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Impacts of License Choice and Organizational Sponsorship on User Interest and Development Activity in Open Source Software Projects

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What differentiates successful from unsuccessful open source software projects? This paper develops and tests a model of the impacts of license restrictiveness and organizational sponsorship on two indicators of success: user interest in, and development activity on, open source software development projects. Using data gathered from Freshmeat.net and project home pages, the main conclusions derived from the analysis are that (1) license restrictiveness and organizational sponsorship interact to influence user perceptions of the likely utility of open source software in such a way that users are most attracted to projects that are sponsored by nonmarket organizations and that employ nonrestrictive licenses, and (2) licensing and sponsorship address complementary developer motivations such that the influence of licensing on development activity depends on what kind of organizational sponsor a project has. Theoretical and practical implications are discussed, and the paper outlines several avenues for future research.

Key words: open source; software development; software licensing; success
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The popular press is full of references to a few successful open source software (OSS) projects, most notably Linux, yet OSS websites are littered with the remains of projects that seem to have suffered an early death. For example, Chengalur-Smith and Sidorova (2003) noted approximately 80% of projects listed on SourceForge.net (hereafter SourceForge) had no activity. The research question addressed in this paper is: Why do some OSS projects succeed and others fail?

The importance of this question is underscored by private and government organizations' increasing dependence on OSS (cf. Bollinger 2002, Koch 2003, Smith 2002). This question is also important because OSS represents a competing model for software development that proponents argue has the potential to create better software cheaper than closed development models (cf. Raymond 2001), and understanding success factors may help predict the possible effects of legal and policy decisions, such as those posed in the SCO-IBM lawsuit (see Raymond and Landley 2003 or www.groklaw.net), on the survival of OSS. To address the research question, this paper focuses on developing and testing hypotheses related to two factors that have been argued to be crucial in determining OSS success: developer motivation and user utility.

The motivation of OSS developers has been the subject of much discussion among both researchers and professionals concerned with OSS (cf. Gacek and Arief 2004, Hann et al. 2002, Hars and Ou 2002). This paper develops the argument that for a project to be successful it must attract the input of developers

and, to do that, characteristics of the project must be aligned with developer motivations.

A subject of similar interest has been the benefits and drawbacks of using OSS, and these discussions have generally focused on the overall utility of OSS to users, including some consideration of costs, quality, and support concerns (cf. Raghunathan et al. 2005, Smith 2002). Based on these discussions, this paper will develop the argument that in order to be successful characteristics of OSS projects must signal to potential users that the project is likely to provide a high level of overall utility.

Prior work has suggested several project characteristics that may be important to OSS success, including project age, intended audience, reputation of participants, the type of software developed by the project, licensing issues, and organizational involvement in the project (Chengalur-Smith and Sidorova 2003, Crowston and Scozzi 2002). This research focuses mainly on license choice (i.e., how restrictive is the license) and organizational sponsorship (i.e., whether the project is affiliated with an organization and, if so, what kind of organization it is) as antecedents to success. These two factors are examined for three reasons. First, licensing and organizational sponsorship are tied to user and developer perceptions that existing theoretical perspectives imply will influence the success outcomes of interest (e.g., Venkatesh et al. 2003). In particular, these are user perceptions of cost and quality and developer perceptions of the outcomes they are likely to experience as a result of working on the project. Second, prior work on OSS implies, but has not tested, the importance of licensing and organizational sponsorship in influencing developers and users (Lerner and Tirole 2005), and current debates about OSS center around issues of ownership, which are closely related to licensing and organizational sponsorship (e.g., Raymond and Landley 2003). Third, license choice and organizational sponsorship may be within the control of project leaders or administrators, and understanding their impact may therefore be of practical significance.

The remainder of the paper is organized as follows. The next section develops a more detailed definition of what OSS is and what success means in the context of OSS development. This is followed by the development of the theoretical basis for hypotheses regarding how and why license restrictiveness and organizational sponsorship influence developer motivations and user perceptions of software utility and thereby lead to greater or lesser levels of success. The final section before the discussion of methods considers the interrelatedness of two success outcomes. The methods section then describes the operationalization of the constructs using data collected at two points in time from two sources: Freshmeat.net (a site that contains information on several thousand OSS projects) and the Web home pages of projects in the sample. The analysis and results section describes the outcomes of the hypothesis tests, and the discussion section explains how these results support and extend the arguments made in the paper as well as the conclusions that may be drawn and implications for future work.

What Is OSS? Defining Features of the Software, Development Processes, and What It Means to Be Successful

There is sometimes confusion among those not intimately familiar with OSS as to exactly what does or does not qualify as OSS. It is not only a matter of access to source code, or else software obtained under Microsoft's shared source initiative[1] might be considered open source, and it most definitely is not, according to OSS leaders (cf. Tiemann 2001). Nor is it a matter of the software being developed by volunteers, because Linux is developed by volunteers as well as individuals paid by their employers to work on it.[2] Perhaps the simplest way to distinguish what is OSS from what is not OSS is by the definition of the Open Source Initiative (OSI). Software is open source if it is released under a license approved by the OSI.[3] OSI standards for OSS licenses include the following provisions: The source code must be available at little

[1] See http://www.microsoft.com/resources/sharedsource/default.mspx.

[2] See, for example, http://www.hotlinuxjobs.com/.

[3] Using this definition also includes in the open source category software that would be described by its creators as free software rather than as open source, because OSI has approved licenses used by the free software community. This is a distinction important to many in the software development community, but one that is not crucial to the arguments in this research.

or no charge; redistribution of the program, in source code or other form, must be allowed without fee; distribution of modified versions must be allowed without discrimination against groups of users or types of uses; and distributions of modified versions must be allowed on the same terms as the original program.[4]

Although we take the position that licensing is the crucial feature distinguishing OSS from other software, it is important to recognize that OSS often has other unique features. OSS development is different from traditional software development in that it frequently depends on volunteers coordinating their efforts without the governance of a common organizational employer, and the end product is often provided for free (Feller and Fitzgerald 2002). Because of these differences, the success indicators applied to commercial software projects—e.g., being on time, on budget, and meeting specifications—may not be readily applied in the OSS setting. In this setting, there often is no a priori budget, timeline, or set of specifications (Scacchi 2002). Nonetheless, there are many ways to define success in the context of OSS development.

Defining Success in OSS

Success is a nebulous concept that may have different meanings across projects and stakeholders. Others have argued that indicators of success among users of OSS projects include traffic on the project website, downloads of the code, and the number of people who monitor announcements and new releases regarding a project (cf. Crowston et al. 2003). Each of these may be an indicator of user interest in or adoption of the project software. IS theories (e.g., Agarwal and Prasad 1999, Davis et al. 1992) position individual psychological constructs between technology characteristics and user behavior such as adoption and actual usage. Thus, we focus on user interest in an OSS project as a dependent variable because it is more proximate to the independent variables and also because of the difficulty of obtaining data on actual usage. The specific indicator of user interest that we focus on in the empirical study is the number of individuals who have subscribed to a project (i.e., registered to receive e-mail about it).

[4] See www.opensource.org for a detailed description of the licensing requirements.

A second type of success relevant in this setting is the success of the project in attracting interest and input from the development community. Because open source projects often rely on voluntary input, attracting and motivating contributors is a key factor in project success; one way of assessing that success is by looking at the level of activity on a project—e.g., how frequently are bugs fixed, support requests answered, or new releases of the software posted. We categorize these kinds of development-oriented success measures as indictors of the development activity on a project, and the specific measure used in this study is the number of new releases that are produced during a fixed period.

Antecedents to OSS Success

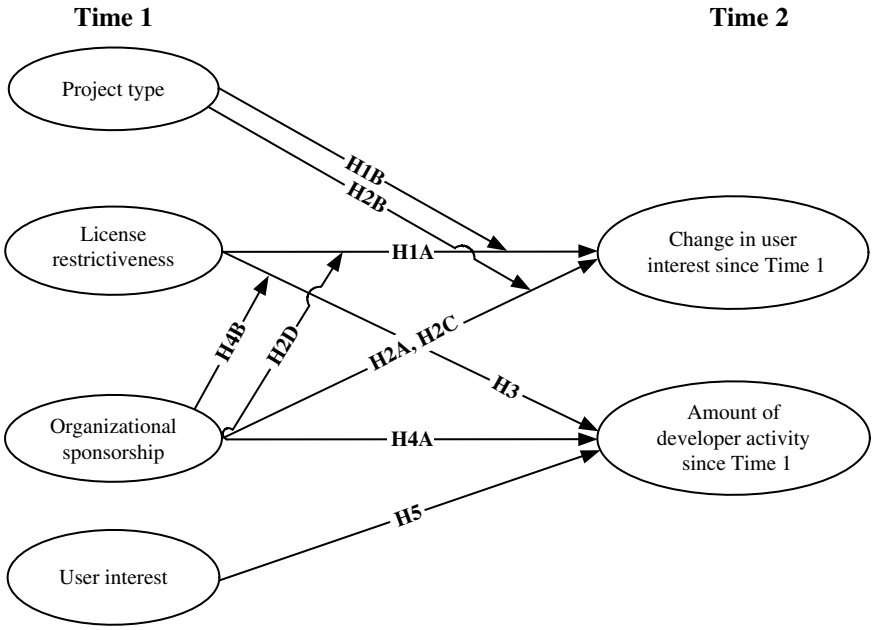
This study focuses on two potential antecedents to project success: the restrictiveness of the license chosen, and organizational sponsorship. License choice refers to which of the many available OSI certified licenses a project uses, and restrictiveness in this context is explained below. Organizational sponsorship refers to the fact that some but not all OSS projects are affiliated with a formal organization such as a for-profit company or a university. We use the term *organizational sponsorship* to indicate a publicly displayed affiliation between an OSS project and an organization.

In the next section, we focus on user interest as an outcome by considering why users may choose one software solution over another. We thus focus the hypothesis development around how license choice and organizational sponsorship may impact user perceptions that prior theoretical work has shown are critical to such choices. After developing hypotheses regarding user interest, the next section focuses on how licensing and sponsorship may influence development activity. We develop hypotheses regarding development activity based on the emerging research on OSS developer motivation. The research model is summarized in Figure 1.

Why Might License and Sponsorship Affect User Interest? Cost and Quality

OSS may be seen by users as a technology product, thus we consider work on consumer behavior

Figure 1 Research Model



(e.g., Zeithaml 1988) and technology acceptance (e.g., Venkatesh et al. 2003) to understand how license choice and organizational sponsorship may influence user interest. Both of these streams of work argue for the importance of the user's (or consumer's) perceptions about the product (in this case OSS) that is under consideration; the perceptions that are argued to be important across these different streams of work are similar. In the next paragraphs, we summarize the key factors discussed in these theoretical conceptions and how they apply to OSS, and in the remainder of this section we leverage them to provide the underlying logic for the hypotheses.

Research on consumer behavior attributes customer purchase decisions to perceived value (Zeithaml 1988). Customers choose to purchase products that offer the highest perceived value, which is assessed based on product cost and product quality (Dodds et al. 1991). Though purchasing may not be required for OSS, both cost and quality have been frequently cited as important factors in user decisions regarding OSS (e.g., Leventhal 2004, Smith 2002). Costs related to software may include the initial purchase price plus the resources required for installation, maintenance, and ongoing use (Szajna 1994). Because the initial licensing fee in OSS is usually close to zero, our discussion of cost focuses on the remaining components. Quality of software, OSS or other software, has frequently been discussed as encompassing the features and performance of the software as well as the number of defects, and the availability of ongoing support (Harter et al. 2000).

The technology acceptance literature, which focuses on individuals' use of software, provides a basis for understanding factors that may affect user cost and quality assessments. This literature focuses on perceived usefulness and perceived ease of use as key determinants of behavioral intention to use and the actual use of technology (Davis et al. 1989, Taylor and Todd 1995, Venkatesh 2000). Davis (1989, p. 320) defined perceived ease of use as "the degree to which a person believes that using a particular system would be free of effort," and effort is a cost associated with use. In their work integrating the technology acceptance model (TAM) with other similar user acceptance models, Venkatesh et al. (2003) concluded that perceived usefulness was a relevant indicator of job-related performance expectancies. Performance expectancies refer to a potential user's impressions of how use of a technology will positively affect his or her productivity at work, and is thus an aspect of quality.

Supporting the suggestion that perceptions of cost and quality may be crucial in determining user

interest in OSS projects, these factors have been cited as major concerns among potential OSS users. A survey of 260 IT corporate managers (Smith 2002) indicated that 41% viewed the inability to hold someone responsible for software breakdown, a quality concern, as one of the major reasons that OSS had not been widely adopted in their companies. In this same survey, 59% of IT managers cited support concerns, which are dependent on quality and impact costs, as a factor reducing their companies' use of OSS.

Impact of OSS License Choice on User Interest

Within the OSI framework, there is room for variance across many dimensions of a license. One such dimension that OSS researchers (Lerner and Tirole 2002a, Scacchi 2004) have suggested as important is the restrictiveness of the license. For example, the most widely used OSI license, the GNU general public license (GPL), has two restrictions that many other popular licenses (e.g., Berkeley Software Distribution) lack: It requires that modified versions of the software also be open (often referred to as a *copyleft* provision), and it requires that the code be combined only with other programs distributed under licenses that share the first requirement (often referred to as a *viral* provision). Below, we use the term *restrictive* to refer to licenses that have both of these provisions, and *nonrestrictive* to refer to licenses that do not. (For example, licenses that have the copyleft provision but not the viral provision are considered nonrestrictive.)

The use of restrictive licenses may affect users' perception of the likely costs and benefits of using the software in at least two ways. First, although requirements to open modified versions and combine the software only with similarly licensed software act to maintain the openness of the code, they are restrictive in the sense that they limit what a user can do with the software. These restrictions may constrain commercialization of OSS applications (Lerner and Tirole 2005, West 2003). In doing so, they may significantly reduce the perceived usefulness of the software among one category of potential users—those seeking to advance commercial interests. Perceived usefulness may also be reduced by restrictive licenses in that such licenses limit potential users' ability to employ the code in conjunction with software distributed under a less restrictive license. An important feature of software is its compatibility with other applications. Compatibility increases the usefulness of a software application to users by increasing the range of functions that can be performed to meet existing and potential needs. The restrictions imposed by a license's viral provision may inhibit the exploitation of some crossapplication compatibility, consequently reducing the potential gains that would otherwise be realized. For example, someone working on a project using a nonrestrictive license may not be able to incorporate software with a restricted license, which, if it did not have such a license, might otherwise have been combined in a synergistic fashion with the nonrestricted software.

A second reason that user interest may be reduced for projects employing a restrictive license results from perceived risks related to the legal implications and enforceability of such licenses. There is a lack of clarity in the interpretation of the terms posed by the GPL (Rosen 2005) that may increase uncertainty among potential adopters and their perception of risks involved in adoption. As Rosen (2005, p. 111) states, "to the extent that [contents of the GPL] raise discomforting questions for potential licensors and licensees—and their attorneys—they discourage adoption."

Both the legal uncertainties posed by restrictive licensing and the constraints it places on redistribution are likely to be most relevant to users considering software for use in conducting business activities (as opposed to personal uses). For this reason, license restrictiveness may be especially important for categories of software that have a wider range of potential business applications (such as utilities that may be employed to connect other software and hardware) than for categories of software that have more limited or focused uses (such as games, which are generally used for personal entertainment).

Hypothesis 1A (H1A). *OSS projects that use a nonrestrictive license will attract greater user interest over time than those that use a restrictive license.*

Hypothesis 1B (H1B). *The effect of license restrictiveness on OSS project user interest over time will be stronger for projects that have a broader range of potential uses than for those that have a narrower range of potential uses.*

Impact of OSS Sponsorship on User Interest

Software attributes such as the license used may be directly evaluated to assess cost and quality, but perceptions of value may also be developed from individuals' use of extrinsic cues in the formation of quality and cost perceptions (Dodds et al. 1991). Brand name and store name are some of the most widely studied extrinsic cues in the marketing literature (Agarwal and Teas 2001). Consumers make product quality inferences based on cues such as brand and store name through a process called affect-referral (Zeithaml 1988). Using *affect-referral*, customers simplify their decision-making process by basing their judgments on summary information (i.e., brand attitudes) rather than on product attribute information alone (Wright 1975).

Organizational sponsorship may be a salient extrinsic cue for evaluating OSS projects' products (i.e., their software releases). Although code is available for inspection, users may not have the necessary background knowledge to evaluate the inner workings and features of the software program before they install it; even if they do have the requisite skill, they may seek to minimize the cognitive effort involved in evaluation by relying instead on more easily interpreted cues. When selecting among different possible OSS (and non-OSS) solutions, individuals may draw conclusions about likely costs and quality based on cues such as the identity of the project sponsor.

At the most basic level, projects may be distinguished by whether or not they have a sponsor. Many projects hosted on sites such as SourceForge have no apparent organizational sponsor, but rather are created and maintained by private individuals. Nonetheless, many different kinds of organizations may be affiliated with an OSS project. For example, *TaskGuide Viewer*, an XML-based tool for creating wizards,[5] is an IBM-sponsored OSS development project, and *C-Kermit* is a communication utility that is sponsored by Columbia University.

Organizational sponsorship could directly affect OSS quality if the sponsoring entity devotes significant resources to the project's development. However, even if actual quality is not affected, or if users do not have the skills or inclination to thoroughly assess actual quality, organizational sponsorship information is analogous to brand or store name in terms of its use as an extrinsic cue. Like brand or store information, sponsorship information may enable potential users to make judgments about the quality of OSS without experientially evaluating it.

Perceived costs associated with using software do not only include price (which for most OSS is close to zero), but also such factors as maintenance time and effort expended in using the product in the future. Potential users' perceptions of software quality may be shaped by a sponsoring entity based on the users' expectations of the sponsor's ability to meet conformance (delivering the right product), service (customizing the product to specific user needs and fixing bugs), and innovation (providing continuous feature enhancements through future upgrades) requirements in the future (Prahalad and Krishnan 1999).

Organizational sponsorship may imply the availability of technical support, upgrades, and other resources that may be needed over the long term by consumers of software products. In fact, beyond merely providing a cue to the likely availability of such resources, sponsors may actively promote their OSS products and services in order to attract users. A greater degree of uncertainty may exist regarding the availability of services for nonsponsored OSS projects. Sweeney et al. (1999) argued that consumers make judgments about uncertainties and the potential future losses that could stem from such uncertainties, and a recent survey of IT managers demonstrates that this is applicable in the case of OSS (Smith 2002). Hence, organizational sponsorship may act as a cue to the likely future costs and quality associated with an OSS product. As with license restrictiveness, the importance of sponsorship to users may be greater for software that can be used in a wider array of projects. For example, support concerns may be more salient for such software because the greater the variety of uses for the software, the more likely the need for support services.

Hypothesis 2A (H2A). *Projects with a sponsor will attract greater user interest over time than those without a sponsor.*

[5] Wizards simplify complex tasks by breaking them down into sequential steps that can be performed with the assistance of a graphical user-friendly interface.

Hypothesis 2B (H2B). *The effects of sponsorship on OSS project user interest over time will be stronger for projects that have a broader range of potential uses than for those that have a narrower range of potential uses.*

As noted above, there are different kinds of organizations that may sponsor OSS projects. Gacek and Arief (2004) suggested types of OSS sponsors: those developing software for their own use, those involved primarily in packaging and selling software, and foundations set up for commercial or research software development. More generally, institutional theory suggests an important distinction between organizations that tend to be market driven, such as for-profit firms, and those that are less so, such as government and educational organizations (cf. Scott 1998). Market organizations are driven by economic needs and incentives and thus focus on signaling product characteristics that consumers are willing to pay for, whereas nonmarket organizations focus on signaling conformity with institutional norms or practices to enhance legitimacy (Downs 1967, Scott 1998, Thompson 1967). Research on market and nonmarket organizations has shown that they have differing motivational drivers. For example, Casile and Davis-Blake (2002) found that market organizations were more responsive to potential economic gains from accreditation, whereas nonmarket organizations were more responsive to institutional motivations such as achieving structural equivalence with others through accreditation.

Applying these findings to the OSS setting, market organizations may be more driven to find ways to capitalize on an OSS project, and nonmarket organizations may be more motivated to conform to the norms associated with OSS development. Potential users in the open source community may therefore be more likely to use an OSS sponsored by a nonmarket organization than one sponsored by a market organization, because the former will be seen as less likely to attempt to derive rents from users and more likely to act in ways congruent with the OSS ideology. Sponsorship by a market organization may introduce in the minds of potential users the threat that the OSS could in the future be hijacked by commercial interests (Lerner and Tirole 2005). When the sponsoring entity is an organization whose purpose is seen as enhancing social welfare (e.g., a government organization), such concerns may be lessened.

Hypothesis 2C (H2C). *Projects with a nonmarket sponsor will attract greater user interest over time than those with a market sponsor.*

As discussed above, sponsorship may address user concerns similar to those affected by license restrictiveness. Although a nonrestrictive license allows more flexibility in use of the software, it also opens up the possibility of future commercialization, which could have negative impacts on the user's flexibility or cost in using the software. Having a nonmarket organization in place as the project sponsor may reduce that concern, because such organizations are not generally driven by commercial interests. Thus, the combination of having a nonmarket sponsor and a nonrestrictive license may create an interaction effect in which users experience both the positive effects hypothesized in H1A and H2A and an additional positive effect, because the drawback of nonrestrictive licensing (the possibility of the project being closed by commercial interests) is belied by the type of sponsor.

Hypothesis 2D (H2D). *Projects with a nonmarket sponsor and a nonrestrictive license will attract greater user interest over time than any other combination of license restrictiveness and sponsorship.*

Antecedents to Development Activity in OSS Projects

Although user interest is an indicator of success among OSS users, development activity is an indicator of success among OSS developers. A project has a high level of development activity if developers devote their time to making contributions and creating enhanced software versions. Contrary to some popular conceptions of OSS development as drawing from an infinite pool of talent, OSS work requires specific skills; there is a limited pool of people with the knowledge to be able to productively contribute, leading to potential competition among projects to attract developer efforts. For example, Krishnamurthy (2002) cited the *Orbiten Free Software Survey* (Ghosh and Prakash 2000), which indicates that the 100 most prolific OSS contributors contribute to 1,886 distinct projects, a contributor to project ratio of approximately 1 to 19. Other analyses (Dempsey et al. 2002,

Lerner and Tirole 2002) also showed that relatively few individuals make most contributions, and that most contributors make only a single contribution. Thus, to understand antecedents to development activity, we look to what may motivate developers to pick one project over another or to devote more or less time to projects they are involved in.

With regard to motivation, researchers have suggested that OSS contributors find programming intrinsically motivating, deriving feelings of competence and self-determination from the activity itself or from helping others (Crowston and Scozzi 2002, Hars and Ou 2002); that they contribute to satisfy their personal needs for software (Hars and Ou 2002, Raymond 2001, von Hippel 2001); and that programmers contribute to enhance their skills and reputations (Krishnamurthy 2002, Fershtman and Gandal 2004), possibly with the expectation of future returns (DiBona et al. 1999, Hann et al. 2002, Hars and Ou 2002, Lerner and Tirole 2002). Future returns might be derived because participation in OSS allows contributors to increase their human capital (e.g., by honing their skills), and to advertise their skills, thereby enhancing their reputations and their prospects for paid development work (Hann et al. 2002, Hars and Ou 2002, Lerner and Tirole 2002).

Impact of OSS License Choice on Development Activity

Licensing may be important to maintain motivations related to reputation and career concerns and producing something of personal use. Lerner and Tirole (2005) suggested that the licensing restrictions outlined above serve to protect the interests of developers by limiting the possibility of commercial exploitation of their contributions by third parties. Commercialization of an open source project may be undesirable from the contributor's viewpoint because it may reduce the market for the open version of the project, thereby reducing visibility of contributions and possible reputation benefits. A complementary argument made by Fershtman and Gandal (2004) is that status and signaling may be more easily achieved in projects with restrictive licenses because long-lasting recognition may result from even minimal contributions. In addition to potentially compromising reputation benefits, if a commercial version becomes dominant, contributors' may end up paying for software that grew out of their own efforts, and simultaneously may be unable to customize the commercial version to best suit their needs. Parker and Van Alstyne (2004) explored the implications of this dilemma in the context of innovation in OSS. They found that free access (via nonrestrictive licenses) is not always incentive compatible for developers. Thus, at least two sources of motivation—utility based on customizability and reputation benefits—may be muted when nonrestrictive licenses are employed.

Hypothesis 3 (H3). *OSS projects using a restrictive license will attract greater development activity over time than those using a nonrestrictive license.*

Impact of OSS Sponsorship on Development Activity

Sponsorship could have both benefits and drawbacks in terms of project development activity. As noted in the discussion of user interest, any organization, market or nonmarket, may provide resources such as paid development, thereby possibly enhancing development activity. Yet an association with a market organization could dampen enthusiasm among some volunteer developers because certain tenets of the open source culture seem to value independence from organizational constraints and, in some cases, disdain of profit motives (DiBona et al. 1999, Stewart and Gosain 2006). Nonmarket organizational sponsors are more likely to be seen as having goals consistent with the ideology of OSS developers and may therefore avoid this problem. Thus, nonmarket organizations may provide resources to a project without being seen by potential volunteer developers as presenting a threat of commercialization.

Hypothesis 4A (H4A). *OSS projects that have a nonmarket sponsor will attract greater development activity over time than those that do not have a sponsor.*

Sponsorship of OSS projects may complicate the effects of licensing on development activity as discussed in H3. For a developer, there are reasons to prefer restrictive licenses. However, developers are also users; Fershtman and Gandal's (2004) finding of a positive effect for nonrestrictive licensing on the amount of code generated by developers suggests

that the developer as user may be affected by benefits of nonrestrictive licensing as predicted in H1A. The concerns argued to lead to a developer preference for restrictive licenses may also be partially addressed by sponsorship in that nonmarket sponsorship may be perceived to reduce the threat of a commercial takeover. If this threat is reduced through nonmarket sponsorship, then restrictive licensing may be less crucial to protecting developer interests, and the utility benefits of nonrestrictive licensing may attract greater activity to the project. Thus we may expect to see a less positive effect of license restrictiveness on development activity when the project has a nonmarket sponsor.

Hypothesis 4B (H4B). *The positive effect of license restrictiveness on development activity will be reduced for nonmarket-sponsored projects versus market-sponsored or nonsponsored projects.*

The Relationship Between Development Activity and User Interest

Mockus et al. (2002) pointed out that OSS developers are often users of the product they develop. Therefore, at any point in time, we may expect development activity and user interest to be correlated such that more active projects also generate greater user interest. Krishnamurthy (2002) provided some evidence of such a relationship, reporting significant correlations between the number of developers and page views and downloads. However, developers and users are not completely overlapping sets. Mockus et al. (2002) suggested that successful projects require many more users than developers. Based on the discussion of developer motivation above, we suggest that user interest will influence development activity over time, an argument also supported by Parker and Van Alstyne's (2004) work on modeling OSS value creation over time. The greater the user interest a project has, the wider the audience for individual contributions and therefore the more visible the efforts of contributors (Parker and Van Alstyne 2004). Hence, there may be greater potential reputation benefits from working on more popular projects (Lerner and Tirole 2002), and we might expect such projects to attract more activity from developers. Furthermore, an active user base will generate defect reports and support requests (Mockus et al. 2002), providing greater opportunities for developers to hone their skills on a variety of tasks, and thereby stimulating more development work.

Hypothesis 5 (H5). *OSS project user interest will have a positive effect on the amount of OSS project development activity over time.*

Methods

Researchers have examined OSS from different levels of analysis including viewing OSS as a phenomenon at the community (e.g., Bergquist and Ljungberg 2001), organization (e.g., Markus et al. 2000), and team or group levels (e.g., Mockus et al. 2002). The focus of this research is limited to understanding OSS success at the project level. Thus, dimensions of and antecedents to success are conceptualized and measured at the project level. Publicly available data on open source projects registered on the Freshmeat website (www.freshmeat.net) were used to test the hypotheses. Data were collected from each project's Freshmeat website at the start and end of an eight-month period (March–December 2002).

Sample

We used a stratified random sampling technique to select projects to be included in the study. We first selected three project categories from which to draw the sample: utilities, software development, and games. These categories were chosen to represent different kinds of software as described in the discussion of independent variables below. To be eligible to be included in the sample, a project had to be listed in exactly one of these three categories (projects may cross-list under multiple categories: We avoided such projects to more clearly differentiate among project types in the study). Within these categories, we further differentiated between relatively new projects, which had been registered on the site within the two weeks prior to the first data collection point, and older projects, which had been registered more than two weeks prior to the initial data collection. This stratification was to ensure ample variance across projects in terms of their development stage and to minimize the possibility of selecting only well-established, successful projects for analysis. The

selection of three project categories and the distinction between older and newer projects created six distinct groups across which we randomly selected a total of 218 projects. Of these, 49 projects disappeared from the Freshmeat website during the period of the data collection and therefore could not be included in the analysis. Because some projects may list on Freshmeat.net (hereafter Freshmeat) as a means of advertising without providing releases through Freshmeat, we checked project home pages for any release history of projects that had zero releases posted on Freshmeat during the observation period. Those projects that posted releases elsewhere but did not announce them on Freshmeat were removed from the sample. The final sample size for analysis was 138 projects.

Dependent Variables

We measured user interest using the number of subscribers associated with a project, as reported on Freshmeat. A *subscriber* is someone who has registered to receive e-mail announcements about a project. The identity of subscribers is not available to project administrators or developers, and the subscriber list is separate from development e-mail groups. To represent the change in user interest over time, we used the change in subscribers over the observation period as the measure of the dependent variable. This was calculated as the number of subscribers at the second observation point minus the number of subscribers at the first observation point. As a measure of development activity, we counted the number of new releases of the project software on Freshmeat over the observation period.

Independent Variables

In addition to calculating the change in user interest as a dependent variable, we recorded the number of subscribers that were associated with each project at the first observation point as the measure of user interest at Time 1 to allow testing of H5.

The type of sponsorship was coded based on the description of the project provided on Freshmeat and by visiting the project home page. A project was categorized as having a *market sponsor* if the description stated an affiliation with a profit-oriented company or if the project home page was hosted by an organization that sought pay for products or services. Likewise, a project was classified as having a *nonmarket sponsor* if it stated an affiliation with a university, government, or other organization that was not profit seeking or that was hosted on such an organization's website. Projects that neither stated an affiliation with an organization nor maintained project pages on an organization's website were categorized as *having no sponsor*. This included projects that were hosted on SourceForge or other OSS community websites and those that were hosted on individuals' websites.

A graduate assistant who was not informed of the hypotheses coded the sponsorship for all projects. To assess the reliability of the coding, the first author later classified a randomly chosen subset of 18 of the projects in the sample. The level of agreement between the coders was 0.89, and in the two cases of disagreement discussion among the coders and the second author determined that the original coding was justified.

The license used by each project is reported on Freshmeat. We used the definitions and categorization provided by Lerner and Tirole (2005) to determine whether a project had a nonrestrictive or a restrictive license.[6] One hundred of the projects (72%) in the final sample used the GNU GPL license and were thus categorized as restrictive. The remaining 38 used other licenses that did not include a viral provision and were thus classified as nonrestrictive. These percentages seem to reflect well the overall distribution of license use in the population of OSS projects as reported by Lerner and Tirole (2005; in their sample, 72% used the GNU GPL).

Project category information for each project is self-reported on Freshmeat. We included three project categories in the sample: software development, games, and utilities. Games and utilities were selected because they represent different extremes in terms of the way that the software is generally used: Games tend to be used for a relatively narrow set of purposes related to entertainment, whereas utilities are software programs created to work with other software or hardware and may be used for a wide variety

[6] Lerner and Tirole discuss three license categories including an intermediate category for licenses that have the copyleft provision but not the viral provision. Our sample included only 12 such projects, and analyses conducted using the more refined categorization schema uncovered no differences between these projects and the projects that used licenses with neither provision.

of purposes. An example of a project in the games category is *KSpaceduel*, a space arcade game that did not display any organizational affiliation but was instead hosted on an individual's Website.[7] *VirusHammer* is an example of a utility project in the sample.[8] This software does virus scanning and the project is affiliated with OpenAntiVirus.org, a nonmarket organization. Software development was the largest remaining intermediate category and was selected as the third project category for the study. An example of a project in this category is the *Ember* scripting language, which is affiliated with Hughes Technologies, a market sponsor.[9]

Control Variables

We sought to control for several factors that may influence the dependent variables. First among these were the levels of user interest and development activity on a project prior to the study period. In addition to serving as an independent variable predicting development activity, user interest at Time 1 also served as a control variable for the change in user interest over the observation period because projects with larger initial user bases might be expected to experience greater positive effects of word-of-mouth recommendations. Development activity prior to the study might spur user interest because activity may enhance the perceived usefulness of the software, and it may also signal high potential benefits to new developers, thereby influencing increases in development activity during the study. We used a statistic calculated on the Freshmeat website, project vitality, measured at Time 1, as a control for the level of development activity prior to the observation period.

Software written using more popular programming languages may have a larger pool of developers from which to draw, thus in predicting development activity a dummy variable was included to control for whether the project used C/C++, which was the largest programming language category on Freshmeat, and in the sampled projects. In addition to using more popular programming languages, some projects are specifically labeled as being targeted at particular audiences. Those targeted at a developer audience may attract greater development activity or be less appealing to users, therefore a dummy variable was used in both models to indicate whether the project description on Freshmeat indicated developers as a target audience.

Finally, the age of a project may serve as a proxy for several factors that could be important to success, including the experience of the development group in working together, the entrenchment of the software in the user community, and the development status of the project. As projects reach a stable development status, the level of development activity may decrease. Thus *age*, measured as the number of days each project had been registered on the Freshmeat website at the second observation point, was used as a control variable.

Analysis and Results

The distributions of the dependent variables were left skewed, hence we used the Box-Cox transformation approach to normalize the variables (Box and Cox 1964, Greene 1993). Given the arguments regarding the relationships between user interest and development activity, we used the Hausman specification test to assess whether a two-stage least squares (2SLS) approach was needed to allow for the possibility that the dependent variables may be codetermined (Berndt 1991). The Hausman test was insignificant ($\chi^2_{33} = 3.58$, $p =$ n.s.), and 2SLS results were not substantively different from ordinary least squares (OLS) results, thus we present and discuss OLS analyses.

Because we had categorical independent variables (license restrictiveness, sponsorship type, and project category) and continuous control and independent variables (project age, initial user interest), we used the general linear model (GLM) procedure in SPSS 12.0 to test the hypotheses. The assumption of homogeneity of variance was tested and supported using Levene's test (for change in user interest $F_{37,100} = 1.082$, $p =$ n.s. and for development activity $F_{37,100} = 0.753$, $p =$ n.s.). There were no empty cells in the sample; however, cells had unequal numbers of observations, therefore the Type III method for calculating the sums of squares was chosen because it is most appropriate for unbalanced models where there are

[7] http://www.azweb.de/kspaceduel/.

[8] http://www.openantivirus.org/virushammer.php.

[9] http://www.hughes.com.au/products/ember/.

Table 1 Descriptive Statistics and Correlation Matrix[a]

Variable	Mean	S. D.	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Change in user interest[b]	1.06	1.61	1												
2. Development activity[c]	−1.79	3.01	0.568***	1											
3. No sponsor[d]	0.73	0.45	−0.201*	−0.093	1										
4. Market sponsor[d]	0.09	0.29	0.033	−0.022	−0.533***	1									
5. Nonmarket sponsor[d]	0.17	0.38	0.209*	0.126	−0.758***	−0.148†	1								
6. Restrictive license[d]	0.72	0.45	−0.211*	0.020	0.103	−0.134	−0.017	1							
7. Software[d]	0.31	0.47	0.117	−0.045	−0.229**	−0.003	0.269**	−0.321***	1						
8. Games[d]	0.31	0.47	−0.106	0.090	0.160†	−0.056	−0.144†	0.135	−0.453***	1					
9. Utilities[d]	0.38	0.49	−0.010	−0.043	0.066	0.056	−0.120	0.178*	−0.523***	−0.523***	1				
10. User interest at Time 1	3.57	6.94	0.475***	0.297***	−0.152†	−0.026	0.198*	−0.034	0.013	−0.062	0.047	1			
11. Project age (days)	592.26	409.05	−0.073	−0.227**	−0.125	0.175*	0.012	−0.052	0.046	0.023	−0.066	−0.015	1		
12. Audience: Developers[d]	0.41	0.49	0.029	−0.129	−0.199*	0.138	0.127	−0.350**	0.687**	−0.397**	−0.277**	0.052	0.062	1	
13. Language: C/C++[d]	0.25	0.44	−0.041	0.207*	0.090	−0.017	−0.092	0.210*	−0.284**	0.111	0.165	−0.096	−0.161	−0.210*	1
14. Project vitality at Time 1	0.03	0.19	0.264**	0.187*	0.072	−0.046	−0.049	−0.102	0.161	−0.070	−0.087	0.176*	0.149	0.154	−0.069

[a] $n = 138$. [b]Transformed variable, untransformed mean = 4.38, S.D. = 9.48. [c]Transformed variable, untransformed mean = 2.29, S.D. = 3.88. [d]Dummy variable. †$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 2 General Linear Models[a]

	Change in user interest since Time 1 F (df)	Partial eta-squared (η^2)	Development activity since Time 1 F (df)	Partial eta-squared (η^2)
Language C/C++			7.550** (1)	0.057
Developer audience	5.547* (1)	0.044	2.637 (1)	0.021
Project age	1.474 (1)	0.012	9.552** (1)	0.071
Project vitality at Time 1	6.347* (1)	0.050	7.925** (1)	0.060
User interest at Time 1	28.289*** (1)	0.191	14.854*** (1)	0.106
Sponsorship	5.849** (2)	0.089	3.823* (2)	0.058
Project category	0.030 (2)	0.000	1.346 (2)	0.021
License	6.620* (1)	0.052	1.609 (1)	0.013
Sponsorship × license	3.730* (2)	0.059	4.618* (2)	0.069
Sponsorship × project category	2.530* (4)	0.078		
License × project category	1.068 (2)	0.017		
R^2 (Adj. R^2)	0.41 (0.33)		0.31 (0.25)	

[a] $n = 138$; $^{\dagger}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

no missing cells (SPSS 2002). Table 1 provides descriptive statistics for all of the variables in the analysis; Table 2 and Figures 2, 3, and 4 present the results of the analyses. The partial eta-squared values in Table 2 are an indicator of effect size, representing the variation in the dependent variable attributable to each factor, partialling out other factors (Pierce et al. 2004).

Tests of Hypotheses Predicting User Interest

H1A suggested that, over time, projects with a nonrestrictive license would experience greater increases in user interest than projects with a restrictive license. The model explained 41.3% of the variance in the change in user interest with a significant main effect for license restrictiveness ($F_{1,137} = 6.620$, $p \leq 0.05$, $\eta^2 = 0.052$) that supported H1A. H1B suggested that license restrictiveness would be more important to the change in user interest of projects that have a wider array of potential uses. The license restrictiveness x project category interaction was not significant, thus H1B was not supported.

A planned contrast of change in user interest across sponsored versus nonsponsored projects (contrast coefficients: 2 −1 −1) was used to test H2A. The contrast yielded a significant mean difference with change in user interest being higher for sponsored

Figure 2 Sponsorship × Project Category Interaction Plot (Change in User Interest)

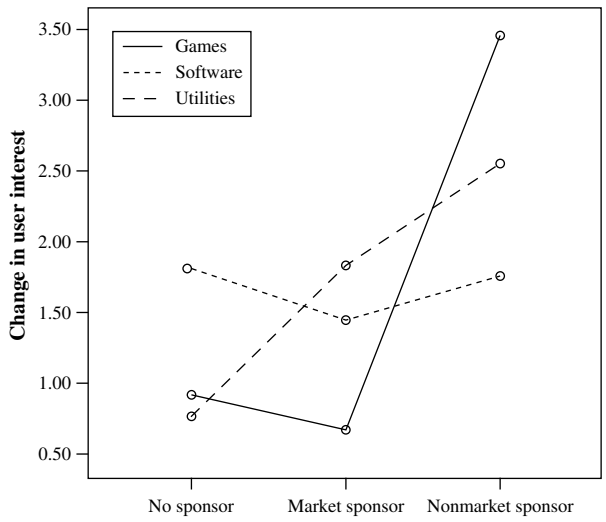


Figure 3 Sponsorship × License Restrictiveness Interaction Plot (Change in User Interest)

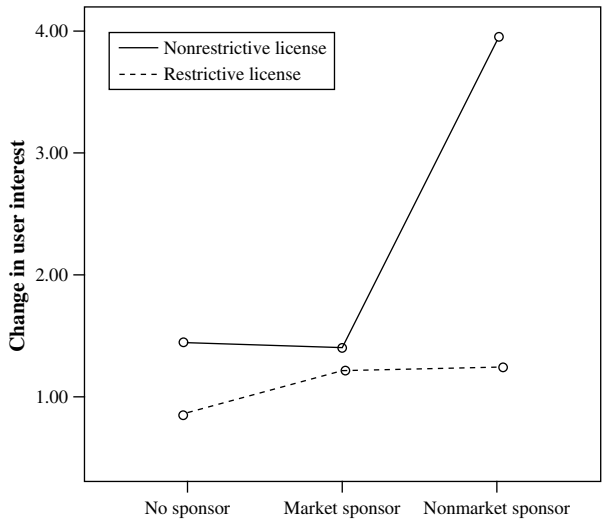
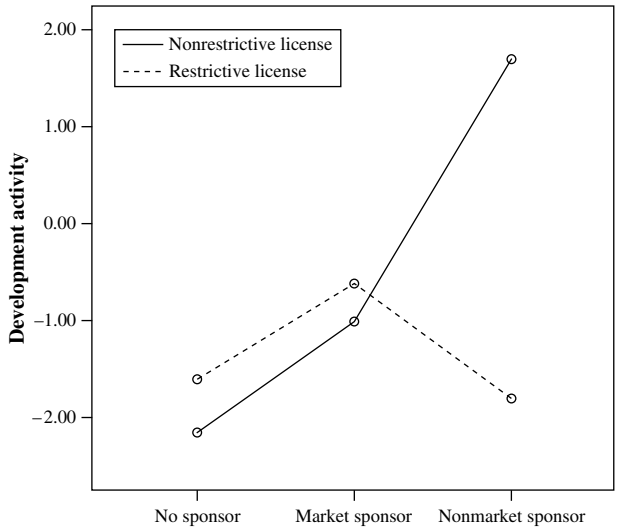


Figure 4 Sponsorship × License Restrictiveness Interaction Plot (Development Activity)



projects (difference = 1.542, $p \leq 0.05$), supporting H2A. The analysis indicated a significant sponsorship x project category interaction effect on change in user interest ($F_{4,137} = 2.530$, $p \leq 0.05$, $\eta^2 = 0.078$). The effect is shown in Figure 2. For utilities projects, nonmarket-sponsored projects had significantly more user interest than nonsponsored projects (difference = 1.702, $p \leq 0.01$), with market-sponsored projects at an intermediate level. For software development tools, there was no significant difference in user interest across sponsorship conditions. For games, there was no significant difference between nonsponsored and market-sponsored projects, but nonmarket-sponsored projects generated significantly more user interest than either other sponsorship condition ($p \leq 0.05$ for both contrasts). The different patterns between utilities and software development tools is consistent with H2B, but the result for games is not, and will be discussed further below.

A planned contrast of change in user interest between projects with market sponsorship and those with nonmarket sponsorship (contrast coefficients: 0 1 −1) was used to test H2C. The contrast yielded a significant mean difference (difference = 1.235, $p \leq 0.05$) with change in user interest being higher for nonmarket-sponsored projects, supporting H2C.

The effect of the interaction term sponsorship x license restrictiveness on change in user interest ($F_{2,137} = 3.730$, $p \leq 0.05$, $\eta^2 = 0.059$) indicated that the change in user interest was significantly higher for projects that had both nonmarket sponsors and nonrestrictive licenses than for any other group of projects ($p < 0.01$ in all contrasts), supporting H2D. This interaction is plotted in Figure 3, which also shows a marginally significant difference ($p < 0.10$) between restrictively and nonrestrictively licensed projects in the no-sponsor category. Differences among other groups were not significant.

Tests of Hypotheses Predicting Development Activity

The model explained 31.2% of the variance in the measure of development activity over the observation period. However, the effect for license restrictiveness was not significant, therefore H3 was not supported. H4A suggested that projects with a nonmarket sponsor would experience higher levels of development activity than projects with no sponsor. A planned contrast of development activity across nonmarket-sponsored and nonsponsored projects (contrast coefficients: 1 0 −1) was used to test H4A. The contrast was significant and in the expected direction (difference: 1.827, $p \leq 0.01$), supporting H4A.

H4B predicted that a positive effect for license restrictiveness on development activity would be reduced in the nonmarket-sponsored projects. The effect of the interaction term sponsorship x license restrictiveness was significant ($F_{2,137} = 4.618$, $p \leq 0.05$, $\eta^2 = 0.069$), supporting this hypothesis, and the effect was stronger than predicted in that the difference was reversed for these projects. The interaction plot is presented in Figure 4, which also shows positive but not statistically significant differences between restrictive and nonrestrictive licensing for nonsponsored projects and market-sponsored projects. H5 predicted that higher levels of user interest in a project would generate greater development activity on the project over time. A significant effect for initial user interest ($F_{1,137} = 14.854$, $p \leq 0.001$, $\eta^2 = 0.106$) on development activity supported H5.

Discussion

The goal of this research was to explore the antecedents to success in OSS projects. We developed and tested hypotheses regarding the effects of two

Table 3 Results of Hypothesis Tests

Hypotheses	Conclusion
Hypothesis 1A: OSS projects that use a nonrestrictive license will attract greater user interest over time than those that use a restrictive license.	Supported
Hypothesis 1B: The effect of license restrictiveness on OSS project user interest over time will be stronger for projects that have a broader range of potential uses than for those that have a narrower range of potential uses.	Not supported
Hypothesis 2A: Projects with a sponsor will attract greater user interest over time than those without a sponsor.	Supported
Hypothesis 2B: The effects of sponsorship on OSS project user interest over time will be stronger for projects that have a broader range of potential uses than for those that have a narrower range of potential uses.	Partially supported
Hypothesis 2C: Projects with a nonmarket sponsor will attract greater user interest over time than those with a market sponsor.	Supported
Hypothesis 2D: Projects with a nonmarket sponsor and a nonrestrictive license will attract greater user interest over time than any other combination of license restrictiveness and sponsorship.	Supported
Hypothesis 3: OSS projects using a restrictive license will attract greater development activity over time than those using a nonrestrictive license.	Not supported
Hypothesis 4A: OSS projects that have a nonmarket sponsor will attract greater development activity over time than those that do not have a sponsor.	Supported
Hypothesis 4B: The positive effect of license restrictiveness on development activity will be reduced for nonmarket-sponsored projects versus market-sponsored or nonsponsored projects.	Supported
Hypothesis 5: OSS project user interest will have a positive effect on the amount of OSS project development activity over time.	Supported

OSS project characteristics—license restrictiveness and organizational sponsorship—on two key outcomes in OSS projects: project development activity and the interest in the project among users and potential users. Results, summarized in Table 3, were generally supportive of the arguments made in this paper, indicating that licensing decisions and organizational affiliations are important to OSS project outcomes both in terms of harnessing the efforts of the development community (the model explained 31.2% of the variance in the measure of development activity) and attracting the interest of the user community (the model explained 41.3% of the variance in the measure of the change in user interest). As a whole, the results paint an interesting picture of the interactive effects of licensing and organizational sponsorship on both user interest and development activity.

Theoretical Implications

Drivers of User Interest. Although there were overall positive effects on user interest for using nonrestrictive licenses and for sponsorship, Figure 3 indicates that these effects were mainly driven by the large difference between nonmarket-sponsored projects that used restrictive versus nonrestrictive licenses, with a marginal, smaller effect between the two license types for nonsponsored projects. License restrictiveness had no effect for market-sponsored projects, and market-sponsored projects did not attract significantly more user interest than nonsponsored projects.

One interpretation of this pattern of results may be that sponsorship trumps licensing in terms of its impact on users' perceptions regarding the likelihood of the software remaining free of commercial control, and the benefits and drawbacks that users infer from market sponsorship essentially cancel each other out. In other words, the benefit that market sponsorship may bring based on the perceived availability of future support may be cancelled out by the concurrent expectation that costs may be higher as the sponsor seeks to generate rents from the project, leading to the lack of difference between nonsponsored and market-sponsored projects. Similarly, the potential user perceived benefits of nonrestrictive licensing in market-sponsored projects may be cancelled by the expectation that the sponsor will control the future direction of the project for its own benefit. For nonmarket-sponsored projects using nonrestrictive licenses, both signals (license and sponsorship) are aligned to indicate that the software will remain available for whatever purpose the user wishes to make of it. However, for market-sponsored projects using nonrestrictive licenses, the signals are somewhat at odds with each other. The license choice indicates an intention to maintain flexibility of use of the software, but the nature of the organization, being a market-driven entity, may bring this intention into question.

Sponsorship was also of varying importance to user interest across project types. Results were mostly

consistent with the reasoning that the user concerns addressed by sponsorship (e.g., support) are more relevant for software that generally has more diverse uses (e.g., utilities) than for software that generally has narrower uses (e.g., software development projects). The exception was a surprisingly large difference between nonmarket-sponsored games and games in the other sponsorship categories. To understand this difference we examined the projects in this category more closely. This point in Figure 2 represented the smallest set of projects in the sample; there were only four nonmarket-sponsored games. On investigating these further, we discovered that three of these projects were actually utilities to work with games. That is, although their owners had classified the projects under the games category on Freshmeat, the software were not actually games, but instead were emulators to allow one to play games on different platforms or consoles. Thus these projects may represent software that is similar to the software found in the utilities category. The fact that they are utilities could explain the significant positive effect of nonmarket sponsorship on user interest based on the reasoning put forth in H2B: These particular kinds of game projects might be used to enhance compatibility of other software (i.e., games) and hardware platforms. Thus, the relevance of issues addressed by sponsorship is higher for these games projects than for others.

Drivers of Development Activity. The main effect of initial user interest on development activity lent support to the argument that having an audience enhances developers' motivation to work on a project and thereby increases development activity. The interaction effect of licensing and sponsorship on development activity indicated that whereas the differences were in the expected direction, the effects of restrictive licensing on development activity for nonsponsored projects and for market-sponsored projects was insignificant. The effect was significant and in the opposite direction for nonmarket-sponsored projects.

Although the pattern in Figure 4 is in keeping with the interaction hypothesis, we had not expected the effect of licensing for nonmarket organizations to reverse (only to decrease). The fact that it did reverse may help explain the lack of support for H3. The results may be interpreted to indicate that for nonsponsored projects the situation is relatively simple: There are no organizational motives to consider, and all developers are volunteers with no organization-instilled motives, therefore the logic leading to the hypothesis that restrictive licensing elicits greater development activity (H3) may hold. When a market sponsor is present and using a restrictive license, the cues as to the project's future are somewhat at odds, in that the license indicates the software will remain open whereas the sponsor's motives may bring that intention into question, thus reducing the difference between license types. The presence of a nonmarket sponsor may alleviate concerns as to the project's future in the same way that a restrictive license would, in the sense that the restrictive license is not perceived as necessary to protect the developers' interests. Thus they are, because of their additional role as users, attracted to the greater flexibility associated with nonrestrictive licenses. The finding that nonrestrictively licensed projects attract greater development activity in this case is consistent with Fershtman and Gandal's (2004) finding that developers generate more code for projects that employ nonrestrictive licenses.

Practical Implications

The independent variables in this study were selected in part because of their practical relevance. Licensing and organizational affiliations are factors that are under the control of the individuals or organizations that start and run OSS projects. The interaction effects observed in this study indicate that decisions regarding these factors should be considered in concert with one another and with other characteristics of a project, such as the type of software being produced. Results show that both users and developers are influenced by these project characteristics. It is to the benefit of project administrators to recognize this, and it may be possible for project administrators to either enhance or reduce the effects observed in the study by communicating to user and developer audiences the reasons for their decisions regarding license choice or sponsorship arrangements rather than allowing these cues to speak for themselves.

Overall, sponsorship generally had a positive effect on the projects in the sample. Perhaps one of the

most interesting practical implications of these results is that, in contrast to some popular conceptions of volunteers banding together to create viable competitive commercial software alternatives, some organizational involvement may be crucial to move OSS into the highest realms of success. Although further research is needed to confirm this suggestion, if it is borne out there may be important policy implications for fostering the development of OSS. For example, government organizations that are interested in leveraging OSS (cf. Leventhal 2004) might also consider taking on sponsorship roles to support the development of projects.

Limitations and Future Research

The results overall support the reasoning put forth in the hypotheses, but there are important limitations that should be addressed in future work in order to rule out possible alternate explanations for the findings and to generate a more detailed understanding of the OSS phenomenon. Perhaps the most significant limitation of the current study is that we were not able to measure the suggested mediating mechanisms, hence it is possible that there are other factors responsible for the effects we observe. In particular, it is impossible to empirically distinguish between restrictiveness and familiarity of the GPL as the cause of the effects for licensing. The GPL, one of the oldest and most widely used open source licenses, could have high name recognition, which could impact the appeal of the software to users or developers. However, there are several reasons why we believe restrictiveness is the more compelling explanation.

First, although familiarity might explain main effects, we observe some relatively complex interaction effects for which we have described a theoretical rationale using restrictiveness, but for which we are unable to generate a theoretical rationale employing familiarity. Second, we find restrictiveness the more compelling explanation because it is more directly related to the incentives of all users, who may or may not be familiar with the GPL based on its relatively long history. Finally, the nonrestrictive license category included the LGPL license, which would share some of the name recognition of the GPL and the BSD, which also has a long history and should therefore share some of the effects of familiarity. Nonetheless, future research should seek to collect more subjective data to confirm the importance of the theoretical mechanisms that are argued to cause the effects found in this study. A further future research question related to licensing might be why, given the negative effect of restrictive licensing on user interest, the GPL remains by far the most popular license. This could be an historical artifact—i.e., because the GPL has been available for a long time, many projects have adopted it and there may be switching costs associated with adopting new licenses that have become available more recently. Similarly, the viral property of the license may cause it to propagate by attaching to software that would otherwise be distributed under different terms. Alternatively, it could be an effect of institutionalization of the license such that new projects continue to choose it because it is seen to enhance legitimacy. Finally, it could reflect the fact that the individuals making licensing choices are more concerned with protecting developer interests than with attracting users.

Other important limitations of the study affect the generalizability of the conclusions. First, although we took a relatively broad view of success by considering two dimensions (success among users and among developers), the operationalization of each dimension was limited to a single measure. The development activity measure, in particular, represents a narrow view of the construct and may be capturing activity that is not directly related to building the software (such as project management activity aimed at controlling the frequency of releases).[10] Other measures, such as actual software usage (for user interest) or the number of software features added over time (for development activity) should be examined in future work. Second, we limited the sample to three software categories, and so the ability to generalize across all categories of software is constrained. Although we see no reason that results should not generalize to other categories, it remains an empirical question. Also, as is evident from the unexpected findings regarding games, the software categorizations may not always be good indicators of their usage. Selection of projects that had registered on Freshmeat also places a constraint on generalizability. Such projects could differ

[10] We thank an anonymous reviewer for this insight.

in important ways from OSS projects that are not registered on Freshmeat. For example, because Freshmeat is targeted at a user population, administrators of these projects may be more motivated to popularize their software than the administrators of non-Freshmeat projects.

Finally, there are potential relationships among the constructs in our model that we were unable to explore, and these may provide fruitful avenues for future work. One of these is the possibility that sponsorship may be an outcome of project success as well as an antecedent to further success. It may be the case that projects that are originally unsponsored and that attract high levels of user interest and development activity also attract sponsors. The statistically significant positive correlation between age and market sponsorship in Table 1 may indicate that this could be especially true for sponsorship by profit-seeking organizations.

Conclusions

The main contribution of this research has been in developing and empirically testing a theoretical basis for the effects of key project characteristics—license choice and organizational sponsorship—on two different kinds of OSS project success—attracting development activity and attracting user interest to a project. The research also complements prior work by (1) providing an analysis of smaller, younger projects than have been the focus of many prior studies; (2) studying these projects over time rather than relying on a cross-sectional snapshot; and (3) going beyond the SourceForge data, which have been the basis of the most closely related prior OSS studies on success (cf. Chengalur-Smith and Sidorova 2003, Crowston and Scozzi 2002, Lerner and Tirole 2005). Taken as a whole, the results support an interesting theoretical picture of the positive and negative effects of licensing and organizational sponsorship on OSS project success. Whereas the basic premises put forth in the paper are supported, the results also serve to highlight many avenues for future research to expand our understanding of the unique context of OSS development.

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