The Role of Social Capital in Open Source Software Communities

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ABSTRACT

Drawing on the theory of social capital, we propose a cross-level model proposing that community-level social capital plays an important role in Open Source Software projects. Social capital, as resources lying within interpersonal relationships, is created and maintained as a by-product of social exchanges between developers working in the same OSS community. Social capital provides benefits both to the overall OSS community and to the individual developers. A high level of social capital in an OSS community can help facilitate the process of software development and make individuals’ experiences of working on OSS projects both satisfying and rewarding.

Keywords
Open Source Software, social capital.

1. INTRODUCTION

Open Source Software (OSS) is a category of software under special licenses that protect users’ right to access and modify the source code. The success of OSS projects, such as Linux operating systems, Apache web server, and the BIND domain name resolution utility software, has impressed software users in industry and sparked interests of scholars in academia. The development process of OSS is different from that of commercial software. In OSS communities, the work is not coordinated by organization superstructure; rather, it is loosely coordinated by informal community governance mechanisms. The majority of OSS developers are primarily volunteers contributing to the project without directly getting economic compensation. According to BCG/OSTG Hacker Survey, 70 percent of OSS developers are volunteers (Lakhani et al., 2002). The end product of OSS development is made available to all at no or very low cost. The process of OSS development illustrates a new model of innovation creation, the so called “private-collective model”, that is, people devote private investments to innovation creation while providing the end product freely to all in the form of public goods (von Hippel and von Krogh, 2003).

Success of OSS projects and sustainability of OSS communities vary from project to project. Although success stories tend to attract attention, some OSS projects have been abandoned or have progressed slowly. This can be evidenced by many inactive OSS projects hosted on sourceforge.com. The prospect and success of an OSS project depends on sustainability of the OSS community, which in turn depends on the individual developer’s constant contributions to the project and participation in the community. In order to benefit from OSS software and sustain the private-collective model of innovation creation, it is critical to thoroughly understand the factors affecting individual developers’ contributions to the project. Although many theoretical and empirical studies have been conducted to investigate this question, most studies have focused on the individual level (Hann et al., 2003, Ye and Kishida, 2003, Hars and Qu, 2000, Hann et al., 2004). Once developers join the OSS community, work on the project, and interact with other community members, community characteristics start to play an important role affecting individual developers’ commitment levels to the project. Drawing on theories of social capital, this research intends to fill this research gap by proposing a cross-level model that explains how community-level factors affect the individual developer’s contribution to a project and the overall success of an OSS project.

2. THEORETICAL MODEL AND RESEARCH PROPOSITIONS

To theorize the OSS phenomenon, levels issues need to be taken into account. Levels issues originate from the idea that social systems consist of hierarchies. Software development contains the commercial software regime and the open source
The open source regime is composed by many OSS communities, each aiming to develop a particular software product. Each OSS community contains many individual developers. In this paper, we propose a cross-level model to explain the role of social capital in OSS communities (as in figure 1). Cross-level theories describe “the relationship between independent and dependent variables at different levels” (Rousseau, 1985), and they are commonly used to describe the impact of group or organizational factors on individual behavior and attitudes.

Our model contains two levels: the community level and the individual level. Social capital and the success of OSS projects are community-level constructs, and individual motivation and contribution are individual-level constructs. In this section, we will discuss how community social capital can be created and maintained as a by-product of ongoing activities within an OSS community. We will also discuss the impacts of social capital on communities and individual developers.

![Figure 1: Theoretical Model of Social Capital in OSS Communities](image)

### 2.1 OSS Projects and OSS Communities

OSS projects are often initiated by an individual developer or a small group of developers who want to develop software to solve problems they encounter in life or work. After the essential components of the software are developed, the software and its source code will be made available to others through the Internet. Other software developers are attracted to make contributions to software development. OSS developers are mainly volunteers who do not get direct economic compensation. The levels of contributions vary among developers. The newcomers may start with reading the codes and fixing a couple of errors. After becoming familiar with the software, they can become active developers or even core developers by making larger contributions and gaining reputation among peer developers. Bonded by their shared interest in using and/or developing a particular OSS software, these developers together with users create an OSS community (Ye and Kishida, 2003).

The governance mechanism and coordination system within OSS communities are flexible or even chaotic to some extent (Raymond, 1999). Developers working on the same project are normally geographically distributed, rarely meet face-to-face, and primarily communicate through Internet technologies. Developers are not assigned to specific tasks, but pick the task they want to work on. Developers submit their software patches to the community. The submitted work first goes through peer review, and then the project leaders decide what to include in the released version of the software.

The characteristics of OSS development combine two traditional innovation creation models and form a new model of innovation creation, the private-collective model (von Hippel and von Krogh, 2003). In OSS communities, developers use their private resources to invest in creating novel software codes. Rather than keeping the innovation proprietary and making profit by selling it, OSS developers reveal the innovation as a public good freely available to all. Social theory shows that when people carry out collective action and produce public goods, “free-riding” problems tend to occur and jeopardize the community and collective action (Ostrom, 1990). In the case of OSS communities, if people only download and use the
software without making contributions to software development, then the OSS community is not likely to be sustained and the OSS project may not succeed.

Proposition 1: The sustained contributions of developers in an OSS community are positively related to the success of OSS development projects.

2.2 Motivations and Contributions of OSS Developers

Hars and Qu identified three main categories of factors leading to participation in OSS projects: intrinsic motivation, personal needs, and expectations of future returns. First, OSS developers are intrinsically motivated to participate in OSS. Some developers enjoy the process of programming; others feel the urge to increase other people’s welfare by writing useful programs. Second, as mentioned by Raymond (1999), “Every good work of software starts by scratching a developer's personal itch”. Developers contribute to OSS development out of their personal need for the software. The third category of motivation is expectation of future returns. Although volunteer developers could not be directly compensated, participation in OSS could potentially increase their future economic return. Improved programming skills can bring opportunities for salary increase, and reputation gained within the OSS community can be mobilized to the commercial software industry and increase the chance of higher compensation (Hann et al., 2003).

Based on the theory of legitimate peripheral participation and observation of an OSS community, Ye et al (2003) argued that OSS developers experience role transformation as they contribute to development. They may assume the role of peripheral members of the community, such as passive users or bug reporters when they join the community. As they increase their contributions, they move toward the center of the community and assume more important roles such as active developers or even core developers. Two categories of motivation drive developers to move along the path of role transformation: learning as intrinsic motivation, and establishing reputation as extrinsic motivation.

Hann, Roberts, and Slaughter (2004) conducted a web-based survey of developers in three large Apache OSS projects to study the underlying dimensions of developers’ motivation and the relative importance of these dimensions. They concluded that five distinct factors of motivations are use-value, reputation, career concerns, normative reasons and recreation.

In summary, people are motivated by various reasons to contribute to the OSS development. Although prior research has generated different categories of motivations, a close look reveals that the differences lie within the granularity of the categorization. For example, three motivation categories proposed in Hars and Qu (2000) covered the five motivation factors found in Hann, Roberts, and Slaughter (2004). Personal use of the software overlaps with the concept of use value; normative and recreation reasons can be categorized as intrinsic motivation; and reputation and career concerns are motivations driven by the expected future return. In our study, we adopt the motivation categorization by Hars and Qu (2000) because it provides coverage of the motivation factors in other studies at a more abstract level.

Proposition 2: Use value, intrinsic motivation, and expected future return motivate individual developers to contribute to OSS development.

2.3 Social Capital as a By-product of OSS Development

The concept of social capital originated from the intuitive idea that social relationships can be valuable resources. Adler and Kwon (2002) integrated different perspectives and defined social capital as “the good will available to individuals or groups. Its source lies in the structure and content of the actor’s social relations. Its effects flow from the information, influence, and solidarity it makes available to others.” (p.23) Among three types of relations in social structure; market relations, hierarchical relations, and social relations, social capital primarily lies within social relations, in which favors and gifts are exchanged under diffuse and tacit terms (Homans, 1974). Alder and Kwon (2002) argue that three elements -- opportunity, motivation, and ability -- need to be present in social relations to form social capital.

2.3.1 Creation and Maintenance of Social Capital in OSS Community

Social relations are primary relations in the social structure of OSS communities. OSS developers are not assigned to the job or bound by explicit employment contracts, and the OSS community provides the final product to users, not for return of economic profits but with the hope that users will contribute back to the community by reporting or fixing bugs. Gift culture and reciprocity norms are valued in the OSS community (Bergquist and Ljungberg, 2001).

OSS communities contain the three elements of sources for social capital. First, the Internet as a communications media creates the opportunity for developers to connect with each other. Second, collective goals and belief in collective action –
developing OSS software – motivate developers to exchange knowledge both about source codes of specific software and about general programming. Third, they have ability to conduct such exchange because they come from similar backgrounds and share experiences and common language. Like other types of capital, social capital needs to be created and maintained. However, social capital cannot be created for the sole sake of creating it, and it is always a by-product of other social activities and interactions.

Proposition 3: Social capital in the OSS community is created and maintained as a by-product of developers’ participation in the community and contributions to the project.

2.3.2 Level of analysis of Social Capital

Social capital can be described both through micro and macro lenses. On a micro level, social capital refers to resources lying within social ties connecting individual actors with others. On a macro level, social capital can be described as an attribute of communities, nations and industry networks. “The social capital of a collectivity (organization, community, nation and so forth) is not so much in that collectivity’s external ties to other external actors as it is in its internal structure – in the linkages among individuals or groups within the collectivity and, specifically, in those features that give the collectivity cohesiveness and thereby facilitate the pursuit of collective goals” (Alder and Kwon, 2002). In this paper we take the view of macro level, social capital in a collectivity. Our focus is on valuable resources embedded in social ties within an OSS community. Although external ties between a particular OSS community and surrounding institutions are also valuable resources for an OSS community, they are outside the scope of this paper.

2.3.3 Dimensions of Social Capital

(Nahapiet and Ghoshal, 1998) developed their understanding of social capital along three dimensions. The structural dimension of social capital is about whether and how people are connected. This dimension includes network ties, network configurations and network appropriability. Network ties are connections between members within a community; network configuration is patterns of ties such as structural holes, centralization and density; network appropriability relates to the ease with which different types of relationships can be transferred within a network. Network ties can facilitate information and knowledge sharing and coordination of tasks. Different configurations of network ties can bring different benefits. (Coleman, 1988) argues that closure of network structure increases cohesiveness, and (Burt, 1992) argues that a sparse network aggregates resources for competitive action. OSS communities can benefit from both of these configurations. An OSS community is generally open to all so that it has potential to create a sparse network to aggregate and rally competency. Meanwhile the team of core developers can enjoy the benefits of closure of the network.

The relational dimension of social capital is characterized by high levels of trust, shared norms and mutual identification (Nahapiet and Ghoshal, 1998). Resilient trust and generalized trust play important roles in social capital creation and maintenance. Resilient trust is based on the experience with other parties and beliefs about their moral integrity without formal and contractual means, and it can survive through occasional transactions in which benefits and costs are not equalized. Generalized trust refers to the trust that can be generalized to all members within a collectivity. The norm of reciprocity is an important ingredient in social capital because the notion that “I do this for you now and down the road somebody else will do the same for me” will promote sharing and collaboration. Identification refers to the phenomenon that people “see themselves as one with another person or group of people” (Nahapiet and Ghoshal, 1998). Identification with a community will make community members concerned about the collective processes and outcome, and align individual actions with collective process and goals. In an OSS community with a high level of relational social capital, individual developers trust each other, adhere to the norm of reciprocity, and internalize their identity as community members.

The cognitive dimension of social capital refers to resources providing shared representations, interpretations, and systems of meaning among parties. It includes shared languages and shared narratives. Shared languages provide community members with the ability to communicate more effectively. A high level of cognitive social capital will enable members within a community to have the same perceptions and interpretations of the same events. Shared narratives include myths, stories, and metaphors that organizational members communicate to one another. Both shared languages and narratives increase the level of understanding among community members. In an OSS community with a high level of cognitive social capital, shared languages enable users and developers to ask and answer questions in a way that can solve problems efficiently, and shared narrative also helps in creating, exchanging and preserving rich sets of meaning within communities.

Proposition 3.1: Social capital in an OSS community includes structural, relational and cognitive social capital.
2.4 Benefits of Social Capital in OSS Communities

Adler and Kwon (2002) identified three benefits of social capital: information, control, and solidarity. These benefits positively affect both individuals within a community and the community as a whole. In this section, we explain how these benefits of social capital help to facilitate the process of OSS development.

The first direct benefit of social capital is information. Connections between people, trust, and mutual understanding lying within connections all make information sharing smoother. Information and knowledge sharing is an essential activity in OSS communities because people within the community are constructing knowledge products collectively. Social capital improves information quality, relevance and timeliness. Sharing relevant information reduces the noise in exchanged messages and keeps a community focused on executing work more quickly. Timeliness of information sharing helps to speed up the bug reporting and fixing processes.

Influence, control and power constitute the second benefit of social capital. People with high visibility and reputations tend to enjoy more of this benefit, but this benefit can also accrue to the collective level. In OSS communities, although work is not assigned according to a formal plan, project leaders assume important roles. Project leaders are either initiators of the project or people who make significant contributions to the project and establish their reputations in the community. They make decisions about what to include in the released versions of software and other critical decisions affecting the community’s destiny. Influence, control and power of the project team facilitates community acceptance of project decisions.

The third benefit of social capital is solidarity. Strong norms and beliefs, together with a high degree of network closure, will encourage compliance with community rules and therefore reduce the need for formal controls. Shared norms can lower the monitoring costs and promote higher commitment. Solidarity enables community members to carry out collective tasks and reach collective goals. In a solidified OSS community, people try to align their own individual behaviors to collective actions and goals, producing an OSS product of high quality. They will more likely to obey rules within the community, and thus formal control and monitoring are not needed.

In summary, three benefits, information, control, and solidarity from social capital are important determinants of OSS project success.

Proposition 4: Benefits of social capital positively affect the success of OSS project.

Proposition 4.1: Information benefits of social capital positively affect the success of OSS project.

Proposition 4.2: Control benefits of social capital positively affect the success of OSS project.

Proposition 4.3: Solidarity benefits of social capital positively affect the success of OSS project.

2.5 Impacts of Community-level Social Capital on the Levels of Individual Developer’s Contributions

Community-level social capital has a positive impact on individual developers’ contributions. One of the solutions to the free-riding problem is found in the creation and awarding of selective incentives (Friedman and McAdam, 1992, Oliver, 1980). Social capital is one of the sources that provide such rewards and helps to reconcile the conflict between personal incentives and collective goals. In an OSS community with a high level of social capital, no matter what personal motivations the individual developers have, they will feel that their participation in the community and contribution to the project are rewarding. Therefore, they are more encouraged to contribute intensively on the project.

First, community-level social capital rewards developers with “use value” motivations. Developers with “use value” motivations care the most about the quality of the software developed in OSS community. As mentioned in the previous section, information, control and solidarity benefits of social capital help facilitate the process of OSS project and thus lead to producing software of superior quality. Software developers are convinced that the way of developing the particular software they need in the OSS community is efficient and effective.

Second, community-level social capital rewards developers with “intrinsic motivations”. Developers with intrinsic motivations contribute to OSS projects because they see programming tasks as learning or recreation. In communities with a high level of social capital, connections between persons, trust and mutual identification, and common cognitive understanding build a great environment, in which people find their experience of working on the project enjoyable while they acquire significant knowledge.

Third, community-level social capital rewards developers who are motivated by “expected future returns”. People expecting future returns want to improve their programming skills and/or increase their reputations with their work on the OSS project.
In communities with high-level social capital, people like to share information about programming knowledge and skills, developers help each other because of reciprocity norms, and reputations are highly valued. Developers will find it easy to polish their programming skills and/or establish reputations.

In addition to the rewards of selective incentives, social capital itself can potentially create an incentive. Although social capital is a resource shared by all members in a community, developers in the center of a community will realize more benefits of social capital than peripheral members. By making contributions to software development and establishing credentials in the community, “Individuals may gain private benefits from credentials in the form of enhanced social relations, enhanced reputation, and privileged access to social relations” (von Hippel and von Krogh, 2003). For example, core developers in large-scale OSS projects can become very reputable in the software industry, and thus increase their chances of getting promoted or increased salary.

Proposition 5: Social capital within an OSS community has a positive impact on the relationship between individual developers’ motivation levels and their contribution levels.

Proposition 5.1: Social capital within an OSS community provides rewards to developers with “software use value” incentive.

Proposition 5.2: Social capital within an OSS community provides rewards to developers with “intrinsic motivations”.

Proposition 5.3: Social capital within an OSS community provides rewards to developers with “expected future return” incentive.

3. DISCUSSION AND CONCLUSION

In this paper, we proposed a cross-level model to explain the role of social capital in OSS communities. We discussed how community-level social capital can be created and maintained as a by-product of ongoing activities within an OSS community. Community-level social capital, as a valuable resource shared by community members, can provide direct information, control, and solidarity benefits to the OSS community as a whole, facilitating the software development process and improving the quality of the public good produced – the OSS product. Community-level social capital works as a positive reinforcement for developers’ contributions. Developers who significantly contribute to the software development and actively participate in community activities actually benefit more than peripheral members from social capital. In an OSS community with a high level of social capital, developers will be more encouraged to make contributions.

The paper is not free of limitations. First, the potential negative impact of social capital was not discussed. As with any other form of capital, investment and efforts need to be made to create and maintain social capital. Social capital could backfire in some situations. For example, cohesion resulting from high levels of social capital could create a barrier for new members to join a collectivity. Closure in small groups of people could jeopardize community-wide solidarity and split the community. Second, the conceptual model needs empirical validation and refinement. As future research, we consider surveying developers within different OSS communities. Multilevel hierarchical modeling could be used to test the propositions in the cross-level model.

The proposed model has great potential to contribute to both research and practice. In terms of research, it advances our understanding of the factors affecting volunteer developers’ contribution level and success of OSS projects. The model can also be generalized to other communities adopting the private-collective model of innovation creation. In terms of practice, the model helps OSS community leaders, as well as commercial software producers who intend to incorporate OSS elements into software development to realize the important role of social capital. Leaders or project managers should strive to create a nurturing community environment with a high level social capital, which will keep the developers motivated and efficiently produce high-quality software.

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