the activities of geographically distributed networks of individuals and organizations; and (3) the use of mediating digital networks—comprising e-mail and mailing lists, websites and bulletin boards, Internet relay chat, bug tracking, and version control systems, etc. (Markus et al. 2000, Robbins 2005).

Although there are many successful exemplars of open source software (e.g., Mozilla, Apache, Linux), the community-based peer production of software often falls short of creating customized software products in the sense that individual and corporate consumers understand. Overcoming this shortcoming has been aptly described by Woods and Guliani (2005) as the need to "productize" open source service (OSS) to meet the needs of both corporate enterprises and individual end users.

Research to date on the commercialization of OSS has focused on revenue generation models (e.g., Krishnamurthy 2005, Markus et al. 2000) and has been dominated by studies of single firms; whether OSS start-ups such as RedHat and JBoss (e.g., Krishnamurthy 2005, Watson et al. 2005) or very large multinationals like Apple, IBM, and Sun (e.g., West 2003). However, to effectively productize OSS for corporate users there is a need for service providers to (i) marry community-driven development capabilities with high levels of sector knowledge in vertical business domains, and (ii) build business models capable of a "whole product" approach to software and service delivery. Consequently, productizing OSS is often beyond the capabilities of many OSS firms; suggesting the need for cooperative business networks (cf. Fitzgerald 2006, Feller et al. 2008).

We have identified one type of OSS business network, similar in character to what (Clemons and Row 1992) term a "move-to-the middle," i.e., networks of organizations that cooperate in order to deliver value to the end consumer. We have labeled this network type an open source service network (OSSN), which we define as follows:

> Open Source Service Network: A network of firms that collaborate in order to service customer software needs based on open source solutions.

To clarify the OSSN concept, *network* is understood to mean a collaborative network with interdependencies between member firms, and a shared identity. This differentiates OSSNs from noninterdependent groupings, such as third-party directories and portals listing OSS firms. Furthermore, the primary purpose of the network is to commercially *service* customer software needs based on *open source* solutions. This differentiates OSSNs from noncommercial groupings such as advocacy networks, nonprofit foundations, development hosts, and research communities, as well as business networks offering solely proprietary solutions (see Table 1).

OSSNs require the flow of resources amongst nonhierarchical and legally separate entities. Thus, its successful operation is dependent on overcoming exchange problems amongst participant firms. Most business networks rely on formal/legal mechanisms to overcome exchange problems (Jones et al. 1997). Open source development communities, in contrast, rely on informal/social mechanisms to do so (Markus et al. 2000, Bergquist and Ljungberg 2001, Hars and Ou 2002). Social mechanisms are effective in OSS communities because their IT infrastructure makes the communication and collaboration activities of the community persistently visible to all participants (Sagers 2004). OSSNs have inherited much of their IT infrastructure from OSS communities; thus enabling the use of social mechanisms to overcome exchange problems. OSSNs are, thus, particularly noteworthy as commercial business networks in that they are shaped by the informal ethos and operational style of the OSS communities from which they originated, and with which they continue to interact.

The objective of our study is to explore how social mechanisms are used to overcome exchange problems, and thus facilitate the access to, and transfer

Table 1 Characterization of Open Source Service Networks

	OSSN	3rd party directories and portals (e.g., SourceForge.net marketplace)	Not-for-profit organizations (e.g. Apache software foundation)	Proprietary software service providers (e.g., Microsoft partner program)
Interdependency	High levels of interdependency between members	No interdependency between members	High levels of interdependency between members	Low levels of interdependency between members
Shared identify	Member firms possess a shared network identity	No shared identity	Shared identity exists but plays a minor role in brand building	Shared identity used in brand building
Focus of services	Network/members commercially service the software needs of customers	Commercially services the discovery needs of customers as they seek solution and/or providers, but does not directly service the customer's software needs	Services user software needs but not on commercial basis	Network/members commercially service the software needs of customers
Value offering and OSS	Value offer is dependent on open source software	Value offer is dependent on open source software	Value offer is dependent on open source software	Value offer relies exclusively on proprietary software
Mechanisms for overcoming exchange problems	Primarily informal	None needed (there is no interdependency, so there is no need to overcome exchange problems)	Mixture of informal and formal Formal mechanisms are civic (e.g., voting mechanisms) rather than contractual	Less need for mechanisms because there are low levels of interdependency Primarily use formal mechanisms that are legal/contractual in nature
Digital infrastructure	Infrastructure builds on the collaborative development environment of open source "in the wild"—Maximizing persistent visibility of action and emphasizing interaction over transaction support	Infrastructure is focused on facilitating customer discovery needs, not interaction between firms listed	Infrastructure builds on the collaborative development environment of open source "in the wild"—Maximizing persistent visibility of action and emphasizing interaction over transaction support	Infrastructure builds on traditional interorganizational systems emphasizing transaction support over interaction

of, strategic resources in OSSNs. We first begin a process of theory building with an analysis of extant research; delineating constructs and the relationships between these constructs in the form of theoretical propositions (§2). We then use a case study of one OSSN to refine our propositions, determine empirical indicators, and propose hypotheses (§3). This is followed by a survey and quantitative analysis of three additional OSSNs (§4). Finally, we conclude by discussing the implications of our work for research and practice (§5).

2. Building a Preliminary Model from Extant Research

In this section, we theorize how participants in OSSNs may use social mechanisms to overcome exchange problems. Our theorizing is posited on the OSSN phenomenon being a critical intersection between (1) cooperative business networks and (2) the communities of OSS developers from which OSSN members emerged, and with which they continue to interact. Both cooperative business networks and OSS communities can be viewed as social networks comprising individuals/organizations, whose interactions are mediated by a digital network infrastructure. We therefore use extant literature on (1) business networks and (2) OSS communities in order to conceptualize the phenomenon and to serve as a guide for data gathering—an approach recommended by Forrester (1961) and Wheeler (2002). Specifically, we utilize the building blocks of theory development proposed by Dubin (1969) and Whetten (1989) to delineate constructs as well as the relationships between these constructs in the form of theoretical propositions.

2.1. Network Effectiveness

Whereas business networks of OSS firms are an emerging phenomenon, cooperative relationships between independent firms (interorganizational networks) have been examined for decades (cf. Kaufman 1966, Van de Ven 1976, Cash and Konsynski 1985, Henderson 1990, Finnegan et al. 2003). An examination of the extant literature on business networks reveals that firms participate in such networks in order to procure and allocate resources (Galaskiewicz 1985, Clemons and Row 1992, Alter and Hage 1993), gain political advantages (Galaskiewicz 1985), share risk and acquire expertise (Alter and Hage 1993), improve stability (Oliver 1990), gain legitimacy (Galaskiewicz 1985, Oliver 1990), improve efficiency (Oliver 1990, Clemons and Row 1992), and facilitate innovation (Ticoll et al. 1998). Indeed, participants in cooperative networks believe that collaboration will result in adaptive efficiency; "the ability to change rapidly and at the same time provide customized services or products, and at low cost" (Alter and Hage 1993, p. 274). De Wever et al. (2005) capture these reasons for participation at a higher level by arguing that effective interfirm networks provide participants with sustainable access to strategic (or value-generating) resources. These concepts are also evident in research on OSS communities where developers network with each other to acquire knowledge and other strategic resources (Crowston and Scozzi 2002), including legal indemnity and contractual identity (Koch and Schneider 2002, German 2003, O'Mahony 2003). We are, therefore, able to identify two aspects of network effectiveness for use in our study:

- *Access to strategic resources*: The potential of the network to help members acquire value-adding resources, and
- *Transfer of strategic resources*: The degree to which value-adding resources are acquired by firms as a result of their membership of the network.

As well as providing access to strategic resources, interfirm cooperation introduces (i) the cost of coordinating activities amongst partners and (ii) transaction risk; opportunistic behavior by one or more partners reducing or eliminating the benefits of cooperating (Clemons and Row 1992). Research illustrates that effective networks must overcome such exchange problems by making it easy and safe for members to work together (cf. Jones et al. 1997, 1998). Research has also illustrated that OSS communities must coordinate and safeguard exchanges if they are to distribute work and code ownership (Mockus et al. 2002), as well as to acquire knowledge and other strategic resources (Crowston and Scozzi 2002). We therefore identify two constructs for use in our study:

- *Coordinating Exchanges*: The ease with which interactions between members are conducted, and
- *Safeguarding Exchanges*: The degree to which interactions between members are protected.

Building on the research discussed above, we can now present our first proposition:

Proposition 1. *Coordinating exchanges and safeguarding exchanges enable the access to, and transfer of, strategic resources.*

2.2. Overcoming Exchange Problems

Having examined the necessity for effective networks to overcome exchange problems by coordinating and safeguarding participant exchanges, we now turn our attention to how such coordination and safeguarding can be accomplished.

Cooperative business relationships are social action systems because they exhibit the fundamental principles of any organized form of collective behavior, namely, that members aim to achieve collective and self-interest goals, the division of tasks and functions among members creates interdependent processes, and the cooperative entity can act as a unit and has a separate identity from its members (Van de Ven 1976). Such relationships are typified by formal structured coordination mechanisms and agreements in order for individual organizations to meet their own goals, as well as the goals of the cooperative entity (Van de Ven and Walker 1984). This usually involves upfront contract negotiations that deal with the form of the contract, the form of the legal entity created, and the political, legal, taxation, and cartel concerns (Bronder and Pritzl 1992).

Although cooperative business networks generally rely on formal mechanisms, an alternative approach to coordinating and safeguarding exchanges exists. *Network governance* is where "interfirm coordination [is] characterized by organic or informal social systems, in contrast to bureaucratic structures within firms and formal contractual relationships

between them" (Jones et al. 1997, p. 913). There are four preconditions for network governance: demand uncertainty, customized (asset-specific) exchanges, complex tasks executed under time pressure, and frequent exchanges between partners. Under such conditions, networks develop structural embeddedness (the extent to which a "dyad's mutual contacts are connected to one another" Granovetter 1992, p. 35); creating both direct and indirect ties between parties, and increasing the visibility of the parties' actions. The presence of high levels of structural embeddedness and visibility of action enables the use of various social mechanisms to resolve exchange problems by coordinating and safeguarding exchanges within networks (Jones et al. 1997, 1998).

OSS communities are recognized as a form of virtual organization (Markus et al. 2000, Crowston and Scozzi 2002), and, thus, may use either formal or informal mechanisms in coordinating and safeguarding exchanges. However, OSS communities tend to rely on implicit and informal (i.e., social) mechanisms (Markus et al. 2000, Gallivan 2001, Bergquist and Ljungberg 2001, Hars and Ou 2002, Mockus et al. 2002, Stewart 2005, Szczepanska et al. 2005), and display the characteristics and dynamics of network governance (Sagers 2004).

We argue that the tendency towards the use of formal mechanisms in business networks, and social mechanisms in OSS communities, is due not only to differences in their dominant cultural values, but also the characteristics and usage of their digital networks. We argue that the continued dominance of formal mechanisms to overcome exchange problems in business networks is influenced by the fact that the IT infrastructures implemented in these networks facilitate transactions (e.g., orders, invoices, etc., cf. Timmers 1999), and hence do not provide the visibility of action required for social mechanisms to be effective. OSS communities, on the other hand, operate IT infrastructures that facilitate interaction rather than transaction, and thus, the main value-adding communication and collaboration activities of the community are persistently visible to participants (cf. Feller and Fitzgerald 2001, Egyedi and van Wendel de Joode 2004, Robbins 2005).

We assert that the ongoing participation of OSSN firms in OSS communities will require adherence to the OSS digital infrastructures and prevailing social mechanisms, and, thus, arrive at our second proposition:

Proposition 2. *Social mechanisms facilitate coordinating exchanges and safeguarding exchanges.*

2.3. Coordinating and Safeguarding Exchanges with Social Mechanisms

We now analyze Proposition 2 by determining what types of social mechanisms might be used for (a) coordinating exchanges and (b) safeguarding exchanges.

In business networks where high levels of structural embeddedness and visibility of action are present, coordinating exchanges can be achieved through two social mechanisms (Jones et al. 1997, 1998): *Restricted Access* (the "strategic reduction in the number of exchange partners in the network," Jones et al. 1997, p. 927) and *Macroculture* (a "system of widely shared assumptions and values . . . that guide actions and create typical behavior patterns among independent entities," Jones et al. 1997, p. 929).

Although OSS development communities are potentially global in size, there is evidence that OSS projects implement forms of restricted access both organizationally (e.g., small core development teams) and technologically (e.g., commit privileges to versioning systems, separate mailing lists for users and developers, etc.) to facilitate the coordination of exchanges (cf. Jorgensen 2001, Koch and Schneider 2002, Mockus et al. 2002, German 2003, Robbins 2005, Sagers 2004). Additionally, a common ethos and world view, a shared set of goals and a consensus surrounding "how things should be done" has been repeatedly observed as contributing to the effective coordination of activity within OSS communities (Markus et al. 2000, Bergquist and Ljungberg 2001, Gallivan 2001, Raymond 2001, Hars and Ou 2002, Sagers 2004, Dahlander and Magnusson 2005, Stewart 2005, Szczepanska et al. 2005). We therefore add two more constructs and delineate a further proposition.

- *Restricted Access*: Having network membership restricted for strategic purposes, and
- *Macroculture:* Having shared assumptions and values that guide actions and create typical behavior patterns by member firms.

Proposition 2A. *Restricted access and macroculture facilitate coordinating exchanges.*

Given the appropriate conditions, business networks can safeguard exchanges using restricted access (previously described), *collective sanctions* (ways in which groups punish members who violate shared norms, values, and goals; Jones et al. 1997, p. 931), and *reputation* ("estimations of one's character, skills, reliability, and other attributes important to exchanges;" Jones et al. 1997, p. 932).

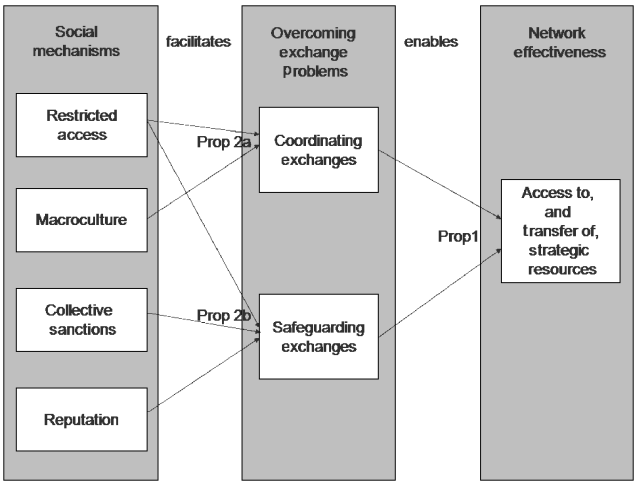
Within OSS communities, restricted access to the membership of core development team (including the technological restriction of who can commit modifications to code) is seen to reduce the risk introduced by the open nature of the OSS development process (Jorgensen 2001, Koch and Schneider 2002, Mockus et al. 2002, German 2003, Robbins 2005, Sagers 2004). In addition, reputation is a mechanism for assessing the capabilities and intentions of others (Bergquist and Ljungberg 2001, Gallivan 2001, Hars and Ou 2002, Sagers 2004, Stewart 2005, Szczepanska et al. 2005). Finally, *collective sanctions*, in the form of humiliation and rebuke (e.g. flaming) and the exclusion and ostracizing of individuals is a mechanism by which OSS communities can manage individuals that transgress or violate agreed-upon norms (Bergquist and Ljungberg 2001, Sagers 2004, Szczepanska et al. 2005). Therefore, we add two further constructs and delineate our final proposition:

- *Collective Sanctions*: Ways in which member firms that violate shared norms, values, and goals are punished, and
- *Reputation*: The assessment of firms' competence, skills, character, reliability, etc. within the network.

Proposition 2B. *Restricted access, collective sanctions, and reputation facilitate safeguarding exchanges.*

We now conclude our process of building a preliminary model from extant research by presenting the constructs and the proposed relationships between them (as Propositions 1, 2A, and 2B) in Figure 1.

Figure 1 Preliminary Model



3. Refining the Preliminary Model Using a Case Study of One OSSN

In building a theory, the steps following the specification of propositions are (i) determining empirical indicators and (ii) producing hypotheses for empirical testing (cf. Wheeler 2002). In this section we use a case study to (i) determine empirical indicators for the constructs in our model and (ii) specify hypotheses for further refinement of our model using a survey (§4).

We adopt a postpositivist epistemology and seek to "approximate reality" (Guba 1990) using methods that emphasize the verification of existing knowledge and the discovery of new knowledge (Denzin and Lincoln 2000). Our method is consistent with the case study approach of Benbasat et al. (1987) and Yin (1994) in that we study the OSSN phenomenon in its natural setting, employing multiple data collection methods to gather information from a few entities, without employing experimental control or manipulation. We thus follow in the tradition of Eisenhardt (1989) and Madill et al. (2000) by seeking to reveal preexisting, relatively stable, and objectively extant phenomena and the relationships among them.

3.1. Participants and Data Collection Procedures

Zea Partners was founded in 2003 as the Zope Europe Association (ZEA), and changed its name to Zea Partners in 2006. Headquartered in Belgium, Zea Partners operates as an international network of businesses that build software and deliver services around the application server technology called Zope; a well-known piece of open-source software widely used for developing content management systems, intranets, portals, and related applications. Zea Partners consists of 25 firms located in Argentina, Belgium, France, Germany, Hungary, India, Ireland, Italy, Netherlands, Norway, South Africa, Spain,

Table 2 Data Sources for the Qualitative Study

Interviews	Founder Zea (five interviews)
	CEO Zea (three interviews)
	Founder, Infrae
	Director BlueFountain
	Chief Architect, Plone Solutions
	Owner, Zetwork
	Owner, Gocept
	Owner, Reflab
	Owner, Zest Software
	Owner, Bubblenet
Workshops with ZEA members	The Hague, The Netherlands
	Paris, France
	Genoa, Italy
	Skovde, Sweden

Switzerland, the United Kingdom, and the United States. The management team seeks project contracts on behalf of network members and performs network management activities such as marketing and project management. They also develop the network's business strategy in conjunction with the managing partners.

Data for the case study were gathered over a 17-month period; focusing on the management team and member companies. Data-gathering techniques included intensive workshops, face-to-face interviews, and telephone interviews (see Table 2). The choice of interviewees was based on:

1. *History of network involvement*. Interviewees had to have been involved in ongoing network planning and/or project activity over a period of time.

2. *Seniority*. In order to get contextual material on business strategy and experience with network activities, it was necessary to speak with senior staff within partner firms.

The interview guide approach (cf. Patton 1980) was used to conduct the interviews because it is more comprehensive and systematic for data collection than the purely conversational interview and more flexible than the standardized, open-ended interview or the closed, fixed-response interview. Interviews were generally of one- to two-hour duration with follow-up telephone conversations and e-mails used to clarify and refine issues that emerged during transcription. Interviews were complemented by comprehensive reviews of documents and presentations/discussions at the workshops.

3.2. Data Analysis

Interview data were transcribed, generating 133 pages of field notes. Content analysis was undertaken using grounded theory coding techniques proposed by Strauss and Corbin (1990) and exemplified by the research of Orlikowski (1993) and Urquhart (1997). This approach is consistent with a postpositivist epistemology (cf. Charmaz 2000). It necessitates the researchers to be immersed in the data (Glaser and Strauss 1967) and to draw on existing theoretical knowledge without imposing a theory (Corbin and Strauss 1990, Urquhart 1997). It thus encourages the researcher to be flexible and creative (Sarker et al. 2000) while imposing systematic coding procedures (Strauss and Corbin 1990).

The first step (*open coding*) involved the data being examined "line by line" to ascertain the main ideas. These were then grouped by meaningful headings (informed by constructs developed in §2) to reveal categories and subcategories/properties. The next step (*axial coding*) was the process of determining hypotheses about the relationships between a category and its subcategories—e.g., conditions, context, action/interaction strategies, and consequences. The focus then turned to the data to assess the validity of these hypothesized relationships. *Relational* and *variational sampling* (cf. Strauss and Corbin 1990) were used to select data for this analysis. This process continued in an iterative manner and resulted in the modification of categories and relationships. Finally, *selective coding* was undertaken to identify the relationships between categories (constructs) using hypothesized conditions, context, strategies, and consequences. *Discriminate sampling* (cf. Strauss and Corbin 1990) was used to select data to examine strong and weak connections between categories.

The issues of trustworthiness (validity) and replicability (reliability) (cf. Denzin and Lincoln 2000, Gay et al. 2006) were addressed as follows. First, the data analysis approach utilized rigorous *coding* and *memoing* processes providing an audit trail of the process by which conclusions are reached. Second, the coding was undertaken by two of the researchers. Third, *venting* (cf. Goetz and LeCompte 1984) was used as results and interpretations were formally discussed with Zea Partners representatives and fellow researchers at the various workshops (see Table 2).

Table 3 Zea Partners as an Open Source Service Network

Characteristics	ZEA partners
Interdependency	Member firms collaborate to fulfill contractual obligations and rely on expertise and resources from other firms
Shared identify	The network has a legal identity outside of the member firms, and member firms reference this identity as part of their corporate brand building activity
Focus of services	Acting both independently and through the network, member firms seek to deliver services to customers on a commercial basis
Value offering and OSS	The services delivered by the network and by the individual member firms are based on the productization of the Zope open source application server and related OSS products
Mechanisms for overcoming exchange problems	Informal mechanisms including strategic restrictions to network membership, a shared set of goals and norms, and collective sanctions against violations of goals/norms in the form of damage to reputation, exclusion from projects, and expulsion from the network
Digital infrastructure	Heavy reliance on the Internet-based communication and collaboration infrastructure used in OSS communities

3.3. Case Study: Analysis and Results

This section outlines the case study of Zea Partners. Table 3 illustrates how the network is characteristic of an OSSN. From the case study data, we are able to (i) identify empirical indicators for the constructs (Tables 4 and 5), (ii) illustrate how the four social mechanisms facilitate coordinating exchanges (Table 6) and safeguarding exchanges (Table 7), and (iii) generate hypotheses for further refinement of the model (Figure 2).

3.3.1. How Coordinating and Safeguarding Exchanges Enable Access to, and Transfer of, Strategic Resources. The member firms of Zea Partners consider the network to be effective because it allows them to access and transfer strategic resources. Specifically, the study indicates five strategic resources which can be accessed/transferred: enhanced reputation, skills/expertise, customer contacts, experiences/knowledge, and the ability to compete for contracts. The owner of one member firm (BubbleNet) describes how network membership affects customers' perceptions of risk; "that may be the biggest advantage, because as I am a one-man shop people can feel that it is a big risk to work with me because if something were to happen to me they would be left without a service provider." The network founder asserts that; "[instead of] companies turning away customers, with the network they can still land the customer and have someone else fulfill it . . . They still have the customer relationship" and argues that such resource sharing allows Zea Partners to "take the 'whole product' and make it offerable by anyone in the network. It has so many benefits on profitability it's just amazing."

It is evident that membership of Zea Partners, in itself, can provide access to certain strategic resources (e.g., enhanced reputation). However, member firms reported the necessity for all network members to continuously act in a professional, competent and trustworthy manner in order to ensure access to and transfer of other strategic resources (e.g., skills, knowledge, etc). The network founder echoed this, noting that safeguarding transactions amongst participants is an important prerequisite for firms to participate in collaborative projects, and coordinating participant exchanges must accompany this safeguarding once the project becomes operational. Coordinating exchanges in Zea Partners is achieved by having transparent and shared routines, supporting technologies, and mechanisms for discussion/collaboration. Safeguarding involved having mechanisms for conflict resolution and encouraging mutual trust. The full set of indicators for coordinating and safeguarding exchanges is shown in Table 4. Given the evidence from Zea Partners, we can refine Proposition 1 by specifying two hypotheses:

Hypothesis 1 (H1). *Coordinating exchanges enables the access to and transfer of strategic resources.*

Hypothesis 2 (H2). *Safeguarding exchanges enables the access to and transfer of strategic resources.*

3.3.2. How Social Mechanisms Facilitate Coordinating and Safeguarding Exchanges. The Zea Partners network meets the preconditions for network governance as described by extant research (e.g., Jones et al. 1997). The availability of contracts is subject to what the network founder calls "*valleys and peaks*." The OSS domain is characterized by constant changes in knowledge and technology, leading to a requirement for information dissemination amongst firms.

Table 4 Empirical Indicators for Coordinating, Safeguarding, and Access/Transfer Constructs

Construct	Definition	Indicators
Access to, and transfer of, strategic resources	The (i) potential of the network to help members acquire value-adding resources, and (ii) degree to which value-adding resources are acquired by firms as a result of their membership of the network	• Network membership is designed to enhance the reputation of member firms • The network is designed to enable members to gain access to the skills/expertise of other members • The network is designed to enable member firms to share customer contacts • The network is designed to enable member firms to compete for contracts that they couldn't compete for on their own • The network is designed to enable member firms to gain access to the experiences/knowledge of other members • Firms believe that their reputation outside of the network is enhanced by their membership of the network • Member firms have benefited from the skills/expertise of other members • Firms have benefited from the sharing of customer contacts with other members • Firms, in conjunction with other members, have competed for contracts that they could not have done on their own
Coordinating exchanges	The ease with which interactions between members are conducted	• Information on the skills and abilities of network members is readily available • Firms find it easy to work with other network members because they are flexible and willing to adapt • Firms find it easy to work with other network members because they use common open source tools and conventions • Firms find it easy to voice their opinions in network decision making • The network has transparent routines for coordinating work between member firms • Firm use IT (e.g., mailing lists, VoIP) to coordinate activities • Firms use face-to-face meetings to coordinate activities • The network enables seamless hand-off of tasks between member firms
Safeguarding exchanges	The degree to which interactions between members is protected	• The cost of interacting with other network members is low • Firms believe that opportunistic behavior by one member at the expense of other members is unlikely • Interactions between firms are based on mutual trust • Interactions between firms are guided by the ideals of the open source movement • Rules and procedures exist to deal with problems that arise between members • Network members can manage conflicts to reach compromise

These factors produce the precondition that Jones et al. term *demand uncertainty*. The small size (typically <10 people), geographic/linguistic limitations, and specialized knowledge of member firms limit the size, location, and complexity of the contracts that they can bid for. The network helps overcome demand uncertainty by allowing firms to pool resources to compete for larger/global contracts. In competing on the basis of a "whole product," the network allows partners to offer a full range of value chain activities rather than concentrating exclusively on their own specialties. *Task complexity* is also evident, because producing the "whole product" for a wide range of markets and customers requires the inputs of specialists across a range of business functions. *Customized exchanges high in human asset specificity* are recognizable as member firms collaborate to produce a customized product/service that is not easily transferred. Interfirm routines are learned emergently through the collaborative process rather than by prior agreement. Due to geographical distance, network members collaborate and *frequently exchange* knowledge in a digital environment. Ongoing interactions between member firms and the mutual sharing of partners, clients, and contacts with the wider OSS community all provide evidence of *structural embeddedness*, and thus the possibility of using social mechanisms to overcome exchange problems.

Access to the Zea Partners network is restricted based on perceptions of a firm's professionalism, reliability, trustworthiness, and performance (reputation) in the OSS community, as well as previous interactions with member firms. According to the network founder,

> . . . the best barometer that we have is the way people act in the community. If they are a competent

Table 5 Empirical Indicators for Social Mechanism Constructs

Construct	Definition	Indicators
Restricted access	Having network membership restricted for strategic purposes	• Firms believe that the number of firms in the network is limited for strategic reasons • Firms believe that the size of the network makes it easy to know the competencies and activities of other members • To become members of the network, candidate firms must have skills/expertise that are beneficial to the existing members • To become members of the network, candidate firms must be known to, or have a prior relationship with, existing members • To become members of the network, candidate firms must demonstrate commitment to the ideals of open source software
Macroculture	Having shared assumptions and values that guide actions and create typical behavior patterns by member firms	• Member firms share a sense of belonging (identity) • Member firms share a common software development philosophy • Member firms share accepted ways of doing business • Member firms share a common set of goals for the network • Member firms share a sense of mutual interest • Member firms share a sense of common destiny
Collective sanctions	Ways in which member firms that violate shared norms, values and goals are punished	• The reputation of a member firm would be damaged if they behaved unacceptably • Member firms may be excluded from projects if they behave unacceptably • Member firms may be expelled from the network if they behave unacceptably
Reputation	The assessment of firms' competence, skills, character, reliability, etc. within the network	• Firms consider the competence and skills of other member firms before doing business with them • Firms consider the character and reliability of other member firms before doing business with them • Firms expect other members to fulfill their obligations because they are members of the network • Firms consider it important to be regarded by other members as being professionally competent • Firms consider it important to be regarded by other members as being reliable and trustworthy • Firms consider it important to fulfill their obligations to other members to maintain their reputation within the network

> developer then you can see them send mails to the mailing lists, do check-ins and file bug reports, write papers for conferences and all those sorts of things. There are a multitude of avenues available . . . to show their competence. If someone is invisible from all those avenues, that itself says something about them . . . [In addition], if you have done business with someone who is already trusted in the network then that trust applies to you.

Consequently, restricted access is not just about keeping numbers low, it is a strategic restriction; firms have to fit in with the shared values (*macroculture*) and needs of the network, as well as exhibit a commitment to Zea Partners' success.

The network's macroculture is typical of values associated with OSS communities; the involvement of users (customers) as equal partners, the visibility of actions, etc. However, this macroculture is evident not just as a shared set of values (including beliefs, language, etc) as proposed by Jones et al. (1997) but also includes the mechanisms by which these ideas are expressed and shared. For example, the Network Founder describes the centrality of the digital network to coordinating exchanges as "it's a little bit like asking a fish how important is water . . . These [technologies] are so intrinsic that you don't really think in terms of living without them." This is a richer view of the cultural process and is in line with the thinking of Hannerz (1992) on cultural complexity in information societies. Once in the network, failure to continue to adhere to the prevailing macroculture could result in damaged reputation and/or exclusion from projects or, indeed, the network (*collective sanctions*). The network founder further explains: "we had one [firm] that we had to decline their re-participation and we had two [firms] that we had to confront a divergent opinion about the outcome and, on mutual accord, they didn't continue participating." Details of how the four social mechanisms are manifested in Zea Partners are shown in Table 5.

In relation to overcoming exchange problems in Zea Partners, the Network Founder explained; "social mechanisms are the only thing. This is an opt-in kind of system." The role of social mechanisms was confirmed by the member firms who described how such mechanisms (discussed further below) were used to facilitate coordinating and safeguarding exchanges. We find support for Proposition 2, and conclude that social mechanisms facilitate coordinating and safeguarding exchanges. We now examine how social mechanisms do so.

3.3.3. How Social Mechanisms Facilitate Coordinating Exchanges. The manner in which social mechanisms facilitate coordinating exchanges is shown in Table 6. The role of restricted access in coordinating exchanges was considered to be particularly important by the founders and managing partners of the network. However, there was little evidence that this view was shared by those that were not involved in the initial design of the network. The network founder explained that the network

> ... focuses on people who've already decided they're interested in OSS, not people who don't understand value and values. The prime consideration is to make sure that the fabric that holds this experiment together doesn't get torn.

Table 6 How Social Mechanisms Facilitate Coordinating Exchanges

Restricted access	• Facilitating the establishment of routines for working together • Reducing coordination cost through increased visibility • Adopting deliberate membership requirements facilitating a component-based approach to work allocation • Giving members a voice in decision making • Reducing variances that parties bring to the exchanges (facilitates mutual adjustment) • Establishing routines for working together
Macroculture	• Fostering a culture of network agility • Ensuring new members fit into network's culture • Creating a sense of mutual interest (good Karma) • Preventing fear of lock-in • Reducing information/knowledge asymmetries
Collective sanctions	• Encourages firms to be transparent in their dealings with other members • Encourages firms to act in a manner that is regarded as competent and professional • Encourages firms to behave in line with network expectations

He further explained

> ... about 50% of the [coordination] problem is solved by working the same way we worked [in OSS communities]. The companies have a set of tools, a way of working together, a common culture and ways of communication that we use on Zea projects.

It is also evident that coordinating exchanges is facilitated by the desire of members to demonstrate that they adhere to the values of the network by acting in a manner that is considered to be competent and professional. The consequences of not acting in this manner include damage to their reputation as well as exclusion from projects and/or the network (i.e., collective sanctions). They thus strive to be flexible and transparent in their dealings with other members, and to abide by the norms that govern participation in open source development communities. We therefore conclude that collective sanctions, as well as restricted access and macroculture, facilitate coordinating exchanges, and we refine Proposition 2A by proposing three hypotheses:

Hypothesis 3 (H3). *Restricted access facilitates coordinating exchanges*.

Hypothesis 4 (H4). *Macroculture facilitates coordinating exchanges*.

Hypothesis 5 (H5). *Collective sanctions facilitate coordinating exchanges*.

3.3.4. How Social Mechanisms Facilitate Safeguarding Exchanges. The manner in which social mechanisms facilitate the safeguarding of exchanges is shown in Table 7. The table illustrates that reputation and collective sanctions facilitate safeguarding exchanges as predicted. Indeed, collective sanctions are seen to facilitate safeguarding exchanges in the same manner as they facilitate coordinating exchanges. The network founder describes instances where "people said yes to a Zea project but were actually overbooked ... this affects their reputation within the network." He believes that

> ... whenever you have a commons, somebody is going to be the shark and try to hijack the commons, and have a winner take all mentality. And you can fight back in the courts, but that takes a lot of time; companies are dead before you get remedied and it's a lot of money ... if you get kicked out of the network, that's just as bad as getting sued, as word will get around to your potential customers.

Table 7 How Social Mechanisms Facilitate Safeguarding Exchanges

Macroculture	• Balancing commercial interests with network objectives • Taking an ethical approach to commercial issues • Creating an environment of trust
Collective sanctions	• Encourages firms to be transparent in their dealings with other members • Encourages firms to act in a manner that is regarded as competent and professional • Encourages firms to behave in line with network expectations
Reputation	• Acting as a prerequisite for participation • Rewarding good behavior • Ensuring that there are economic consequences of reputation

This is confirmed by the owner of Bubblenet: "Getting a reputation in the community is very important; other companies will send me projects that they cannot handle."

As is evident from Table 7, the social mechanisms that facilitate safeguarding exchanges include macroculture rather than restricted access as previously predicted. The network founder believes that restricted access reduces the danger of opportunistic behavior because "each applicant we evaluate has to accept a mutual respect culture. We have had cases where we felt they might be 'disruptive' and so we said no." However, the study demonstrates that Zea members believe that the culture within the network (rather than just restricting access) is much more important in safeguarding exchanges. The owner of Bubblenet says that "most of us are in this for the lifestyle rather than purely to make money; that's difficult to formalize." The director of Blue Fountain reveals that "we do three things: transparency, integrity, and honesty. If there's a problem we'll always put our hand up." The chief architect of Plone Solutions reported that "We wouldn't leave a client hanging just because it didn't suit us to go back to that deployment. It's a value thing." We thus refine Proposition 2B by proposing three hypotheses:

Hypothesis 6 (H6). *Collective sanctions facilitate safeguarding exchanges*.

Hypothesis 7 (H7). *Reputation facilitates safeguarding exchanges*.

Hypothesis 8 (H8). *Macroculture facilitates safeguarding exchanges*.

In conclusion, the case study allowed us to (i) test and refine our theoretical propositions, (ii) delineate empirical measures for our constructs (Tables 4 and 5), and (iii) explain how social mechanisms facilitate coordinating and safeguarding exchanges (Tables 6 and 7). We can now refine our model through a series of hypotheses (Figure 2).

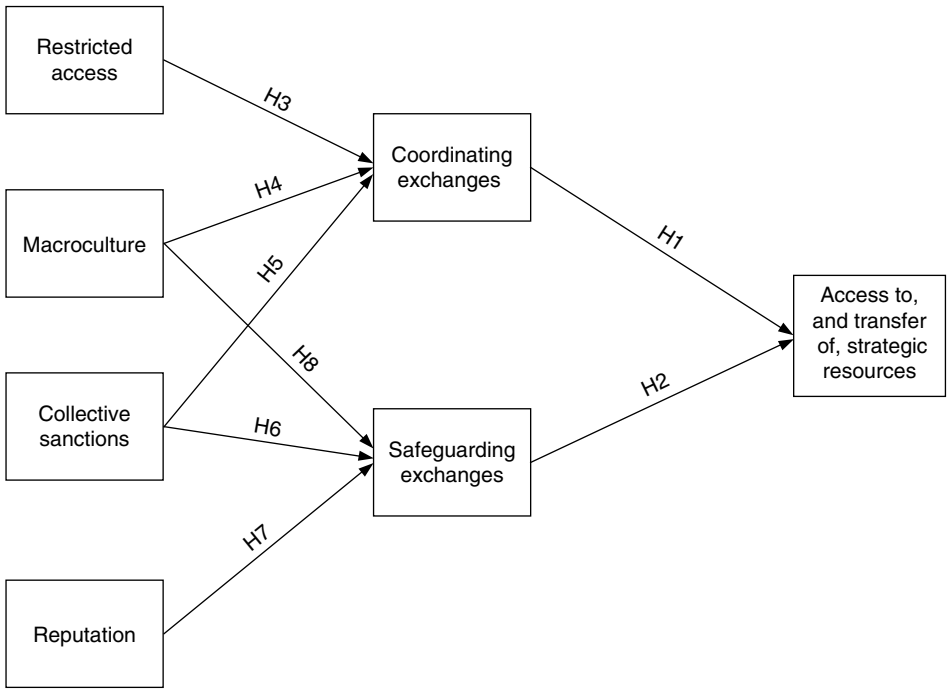
4. Further Investigation of the Model Using a Survey of OSSNs

In the next stage of the study, we sought to triangulate by using a quantitative analysis of survey data to investigate the model (Figure 2) that had emerged from the case study. A survey questionnaire was constructed based on the empirical indicators that emerged from the qualitative study (see Tables 4 and 5). This questionnaire was then pretested using three practitioners with experience in OSS networks. Following this, we considered the issue of population and sampling.

We searched public domain material to determine the existence of other networks that met the definition of an OSSN, and we secured the cooperation of three additional OSSNs. These were: CIRS (Consortium Italicum Ratione Soluta), comprising partner companies based in Italy and focusing on providing "best of breed" OSS mostly for public administration; ObjectWeb, a multinational network focused on providing open source middleware solutions; and the Open Source Consortium, a UK network focused on OSS provision for the public sector. The principal contact in each of these OSSNs promoted our online survey to the members. We eventually received a total of 71 valid and usable responses.

Because the survey was online, and our contact was with a representative of the network rather than the individual member firms, we could not accurately estimate the total population size. The issue of nonresponse bias was, thus, quite important. We investigated this through the use of late respondents as surrogates for nonrespondents (Wallace and Mellor 1988). We compared the responses of a sample of 20 early respondents with 20 late respondents. Although early respondents tended to have slightly

Figure 2 Refined Model and Hypotheses



Note. H1–H8 refer to hypotheses.

more experience of the OSS phenomenon than the sampled cohort of late respondents, there were no statistically significant differences ($p < 0.05$) between responses of early and late respondents in other areas.

4.1. Survey Analysis

As shown in Table 8, the survey respondents were primarily in senior management positions in small firms (fewer than 20 employees) with considerable personal and organizational experience in the open source field.

We investigated the reliability of factors as outlined in Table 9, which shows descriptive statistics, correlations and Cronbach's α values. The Cronbach's α values (in parentheses on the diagonal) ranged from 0.53 to 0.87. The two factors with the lower α values are a reflection of the low number of items making up these factors because Cronbach's α is affected by scale length. Also, our constructs in these cases were formative and, as such, α values may be more moderate (cf. Petter et al. 2007). There were no indications of extreme cases of multicollinearity because none of the off-diagonal correlations were above 0.80 (cf. Ghiselli et al. 1981).

Table 8 Demographic Profile of Respondents

Role	Employees		Respondent experience of OSS (yrs)		Org experience of OSS (yrs)	
Technical 29%	1–5	44%	<1	3%	<1	4%
Managerial 20%	6–20	42%	1–5	28%	1–5	37%
Owner/director 51%	21–100	7%	>5	69%	>5	59%
	101–1,000	3%				
	>1,000	4%				

Petter et al. (2007) have identified some guidelines for validating constructs that are formative in nature. They stress the importance of an a priori theoretical/conceptual approach to validity. In this study, the initial theoretical grounding of our factors in previous research helped to ensure content validity for our constructs. Subsequently, construct validity was addressed through basing our measures on conceptual analysis arising from the case study context. We used axial coding to determine the indicators for each construct. The validity of these indicators was then assessed using relational and variational sampling as recommended by Strauss and Corbin (1990). Finally, results were confirmed in workshops with case study

Table 9 Means, Standard Deviations, Scale Reliabilities, and Intercorrelations

Variable[a]	*M*	SD	1	2	3	4	5	6	7
1. Restricted access	3.19	0.66	(0.55)						
2. Reputation	4.31	0.62	0.19	(0.78)					
3. Macroculture	3.43	0.55	0.24*	0.12	(0.70)				
4. Collective sanctions	4.13	0.61	0.04	0.20	0.39**	(0.79)			
5. Coordinating exchanges	3.50	0.43	0.02	0.03	0.47**	0.46**	(0.64)		
6. Safeguarding exchanges	3.65	0.38	−0.07	0.04	0.30**	0.46**	0.37**	(0.53)	
7. Access/transfer strategic resources	3.71	0.49	0.12	0.19	0.45**	0.38**	0.41**	0.50**	(0.80)

[a]Items measured on a five-point scale (1 = strongly disagree, 5 = strongly agree); Reliability coefficients in parentheses on diagonal.
$N = 71$, $^{*}p < 0.05$, $^{**}p < 0.01$.

participants, effectively constituting an expert panel review process recommended by Rossiter (2002).

4.2. Hypothesis and Model Testing

The model in Figure 2 was specified and estimated using LISREL. A covariance matrix was computed using PRELIS, and parameters were estimated using maximum likelihood. Missing data were imputed using the EM (expectation maximization) algorithm (cf. Dempster et al. 1977). The benefits of using the EM algorithm to treat missing data, rather than traditional methods such as listwise deletion, have been amply demonstrated (cf. Bunting et al. 2002). The results of the analysis are presented in Table 10.

In terms of model validity, the fit indices are encouraging. The nonsignificant p value for $\aleph^2$ and its ratio to degrees of freedom being just over 1 supports this (if this ratio is less than 2, the model can be considered well fitted, Schumacker 2004). In addition, the root mean square error of approximation (RMSEA) with 90% confidence intervals are reported, where a value less than 0.08 indicates a good fit with reasonable errors of approximation in the population (Jöreskog and Sörbom 1993, Steiger 1990). In our model, the RMSEA value of 0.07 indicates a good fit. The standardized root-mean-square residual (SRMR) has been shown to be sensitive to model misspecification and its use recommended by Hu and Bentler (1999). Values less than 0.08 are considered to be indicative of acceptable model fit (Hu and Bentler 1999). In our model, the SRMR value is 0.05. Finally, in terms of fit, the GFI index of 0.96 for our model is greater than the recommended threshold of 0.9, which further indicates a close fit. Obviously, our small sample size is an issue, but Fan et al. (1999) have demonstrated that with small samples the rejection rate for $\aleph^2$ is not inflated, and the RMSEA is relatively independent of sample size.

Table 10 Model Fit Indices and Path Coefficients

Fit indices	
$\aleph^2$	9.33
Df	7
p value	0.23
RMSEA	0.07
90%CI	(0.00–0.18)
SRMR	0.05
GFI	0.96
Paths	Path coefficient
H1: coordinating exchanges → access/transfer of strategic resources	0.28*
H2: Safeguarding exchanges → access/transfer of strategic resources	0.43*
H3: Restricted access → coordinating exchanges	−0.08
H4: Macroculture → coordinating exchanges	0.36*
H5: collective sanctions → coordinating exchanges	0.33*
H6: collective sanctions → safeguarding exchanges	0.41*
H7: Reputation → safeguarding exchanges.	−0.02
H8: Macroculture → safeguarding exchanges	0.17

$^{*}p < 0.05$.

In terms of hypotheses, the paths representing H1, H2, H4, H5, and H6 (in Figure 2) were significant ($p < 0.05$), and the standardized β values are provided in Table 10. The three paths representing hypotheses (H3, H7, and H8) were not significant. The implications of the analysis and a synthesis of the qualitative and quantitative findings are discussed in the next section.

4.3. Synthesis of Qualitative and Quantitative Findings

We have identified that to effectively deliver a "whole product" to customers, OSSNs must enable

member firms to access and transfer a number of key strategic resources (e.g., skills/competencies, experiences/knowledge, and customer contacts). In traditional business networks, formal/legal arrangements are used for coordinating exchanges and safeguarding exchanges in order to enable such access/transfer of strategic resources (H1, H2). However, the establishment of the agreements (contracts) and the legal recourse available to participants (litigation) when agreements are violated incurs substantial overheads in their implementation and lack flexibility. In contrast, in OSSNs, macroculture (shared assumptions and values that guide actions and create typical behavior patterns) is central to effectiveness because (i) it allows firms to work easily without the imposition of formal agreements; and (ii) because the specific macroculture observed in OSSNs reflects that of OSS communities, there is an emphasis on collaboration, sharing, and the preservation of the "commons". Similarly, when member firms violate shared norms, values, and goals, the ways in which they are punished (collective sanctions) are a very powerful tool for coordinating exchanges and safeguarding exchanges (H5, H6). The size of typical member firms and the commercial importance of network membership, both in terms of enhanced reputation and bidding leverage, serve to increase the potency of the specific collective sanctions observed. Potential damage to reputation, the threat of exclusion from projects, and the possibility of expulsion from the network all serve to ensure that firms behave as proscribed by the macroculture (thus facilitating coordinating exchanges (H4)), and that violators can be dealt with more effectively than with recourse to legal action (thus facilitating safeguarding exchanges).

Although both our qualitative and quantitative analyses provided evidence for the roles played by macroculture and collective sanctions, there were differences between the two parts of the study vis-à-vis the mechanisms of restricted access and reputation. The qualitative analysis revealed the importance of restricting network membership for strategic purposes for coordinating exchanges. Coordinating exchanges is facilitated not just by limiting the size of the network (which makes interactions more visible), but by making it easier for members to work together by reducing the variances in the types of participants involved. The quantitative analysis, however, revealed no significant relationship between restricted access and coordinating exchanges (H3). Similarly, the qualitative analysis revealed that the assessment of firms' competence, skills, character, reliability, etc. (reputation), facilitates safeguarding exchanges (H7) by ensuring that only those that are least likely to disrupt the operations of the network become involved. The quantitative analysis revealed no significant relationship between reputation and safeguarding exchanges.

We explain the lack of support for these particular hypotheses as follows: The differences between the qualitative case study (which was informed primarily by participants at the network design level) and the quantitative analysis (which was based on data gathered from a larger and more diverse population) offers us the opportunity to potentially distinguish between the social mechanisms used primarily at a network design level and those that are important for both design and ongoing operations. Coordinating and safeguarding exchanges on a day-to-day basis is facilitated by macroculture and collective sanctions as previously described. However, at the network design level, restricted access and reputation are also utilized to ensure that only those that are least likely to disrupt the operations of the network (either through incompetence or misbehavior) become involved; thus facilitating coordinating exchanges and safeguarding exchanges. Once in the network, these mechanisms become less important; members must adhere to the prevailing macroculture or face collective sanctions. Nevertheless, despite the lack of significance for some hypotheses, the overall model (Figure 2) was shown to be a good fit to our sample data, and no additional or alternative hypothetical paths were suggested by the quantitative analysis.

Overall, it is evident that the interplay between digital and social networks is particularly strong in OSSNs because the four social mechanisms are inherently dependent upon the underlying IT infrastructure. Much of the collaborative development activity within an OSSN takes place in the digital environments of open source community sites. Even when the production of software is not intended for release into the "commons" (e.g., where customizations are being created for a specific client), the OSSNs continue to use the OSS collaborative development infrastructure.

Additionally, ongoing communication between firms is dependent on e-mail/mailing lists, VoIP, Internet chat, etc. These collaborative and communicative IT environments create a visible and persistent record of participants' activities. This transparency means that a members' (or potential members') adherence to (and violation of) shared values and goals are immediately evident to all.

5. Conclusion

This study has articulated the "productization" challenge associated with delivering peer-produced goods to consumers, and has identified the open source service network (OSSN), an emerging business network archetype designed to meet this challenge for open source software. OSSNs are of scientific and practical interest for a number of reasons.

- First, OSSNs demonstrate that a business network model can be particularly effective in delivering the "whole product" needed to commercially exploit peer-produced goods. OSSNs, thus, directly address key challenges in the commercialization of open source software, and are of interest to both research and practice.
- Second, the ways in which OSSNs overcome exchange problems contrast with other business networks in that social mechanisms play a primary role in coordinating and safeguarding exchanges amongst participants.
- Third, the IT infrastructure utilized by OSSNs builds upon the collaborative development and communication environments found in OSS communities, and is focused on enabling rich, transparent interactions between firms. This is in contrast to the transaction-oriented focus of other interorganizational systems.

5.1. Implications for Practice

We have demonstrated that firms seeking to "productize" the software goods created by peer production communities in a sustainable and profitable fashion must; (1) maintain a productive relationship with these communities; (2) easily and safely exchange resources with each other in order to deliver the "whole product;" and (3) fulfill their contractual obligations to customers, thus leaving little room for error and recovery. We have shown that OSSNs, by leveraging both the IT infrastructure and social mechanisms characteristic of open source communities, are able to effectively address these concerns. For firms seeking to meet these or similar challenges, we see three specific, actionable implications of the current study.

First, the membership of such business networks must be carefully managed to facilitate the use of social mechanisms as a low-overhead, flexible means to overcome exchange problems. Specifically, we have shown that one of the roles of the network designer is to assess potential members and restrict access to the network, thus allowing participants to rely on macroculture and collective sanctions for the day-to-day coordinating and safeguarding exchanges.

Second, the use of social mechanisms to overcome exchange problems is only possible if the actions of members are persistently visible to the rest of the network. Our study implies that the mode of operation evident in OSSNs is inherently dependent on the interactioncentric IT infrastructure used, and that it would not be possible to implement such a system using the transactioncentric infrastructure characteristic of many interorganizational networks.

Third, our study indicates that actively participating in noncommercial peer production communities (e.g., OSS projects) is an effective way for firms to acquire the competencies needed to participate in OSSNs (or similar networks). This implies that the barriers to entry for OSSN formation, operation, and participation are lower for firms emerging from peer production communities than for firms coming from outside these communities.

5.2. Implications for Research

The four-phase process described in the paper (defining and bounding an emergent and observable phenomenon, articulating propositions based on extant research, refining our preliminary model through qualitative case study analysis, and further refining the model through quantitative analysis of survey data) proved to be a highly effective process. Specifically, the methodological pluralism of the study

was particularly useful in addressing a social phenomenon, which requires both broad and deep analysis. We therefore call for multimethod research on social mechanisms in overcoming exchange problems in both OSS communities and in business networks other than OSSNs. In addition to calling for replication studies, our work has implications for how researchers should conceptualize their studies of business networks and interorganizational systems.

Existing research (as discussed in §2) has primarily considered the design of business networks from the perspective of how processes, structures, and technologies implement the formal/legal agreements that characterize business activities. Almost no attention has been given to the use of informal mechanisms as an explicit design consideration in business networks. It is therefore not surprising that, in addressing the issue of commercializing peer-produced goods in conjunction with peer production communities, the dominant perspective has been on integrating communities into prevailing business practices. However, our study reveals the importance of community-based practices to business success, and thus implies the need for researchers to fully address the potential impact of *both* business and community practices/structures in commercializing peer-produced goods.

Finally, we call for research that reconsiders the role of interorganizational systems in business networks. Extant research primarily frames interorganizational systems in the context of transactions that implement formal/legal agreements, and does not recognize the role played by such systems in supporting the interactions characteristic of social action networks. We see the need to focus on designing digital interorganizational infrastructures to facilitate the full range of primary interactions that characterize interorganizational activities, rather than just implementing the secondary arrangements that govern them.

Acknowledgments

This work has been financially supported by the Irish Research Council for the Humanities and Social Sciences (IRCHSS), the Science Foundation Ireland (SFI) award to Lero—the Irish Software Engineering Research Centre, and the EU FP6 Project OPAALS and EU FP 7 Project NEXOF.

References

Alter, C., J. Hage. 1993. *Organizations Working Together*. Sage Publications, London.

Benbasat, I., D. K. Goldstein, M. Mead. 1987. The case study research strategy in studies of information systems. *MIS Quart.* **11**(3) 369–386.

Benkler, Y. 2002. Coase's Penguin, or Linux and the nature of the firm. *Yale Law J.* **112**(3) 369–446.

Benkler, Y. 2006. *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. Yale University Press, New Haven, CT.

Bergquist, M., J. Ljungberg. 2001. The power of gifts: Organising social relationships in open source communities. *Inform. Systems J.* **11**(4) 305–320.

Bronder, C., R. Pritzl. 1992. Developing strategic alliances: A conceptual framework for successful co-operation. *Eur. Management J.* **10**(4) 412–421.

Bunting, B., G. Adamson, P. K. Mulhall. 2002. A Monte Carlo examination of an MTMM model with planned incomplete data structures. *Structural Equation Model.* **9** 369–389.

Cash, J. I., B. R. Konsynski. 1985. IS redraws competitive boundaries. *Harvard Bus. Rev.* **63**(2) 131–142.

Charmaz, K. 2000. Grounded theory: Objectivist and constructivist methods. N. K. Denzin, Y. S. Lincoln, eds. *Handbook of Qualitative Research*. Sage Publications, Thousand Oaks, CA.

Chesbrough, H. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business School Press, Boston.

Clemons, E., M. Row. 1992. Information technology and industrial co-operation: The changing economics of coordination and ownership. *J. Management Inform. Systems* **9**(2) 9–28.

Coase, R. 1937. The nature of the firm. *Economica* **4**(16) 386–405.

Corbin, J., A. Strauss. 1990. Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Soc.* **13**(1) 3–21.

Crowston, K., B. Scozzi. 2002. Open source software projects as virtual organizations: Competency rallying for software development. *IEE Proc. - Software* **149**(1) 3–17.

Dahlander, L., M. G. Magnusson. 2005. Relationships between open source software companies and communities: Observations from Nordic firms. *Res. Policy* **34**(4) 481–493.

De Wever, S., R. Martens, K. Vandenbempt. 2005. The impact of trust on strategic resource acquisition through interorganizational networks: Towards a conceptual model. *Human Relations*. **58**(12) 1523–1543.

Dempster, A., N. Laird, D. Rubin. 1977. Maximum likelihood from incomplete data via the EM algorithm. *J. Roy. Statist. Soc. Ser. B (Methodological)* **39**(1) 1–38.

Denzin, N. K., Y. S. Lincoln. 2000. The discipline and practice of qualitative research. N. K. Denzin, Y. S. Lincoln, eds. *Handbook of Qualitative Research*. Sage Publications, Thousand Oaks, CA.

Dubin, R. 1969. *Theory Building*. Free Press, New York.

Egyedi, T. M., R. van Wendel de Joode. 2004. Standardization and other coordination mechanisms in open source software. *Internat. J. IT Standards & Standardization Res.* **2**(2) 1–17.

Eisendardt, K. M. 1989. Building theories from case study research. *Acad. Management Rev.* **14**(4) 532–550.

Fan, X., B. Thompson, L. Wang. 1999. The effects of sample size, estimation methods, and model specification on SEM fit indices. *Structural Equation Model.* **6** 56–83.

Feller, J., B. Fitzgerald. 2001. *Understanding Open Source Software Development*. Addison-Wesley, London.

Feller, J., P. Finnegan, J. Hayes. 2008. Delivering the "whole product:" Business model impacts and agility challenges in a network of open source firms. *J. Database Management* **12**(2) 95–108.

Finnegan, P., R. D. Galliers, P. Powell. 2003. Applying triple loop learning to planning electronic trading systems. *Inform. Tech. People* **16**(4) 461–483.

Fitzgerald, B. 2006. The transformation of open source software. *MIS Quart.* **30**(3) 587–598.

Forrester, J. W. 1961. *Industrial Dynamics*. The MIT Press, Cambridge, MA.

Galaskiewicz, J. 1985. Interorganisational relations. *Ann. Rev. Soc.* **11** 281–304.

Gallivan, M. J. 2001. Striking a balance between trust and control in a virtual organisation: A content analysis of open source software case studies. *Inform. Systems J.* **11**(4) 277–304.

Gay, L. R., G. E. Mills, P. Airasian. 2006. *Educational Research: Competencies for Analysis and Applications*. Pearson Merrill, Prentice Hall, Upper Saddle River, NJ.

German, D. 2003. The GNOME project: A case study of open source, global software development. *Software Process Improvement Practice* **8**(4) 201–215.

Ghiselli, E., J. Campbell, S. Zedeck. 1981. *Measurement Theory for the Behavioral Sciences*. W. H. Freeman, San Francisco.

Glaser, B., A. Strauss. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine Publishing Company, Chicago.

Goetz, J. P., M. D. LeCompte. 1984. *Ethnography and Qualitative Design in Educational Research*. Harcourt Brace Jovanovich, New York.

Granovetter, M. 1992. Problems of explanation in economic sociology. N. Nohria, R. G. Eccles, eds. *Networks and Organizations: Structure, Form, and Action*. Harvard Business School Press, Cambridge, MA, 25–56.

Guba, E. G. 1990. The alternative paradigm dialog. E. G. Guba, ed. *The Paradigm Dialog*. Sage, Newbury Park, CA.

Hannerz, U. 1992. *Cultural Complexity: Studies in the Social Organization of Meaning*. Columbia University Press, New York.

Hars, A., S. Ou. 2002. Working for free? Motivations for participating in open-source projects. *Internat. J. Electron. Commerce* **6**(3) 25–39.

Hayek, F. A. 1945. The use of knowledge in society. *Amer. Econom. Rev.* **35**(4) 519–530.

Henderson, J. C. 1990. Plugging into strategic partnerships: The critical IS connection. *Sloan Management Rev.* **30**(3) 7–18.

Hu, L., P. M. Bentler. 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Eq. Model.* **6** 1–55.

Jones, C., W. Hesterly, S. Borgatti. 1997. A general theory of network governance: Exchange conditions and social mechanisms. *Acad. Management Rev.* **22**(4) 911–944.

Jones, C., W. Hesterly, K. Fladmoe-Lindquist, S. Borgatti. 1998. Professional service constellations: How strategies and capabilities influence collaborative stability and change. *Organ. Sci.* **9**(3) 396–410.

Jöreskog, K. G., D. Sörbom. 1993. *Structural Equation Modeling with the SIMPLIS Command Language*. Scientific Software, Inc., Chicago.

Jorgensen, N. 2001. Putting it all in the trunk: Incremental software development in the FreeBSD open source project. *Inform. Systems J.* **11**(4) 321–336.

Kaufman, F. 1966. Data systems that cross company boundaries. *Harvard Bus. Rev.* **44**(1) 141–155.

Koch, S., G. Schneider. 2002. Effort, cooperation and coordination in an open source software project: GNOME. *Inform. Systems J.* **12**(1) 27–42.

Krishnamurthy, S. 2005. An analysis of open source business models. J. Feller, B. Fitzgerald, S. A. Hissam, K. R. Lakhani, eds. *Perspectives on Free and Open Source Software*. The MIT Press, Cambridge, MA, 279–296.

Madill, A., A. Jordan, C. Shirley. 2000. Objectivity and reliability in qualitative analysis: Realist, contextualist and radical constructionist epistemologies. *British J. Psych.* **91**(1) 1–20.

Markus, M. L., B. Manville, C. E. Agres. 2000. What makes a virtual organization work? *Sloan Management Rev.* **42**(1) 13–26.

Mockus, A., R. T. Fielding, J. D. Herbsleb. 2002. Two case studies of open source software development: Apache and Mozilla. *ACM Trans. Software Engrg. Methodology* **11**(3) 309–364.

Oliver, C. 1990. Determinants of interorganizational relationships: Integration and future directions. *Acad. Management Rev.* **15**(2) 241–265.

O'Mahony, S. 2003. Guarding the commons: How community managed software projects protect their work. *Res. Policy* **32**(7) 1179–1198.

Orlikowski, W. J. 1993. CASE tools as organizational change: Investigating incremental and radical changes in systems development. *MIS Quart.* **17**(3) 309–340.

Patton, M. Q. 1980. *Qualitative Evaluation and Research Methods*. Sage Publications, Newbury Park, CA.

Petter, S., D. Straub, A. Rai. 2007. Specifying formative constructs in IS research. *MIS Quart.* **31**(4) 623–656.

Raymond, E. S. 2001. *The Cathedral & the Bazaar*, 2nd ed. O'Reilly, Sebastapol, CA.

Robbins, J. 2005. Adopting open source software engineering (OSSE) practice by adopting OSSE tools. J. Feller, B. Fitzgerald, S. A. Hissam, K. R. Lackhani, eds. *Perspectives on Free and Open Source Software*. MIT Press, Cambridge, MA, 245–264.

Rossiter, J. 2002. The C-OAR-SE procedure for scale development in marketing. *Internat. J. Res. Marketing* **19** 305–335.

Sagers, G. 2004. The influence of network governance factors on success in open source software development projects. R. Agarwal, L. Kirsch, eds. *Proc. Twenty-Fifth Internat. Conf. Inform. Systems*, Washington, D.C., 427–438.

Sarker, S., F. Lau, S. Sahay. 2000. Building an inductive theory of collaboration in virtual teams: An adapted grounded theory approach. *Proc. 33rd Hawaii Internat. Conf. System Sci.*, Maui, HI.

Schumacker, R. 2004. Rasch measurement: The dichotomous model. R. Smith, E. Smith, eds. *Introduction to Rasch Measurement*, Chapter 10. JAM Press, Maple Grove, MN.

Steiger, J. H. 1990. Structural model evaluation and modification: An interval estimation approach. *Multivariate Behavioural Res.* **25** 173–180.

Stewart, D. 2005. Social status in an open source community. *Amer. Sociol. Rev.* **70**(5) 823–842.

Strauss, A., J. Corbin. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Sage Publications, Newbury Park, CA.

Szczepanska, A. M., M. Bergquist, J. Ljunberg. 2005. High noon at os corral: Duals and shootouts in open source. J. Feller, B. Fitzgerald, S. A. Hissam, K. R. Lakhani, eds. *Perspectives on Free and Open Source Software*. MIT Press, Cambridge, MA, 431–446.

Ticoll, D., A. Lowy, R. Kalakota. 1998. Joined at the bit: The emergence of the e-business community. D. Tapscott, ed. *Blueprint to the Digital Economy: Creating Wealth in the Era of e-Business*. McGraw-Hill, New York.

Timmers, P. 1999. *Electronic Commerce: Strategies and Models for Business-to-Business Trading*. John Wiley and Sons, Ltd., Chichester, UK.

Urquhart, C. 1997. Exploring analyst-client communication: Using grounded theory techniques to investigate interaction in informal requirements gathering. A. S. Lee, J. Liebenau, J. I. Degross, eds. *Information Systems and Qualitative Research*. Chapman and Hall, London.

Van de Ven, A. H. 1976. On the nature, formation and maintenance of relations among organizations. *Acad. Management Rev.* **1**(4) 24–36.

Van de Ven, A. H., G. Walker. 1984. The dynamics of interorganizational coordination. *Admin. Sci. Quart.* **29**(4) 598–621.

Wallace, R., C. Mellor. 1988. Non-response bias in mail accounting surveys: A pedagogical note. *British Accounting Rev.* **20**(2) 131–139.

Watson, R. T., D. Wynn, M. Boudreau. 2005. JBoss: The evolution of professional open source software. *MIS Quart. Executive* **4**(3) 329–341.

West, J. 2003. How open is open enough? Melding proprietary and open source platform strategies. *Res. Policy* **32** 1259–1285.

Wheeler, B. C. 2002. NEBIC: A dynamic capabilities theory for assessing net-enablement. *Inform. Systems Res.* **13**(2) 125–146.

Whetten, D. A. 1989. What constitutes a theoretical contribution? *Acad. Management Rev.* **14**(4) 490–495.

Woods, D., G. Guliani. 2005. *Open Source for the Enterprise*. O'Reilly Media, Sebastopol, CA.

Yin, R. K. 1994. *Case Study Research, Design and Methods*. Sage Publications, Newbury Park, CA.