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# Understanding the Motivations, Participation and Performance of Open Source Software Developers: A Longitudinal Study of the Apache Projects

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Understanding what motivates participation is a central theme in the research on open source software (OSS) development. Our study contributes by revealing how the different motivations of OSS developers are interrelated, how these motivations influence participation leading to performance, and how past performance influences subsequent motivations. Drawing on theories of intrinsic and extrinsic motivation, we develop a theoretical model relating the motivations, participation, and performance of OSS developers. We evaluate our model using survey and archival data collected from a longitudinal field study of software developers in the Apache projects. Our results reveal several important findings. First, we find that developers' motivations are not independent but rather are related in complex ways. Being paid to contribute to Apache projects is positively related to developers' status motivations but negatively related to their use value motivations. Perhaps surprisingly, we find no evidence of diminished intrinsic motivation in the presence of extrinsic motivations; rather, status motivations enhance intrinsic motivations. Second, we find that different motivations differentially impact participation. Developers' paid participation and status motivations lead to above average contribution levels, but use value motivations lead to below average contribution levels, and intrinsic motivations do not significantly impact average contribution levels. Third, we find that developers' contribution levels positively impact their performance rankings. Finally, our results suggest that past performance rankings enhance developers' subsequent status motivations.

*(Open Source Software; Intrinsic Motivation; Extrinsic Motivation; Software Development Performance)*

## 1. Introduction

Open source software (OSS) communities cannot exist or prosper without the contributions of highly motivated developers who are willing to donate their time and effort to the community. However, because these participants are often self-employed freelancers and volunteers, rather than traditional employees, it is not possible to solely rely on employment relationships or employment contracts to manage them. Thus, vital questions in open source software communities concern how to motivate participants and how to direct, sustain and influence their behaviors (Markus *et al.* 2000).

Several studies have revealed different motivations for contributing to open source projects (for a review see Rossi 2004). Often quoted motivations for participating in OSS development projects cover a broad spectrum including scratching a "personal itch" with respect to software functionality, enjoyment, and a desire to be "part of a team" (Ghosh 1998). Others liken the OSS community to a gift culture where the status of a participant depends on "what he gives away" (Raymond 1999). Alternatively, Lerner and Tirole

(2002) suggest that OSS participation may in part be explained by existing theories of labor economics. Lastly, as commercial companies increase their involvement in OSS projects, there are more developers being paid to contribute, adding the traditional incentive – pay – as a potential motivation to participate and raising the issue of how paid participation may affect other motivations to contribute.

Although there is no consensus in the OSS literature as to which motivation is most dominant, individual contributors could likely have multiple salient reasons for participating. This raises an important and unanswered question that we address in this study: *how are the motivations of contributors related, i.e., are they independent, complementary or contradictory?* Answering this question is significant because an assumption in studies on OSS participation is that motivations are complementary or "mutually reinforcing" (*e.g.*, Markus *et al*. 2000). However, if, for example, some motivations are negatively related to others, increasing the level of those motivations may crowd out other motivations for participating. This issue is particularly relevant when considering how paid participation affects other motivations for open source contributions. In sum, understanding whether an OSS participant's different motivations are in harmony or at odds matters because it is the participant's set of motivations, combined with knowledge, skills and abilities, that produces the participant's behaviors and performance (Mitchell & Daniels 2003).

In OSS development, the different motivations to participate have been generally classified as either intrinsic or extrinsic (Rossi 2004). Intrinsic motivation occurs when an activity satisfies basic human needs for competence, control and autonomy. This makes the activity interesting and likely to be performed for its own sake rather than as a means to an end (Deci & Ryan 2000). In contrast, extrinsic motivation stems from the environment external to the task and is usually applied by someone other than the person being motivated (Johns 1996). Contributing to OSS projects for the sheer enjoyment of coding is clearly an intrinsic motivation while being paid to contribute is the quintessential extrinsic motivation. Other motivations, such as contributing to solve a problem of personal use benefit (use value) or contributing to enhance status or career opportunities are, by definition, extrinsic, but, following Deci & Ryan (2000), contributors could *internalize* these motivations so that they are self-regulated rather than externally imposed. Following the literature in psychology (Deci & Ryan 1987), we classify these motivations as *internalized extrinsic*

*motivations*. Distinguishing the different types of motivations (pure extrinsic, internalized extrinsic, and pure intrinsic) allows us to examine a second question: *how do differences in OSS contributors' motivations relate to differences in their participation?* It is important to understand whether all types of motivations affect OSS participation equally or in the same way. Studies of OSS participants do not often consider whether different motivations differentially relate to participation. However, some motivations may strongly affect participation, while others may not be as salient. For leaders of OSS projects who are trying to attract developers to participate in projects or to sustain their level of participation, it is imperative to understand which types of motivations are likely to generate more (or less) participation.

Our third question concerns the link between the level of participation and performance ranking, *i.e.*, *how do levels of participation relate to changes in performance rankings?* This question is salient for OSS communities like Apache (the focus of our study). The Apache projects were not originally organized around a single person or primary contributor. As such, the success of the Apache projects depends on shared leadership and the contributions of participants. The projects are organized using a meritocracy, or as Roy Fielding explains it: "the more work you have done, the more you are allowed to do" (Fielding 1999, p. 43). For the meritocracy to be effective, promotions within the Apache community should be based on contributions to the Apache projects. In answering our third question, we relate a participant's promotion (or performance ranking) to the level of his or her prior contributions to the Apache software code. This provides an important validation of whether the meritocracy is functioning as intended.

Finally, while motivation is an antecedent of behavior and performance, research in psychology has also recognized the effect of performance feedback on motivation. For example, it has been shown that feedback considered controlling tends to decrease intrinsic motivation. On the other hand, research by Sansone (1986) suggests that feedback regarded as competence-enhancing can increase subsequent intrinsic and extrinsic motivation. One of the tenets of OSS projects is the frequent provision of feedback to contributors (Moon & Sproull 2002). As we have noted, in some OSS projects like Apache, continued contribution is rewarded with a change in performance ranking. Hence, the last question on our agenda: *how does a change in performance ranking affect the subsequent motivations of OSS participants?* To the best of our knowledge, no studies of

OSS communities have considered how changes in performance rankings affect subsequent motivations for participating. However, the answer to this question has important implications for open source communities that wish to enhance or sustain the motivations of their participants over the longer term.

In §2 of the paper, we draw on the relevant literature in psychology to develop our theoretical model. §3 describes the empirical evaluation of our model involving a longitudinal field study of the motivations, contributions and performance of software developers in the Apache web server projects. §4 presents the analysis and results. We discuss our results in §5, and conclude in §6 by identifying the contributions and limitations of our study and its implications for research and practice in OSS development.

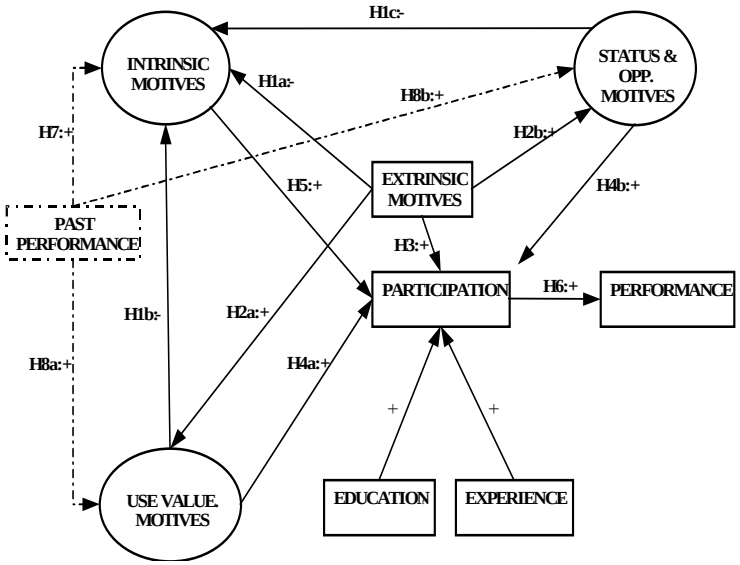
## 2. Theoretical Framework

The theoretical framework for our study leverages the general model of motivation and performance in organizational and social psychology (Campbell & Pritchard 1976). In this framework, motivations vary across individuals and combine with individuals' knowledge, skills and abilities to produce task-relevant behaviors. These behaviors contribute to individual performance. It is important to distinguish motivation from behavior. Work motivation is the psychological force within an individual that determines the direction of the individual's behavior in an organization, the individual's level of effort, and the individual's level of persistence in the face of obstacles (Kanfer 1990). Motivation has an important influence on performance because it focuses attention on particular task elements and produces effort as people work harder when they are motivated. While motivation is a psychological state, the outcome or results of that state is behavior (Mitchell & Daniels 2003). Behavior also differs from performance because performance is an *evaluation* of the results of an individual's behavior usually by someone other than the individual – it involves determining how well or poorly an individual has accomplished a task (Kanfer 1990).

Applying the general model of motivation and performance to the OSS context, we stipulate that motivations vary across OSS contributors. Combined with developers' knowledge, skills, and abilities, motivations influence their participation in OSS projects as exemplified by the level of their contributions to the source code. Over time, contributors' participation is evaluated by the OSS community. This performance evaluation may lead to an increase in a contributor's rank within the community. An advance in

rank can, in turn, act as feedback to influence the future motivations of contributors. Figure 1 illustrates our theoretical model.

**Figure 1: Theoretical Model**




### 2.1 Intrinsic and Extrinsic Motivations in OSS Development

OSS development affords a particularly rich context in which to examine individual motivations. On the one hand, intrinsic motivations are likely to be important as contributors have a high degree of autonomy and self-determination and are valued for their competence. On the other hand, the OSS community provides extrinsic motivations such as reputation or status. Indeed, empirical studies of OSS contributors find that the participants report a variety of reasons for participating in projects (Hertel *et al*. 2003). Thus, our model includes an array of OSS participation motivations ranging from strictly intrinsic to strictly extrinsic to those that have both intrinsic and extrinsic characteristics.

Research has investigated the relationship between psychological needs and intrinsic motivation. Specifically, intrinsic motivation has been linked to the satisfaction of human needs for autonomy and competence (Deci 1975). In the OSS context, human needs for autonomy and competence are readily satisfied. As researchers have established, software development is an inherently motivating task as it is complicated and creative, yet difficult to observe and thus not easily monitored (Kirsch 1996; Weinberg 1998). Compared to software development in an organizational setting, contributing to OSS projects allows individuals even greater opportunities to express their creativity, enjoy their work, and experience a sense of

satisfaction and accomplishment (Lakhani & Wolf 2005). It is these characteristics that draw many competent, self-directed programmers into OSS communities.

At the other extreme, extrinsic motivation has been linked to the operant conditioning literature (Skinner 1953) that advocates the use of incentives to reinforce desired behavior. Hence, extrinsic motivation is characterized by a strong focus on reward contingencies, which in Western-oriented economies is often represented by pecuniary compensation. While OSS communities do not have a profit motive per se and hence do not offer monetary compensation to contributors, the pervasive commercial interest in many OSS products has generated a thriving OSS industry. It is not unusual for third parties to employ programmers for the specific purpose to contribute to OSS projects. Examples include Time Warner's engagement in Mozilla and IBM's involvement in both the Linux and Apache OSS projects.

Between intrinsic and extrinsic motivations there exists a continuum of motivations that are considered a mix of intrinsic and extrinsic as they are clearly not intrinsic at the outset, but undergo an internalization process that moves them away from strictly extrinsic motivations (Ryan & Connell 1989). Deci & Ryan (1987) refer to these motivations as *internalized extrinsic motivations*. According to Deci & Ryan (2000), internalization occurs when individuals assimilate and reconstitute external incentives or contingencies, transforming these external incentives into their own motives and leading to self-regulation. Self-regulation can take place in two ways: through introjection or through identification (Deci & Ryan 2000). Internalized extrinsic motivation based on *introjected regulation* is related to attainment of ego-enhancement and feelings of worth. In the OSS context, an example of this motivation involves two related quests: for status and for career opportunities. Raymond (1999) early on recognized status, or what he termed "ego-boo," as an important driver of participation in OSS communities. Similarly, OSS participation can be seen as a move to enhance career prospects. As described by Lerner & Tirole (2002), OSS communities offer an excellent setting in which a participant motivated by career concerns can signal his or her abilities to the labor market. Likewise, von Hippel and von Krogh (2003) argue for the existence of private incentives for the provision of a public good such as OSS. It is important to note that motivations based on either status seeking or career enhancement may both be internalized in an effort to increase one's standing in a reference group.

Internalized extrinsic motivation based on *identified regulation* is a more self-determined form of extrinsic motivation. In this form of regulation, individuals identify with an action and personally endorse it, leading to an identification that is accompanied by a higher degree of perceived autonomy. By definition, this type of motivation is extrinsic as it derives from the personal importance of the outcome, rather than the performance of the task (Ryan & Deci 2002). In OSS communities, an example of an *internalized extrinsic motivation* is "use value," or the desire to fix a bug or solve a problem of immediate relevance to the contributor. Some studies have identified use value as a dominant motivation of OSS contributors (*e.g.*, Ghosh *et al*. 2002; Hertel *et al*. 2003; von Hippel 2001). While use-value is extrinsic because of the personal benefit to the user (Markus *et al*. 2000; Rossi 2004), from a psychological point of view, use value is internalized as a value of the OSS community and transformed into a personally endorsed value.

In this study, we examine the relationships *between* different OSS motivations. The literature in psychology on motivation has examined the relationships between intrinsic and extrinsic motivations (Lepper & Henderlong 2000). We consider how these relationships may apply in the OSS context.

Experimental research in psychology (Deci 1971; Lepper *et al*. 1973) has shown that under certain conditions, extrinsic motivations displace intrinsic motivations. In cases where incentives are contingent upon performance, individuals expect to be rewarded, or incentives are tangible, external incentives undermine characteristics of intrinsic motivation such as free-choice behavior and self-reported interest. Multiple meta-analysis studies (Rummel & Feinberg 1988; Wiersma 1992; Deci *et al*. 1999) have found general support for this finding; Osterloh & Frey (2000) refer to this as the "crowding-out" effect. In general, previous research has found that the undermining effect of external incentives is especially powerful for monetary compensations that are perceived to be controlling. The effects are larger for monetary rather than symbolic incentives and for expected rather than unexpected incentives. The crowding out effect is also more observable for complicated rather than simple tasks (Deci *et al*. 1999; Lepper & Henderlong 2000).

In the context of OSS projects, strictly extrinsic motivations apply directly to those participants who are remunerated for their activities. Drawing on the logic of the crowding out effect, we would expect that monetary incentives for involvement in OSS projects would weaken intrinsic motives for participating.

When participants are engaged in a traditional employment relationship with a firm, the employer has the right to establish the policies, rules and terms of employment, to structure the work environment, and to assign tasks to employees. This suggests that participants who are paid to contribute to OSS projects are likely to have less autonomy in choosing which features they want to code and less freedom in how they do their work. If, as Weinberg (1998) argues, programming itself provides the strongest intrinsic motivation for software development, "… *if the programmer is given a chance to do it his way*…" (p.184), any restriction of participants' task autonomy should be negatively associated with their intrinsic motivations to participate in OSS projects. Thus, we hypothesize that:

**H1a**: *Contributors' intrinsic motivations to participate in OSS projects are negatively related to being paid to participate.*

The literature in psychology suggests that other extrinsic motivations, even those that are internalized (and thus not strictly extrinsic) could crowd out intrinsic motivations. A meta-analysis by Deci *et al*. (1999) examined the results of 128 laboratory studies of extrinsic and intrinsic motivation conducted over the past 25 years. The results from this meta-analysis show that most types of extrinsic motivations (and especially those specifying contingencies related to the task being performed) undermined intrinsic motivation. The authors found a positive effect of extrinsic motivations on intrinsic motivation only when the feedback was both positive and verbal. With respect to internalized extrinsic motivations that are based on the identification of values, Ryan & Deci (2002) observe that such identification is often compartmentalized and separated from one's other beliefs and values and is characterized by a reduced self-determination. Hence, a contributor may identify with the OSS community through use value motivation only in a restricted, practical sense with limited self-determination and reduced pure intrinsic motivation. For example, a contributor who identifies strongly with an OSS community may choose to work on tasks that are not inherently interesting because completing the tasks provides value to the community. In her review of the literature on OSS motivations, Rossi (2004) states that use value motivations can provide a powerful explanation for why people do tasks that may be uninteresting and mundane and that are not "appreciated per se, for the intrinsic pleasure and enjoyment a programmer may derive from them" (p. 5). Thus, we expect:

**H1b**: *Contributors' intrinsic motivations to participate in OSS projects are negatively related to their use value motivations to participate.*

Ryan (1982) finds that internalized extrinsic motivations based on introjection such as ego-enhancing motivations reduce intrinsic motivation for the target activity. Individuals may develop mastery for the purposes of gaining reputation, but find that motivation based on introjected regulation is quite controlling and less self-regulated. In the context of OSS development, individuals who are highly motivated by status could find themselves working on tasks they may not necessarily enjoy but rather that are likely to enhance their reputation in the community. For example, writing open source software and helping to test and debug it are critical ways to earn respect in OSS communities (Markus *et al*. 2000). However, a contributor who is motivated by reputation concerns may not particularly enjoy testing and debugging software, but may feel it necessary to do these activities to gain status in the OSS community. This suggests that motivations grounded in status seeking motivation are likely to be negatively associated with the pure enjoyment of contributing. Thus, we posit that:

**H1c**: *Contributors' intrinsic motivations to participate in OSS projects are negatively related to their status motivations to participate.*

Much of the research in psychology has focused on the effects of external incentives on intrinsic motivation. However, Ryan and Deci (2002) suggest that external incentives that promote feelings of self-determination can promote self-determined (*i.e.*, internalized) extrinsic motivations. Performance-contingent incentives (such as pay) can influence how individuals approach a task as well as their motivations during the performance period (Hennessey 2000) because such incentives can make doing well more personally important. That is, incentives that motivate individuals to strive for competence can amplify or enhance their other extrinsic motivations. Following this logic, we would expect that being paid to contribute to OSS projects is complementary with other extrinsic motivations including use value and status. Thus, individuals who are being paid to contribute to OSS projects could also have a high use value motivation because making contributions that improve the use value of the source code demonstrates competence for which they will be financially rewarded. Hence, we hypothesize:

**H2a**: *Being paid to participate in OSS projects is positively related to contributors' use value motivations to participate.*

Similarly, individuals who are being paid to contribute to OSS projects are likely to have higher status motivations because an interest in attaining status motivates individuals to demonstrate competence for which they will be financially rewarded. Therefore, we expect that:

**H2b**: *Being paid to participate in OSS projects is positively related to contributors' status motivations to participate.*

### 2.2 Motivations and Participation in OSS Development

According to the classic literature on operant conditioning (Skinner 1953), behavior that is rewarded with positive reinforcement is more likely to be repeated in the future. In Western societies, monetary compensation is the ultimate positive reinforcer to regulate economic activities in organizations. Hence, we would expect that contributors who are paid to participate in Apache projects would participate more intensely than those who are not paid. This is because their wages act as a constant positive reinforcer of their participation behavior. Thus,

**H3**: *Being paid to participate in OSS projects is positively related to contributors' level of participation.*

We would also expect that individuals with higher levels of use value motivations would exhibit higher levels of participation. In terms of use value motivations, one of the most often cited drivers of OSS participation is the opportunity to create code that meets the specific needs of a developer (Raymond 1999). Fixing a bug or solving a problem of immediate relevance to the programmer provides a powerful motivation to create the software code in the first place (Lerner & Tirole 2002). High levels of "use value" motivation therefore suggest a high level of participation. Thus,

**H4a**: *Contributors' use value motivations to participate in OSS projects are positively related to their level of participation.*

Status motivations should also be a strong driver of participation. Raymond (1999) likened OSS communities to gift cultures, where the sought-after status is determined by the programmer's contribution. In addition, human capital theory (Becker 1962) suggests that individuals, endowed with differing aptitudes

and abilities, will strive to acquire additional knowledge and experience as long as the expected incentives are greater than the expected costs. In a slight variation, signaling theory (Spence 1976) presumes that individuals showcase their education and experience to signal imperfectly observable productivity characteristics to current and future employers. Human capital and signaling theories suggest that OSS contributors who are motivated by status concerns will participate as a way of improving and signaling their programming abilities and competencies (Hann *et al*. 2002). Therefore, we hypothesize that:

**H4b**: *Contributors' status motivations to participate in OSS projects are positively related to their level of participation.*

The literature in organizational psychology suggests that the "ideal" intrinsic motivation is "in the work content itself" (Calder & Staw 1975, p. 539). Tasks that are intrinsically motivating have a direct and strong association between the activity and the individual's purpose for performing the activity. Therefore, engaging in the task directly satisfies the individual's goals. In an experimental study, Shah and Kruglanski (2000) find that the strength of the activity-goal association is positively related to indices of intrinsic motivation, including the self-reported frequency of engagement in the activity and the importance one places in doing the activity. Thus, Shah and Kruglanski conclude that individuals who are intrinsically motivated to perform some activity will perform it very intensely. In the context of OSS development, intrinsically motivated contributors should have higher levels of participation because they like to code, and by coding they are directly satisfying their desires.

Other psychologists have linked intrinsic motivation to task participation via its effect on creativity, because an intrinsically motivated orientation to task performance promotes characteristics that are essential for creativity (Amabile, *et al*. 1986). For example, individuals with high levels of intrinsic motivation focus more on the task, are more willing to take risks, and will explore alternative strategies for performing the task (Hennessey 2000; Osterloh & Frey 2000). Higher creativity should lead to higher participation in OSS projects for several reasons. First, it should focus the developer's attention on the task of coding. Second, it should help developers to persist in solving difficult or challenging problems by exploring alternatives and "thinking outside the box." Indeed, a survey study by Lakhani & Wolf (2005) provides empirical support for

a link between creativity and task participation. The researchers found that a personal sense of creativity has the strongest association with effort (hours worked) by contributors to OSS projects. As such, we would expect contributors with higher intrinsic motivations to participate more substantially in OSS projects, because intrinsic motivation promotes the characteristics needed to perform software development. Thus:

**H5**: *Contributors' intrinsic motivations to participate in OSS projects are positively related to their level of participation*.

### 2.3 Participation and Performance in OSS Development

As we have noted, psychologists distinguish performance from behavior. Performance is the outcome of an evaluation by others of an individual's behavior, and this behavior is often manifested by individuals' task output (Mitchell & Daniels 2003). In the context of OSS development, several OSS communities periodically evaluate the actual contributions of their members and assign each member a certain performance ranking. These rankings are based on merit and reflect the contributors' level of participation in the OSS community. Advancement within the meritocracy recognizes individuals' commitment and contributions to the OSS projects (Fielding 1999). Hence, we expect that:

**H6**: *Contributors' level of participation in OSS projects is positively related to their performance ranking.*

In considering the antecedents of participation and performance, we control for individual contributors' knowledge, skills, and abilities in terms of their level of education and experience. In software development, both education and experience are very important antecedents of productive capacity (Ang *et al*. 2002). Thus, consistent with the literature on task performance (Campbell & Pritchard 1976), we expect that developers' education and experience positively relate to their level of participation in OSS projects.

### 2.4 Past Performance and Subsequent Motivations in OSS Development

Studies in psychology show that although incentives and feedback that are viewed as controlling can decrease an individual's subsequent intrinsic motivation (Deci & Ryan 2000), the opposite is true if these external evaluations are presented as indicators of personal competence (Pittman *et al*. 1980; Ryan *et al*. 1983). Incentives that have an informing aspect about task performance can increase individuals' feelings of

internal control and self-efficacy, and can raise their level of enjoyment in the task (Lepper & Henderlong 2000). This is because people tend to like to do things they think they are good at (Sansone 1986). Thus, all else equal, an increase in an individual's perceived competence at an activity should increase his or her level of intrinsic motivation for the task. In the OSS context, we expect that merit-based performance rankings would have more of an informing aspect than a controlling aspect. An advance in rank communicates important information to contributors about their ability and productive capacity in software development as well as the value of their contributions to the OSS community. Following Sansone (1986), an increase in ranking should therefore enhance contributors' sense of competence, self-efficacy and enjoyment in participating. This implies that,

**H7**: *An increase in contributors' performance ranking is associated with an increase in their intrinsic motivations to participate.*

As early as 1943, Hull proposed that motivation can arise from the reinforcer itself. He termed this incentive motivation. Incentive motivation is dependent upon the strength of the incentive. As the size of an incentive increases, so does the level of incentive motivation and the likelihood of the individual behaving in such a way as to bring about an even greater incentive in the future. This is because the receipt of extrinsic incentives imparts information about the likelihood of receiving future extrinsic incentives for similar behaviors (Lepper & Henderlong 2000). Expectations of future incentives can thus provide continued extrinsic motivation for an individual to engage in previously rewarded activities.

In the context of OSS communities, increases in performance ranking could increase contributors' internalized extrinsic motivations in several ways. From a psychological point of view, a developer who contributes code that improves the use value of the software will experience a subsequent increase in rank, and this will reinforce the internalization process of the use value motivation through identification (Ryan & Deci 2002). Thus, she could expect that future use value contributions will strengthen her identification with the community and lead to renewed internalization through future increases in rank. In this way, a prior increase in rank could increase developer's internalized extrinsic motivation to make use value contributions in the future. Hence:

**H8a**: *An increase in contributors' performance ranking is associated with an increase in their subsequent use value motivations to participate.*

In addition, a promotion in rank is certainly associated with greater status in the OSS community (Raymond 1999; Lerner & Tirole 2002). Following Ryan (1982), a promotion in rank in one time period could therefore reinforce internalization of the status motivation through introjection. The increase in a contributor's status motivation could then lead to future source code contributions. Inasmuch as an increase in status is seen as career enhancing (Lerner & Tirole 2002; Hann *et al*. 2002), a rank increase will also lead to a reinforcement of the status motivation through introjection. Thus, we hypothesize that:

**H8b**: *An increase in contributors' performance ranking is associated with an increase in their subsequent status motivations to participate.*

## 3. Method

We evaluate our hypotheses empirically, analyzing archival data collected from OSS project records over a period of four years, and from a targeted survey of OSS participants. The following describes the setting of the data collection, each data source, and our measures of key variables.

### 3.1 Research Setting

We investigated three major OSS projects under the control of the Apache Software Foundation (ASF). The ASF includes a number of subprojects related to the development of a full-featured web-server product offering. We studied the largest and most significant of these projects including the Apache web server project which is a freely available source code implementation of an HTTP server and is the project around which the Apache Group initially formed; the Jakarta project which currently consists of 19 Apache related Java subprojects; and the XML project which currently consists of 16 Apache related XML subprojects.

The Apache context is very well suited for examining the relationships between motivation, participation and performance in OSS development. As a meritocracy, status, responsibility, and benefits are commensurate with contribution (Fielding 1999). There are several observable levels of recognition or rank within the ASF. In order of increasing status, these are *developer*, *committer*, *project management committee member*, and *ASF member*. In all cases, advancement within the hierarchy is in recognition of an individual's

commitment and contributions to an Apache project. Further, while the number of attainable ranks is limited, the number of promotion opportunities at any rank is not constrained. For example, there is no limit to the number of contributors who can achieve the rank of "developer" or to the number of developers who can be promoted to the rank of "committer". Similarly, a promotion to ASF member is not contingent on a number of predetermined positions (Fielding 1999). Thus, there is no rationing of promotion opportunities, and advancement reflects an objective measure of a positive peer review of one's performance.[1]

### 3.2 Data Collection

**3.2.1 Archival Data.** All OSS work products are placed in the public domain under various "free software" licensing arrangements. Apart from the source and binary codes of the actual software programs, Apache products include developer web sites, change logs, documentation, and developer communications in the form of email archives. From these products, we extracted two types of information: each contributor's progression along the Apache career path, and each contributor's source code contributions to the project.

To assess a contributor's performance, we captured the upward progression as a series of discrete transitions from one level to another in the ASF meritocracy. This resulted in a time line for the promotion of individuals within each project. To extract information about individual contributions, we developed tools to mine submissions of the individual developers. A submission to an OSS project is known as a "patch" – an analogue to modification requests in traditional software development environments. The data encompassed contributions made and accepted into any of our three target Apache projects. Data collection was completed in January 2003 and included all contributions from 1999 through 2002.[2]

**3.2.2 Survey Data.** A secure, web-based survey of Apache contributors was conducted to obtain respondent motivations for participation in the project. Dr. Roy Fielding, then chairman of the ASF, introduced the survey to 1,301 uniquely identified contributors via e-mail in November 2000. Two hundred thirty-three e-mail invitations were undeliverable. Of the remaining 1,068 contributors, 325 completed the instrument, yielding a response rate of 30%. Thirty-seven responses contained one or more missing pieces of information and were thus dropped from further analysis, yielding a usable sample of 288 responses. An

[1] Further details on the research site can be found in the online Appendix.
[2] A more detailed description of the archival data and the data extraction process are in the online Appendix.

analysis of response bias using nonparametric tests of location and empirical distribution indicates that our sample is representative of the overall population of Apache contributors.[3]

### 3.3 Measures

In the following paragraphs, we first define our measures of motivation followed by a description of our measures of OSS participation and performance. Our data form a panel covering years 1999 through 2002 (denoted as periods 1 through 4) with measures of individual participation (in periods 2 and 3), performance (in periods 3 and 4), and past performance (in periods 1 and 2). To this panel, we add cross-sectional survey data, collected toward the end of period 2, containing the indicators of respondent motivations. The panel provides the basis for the development of all subsequent measures and tests of hypotheses. To highlight the temporal nature of the measures and their relationships, we use the following notation. For variables denoted as $X_{t_a^z}$, the subscript $t_a^z$ denotes the sum of variable *X* for periods *a* through *z*. Also note that, $X_{t_a^a}$, represents the cross-sectional value of variable *X* for period *a*.

**3.3.1 Motivations.** Following theoretical discussions of work motivation (Mitchell & Daniels 2003), we conceptualize OSS participation behavior as being "driven" by different motivational underpinnings. These motivations can be thought of as existing on a continuum ranging from purely *extrinsic* to purely *intrinsic*. Adopting this perspective, monetary compensation is viewed as more strictly extrinsic than other types of extrinsic incentives (*e.g.*, Calder & Staw, 1975). Individuals are extrinsically motivated if they are able to satisfy their needs indirectly, especially through monetary compensation; indeed, the "ideal" extrinsic incentive identified in the literature is strict "pay for performance" (Osterloh & Frey 2000, p. 539). Consistent with this literature, we measured *extrinsic* motivation ($\text{EXTRINSIC}_{t_2^2}$) as the average number of hours per week for which respondents were paid for their Apache development efforts.

We also conceptualized two internalized extrinsic motivations: *use value* and *status*. To measure *use value* motivations ($\text{USEVALUE}_{t_2^2}$), we draw upon the conceptualization of use value in the OSS literature (*e.g.*, von Hippel 2001), using two scale items that capture the extent to which solving bugs or problems or adding needed features is important to developers in motivating their participation. We assess *status*

[3] Detailed results from our assessment of response bias are reported in the online Appendix.

motivations ($STATUS_{t_2}^2$) using measures consistent with the OSS literature regarding the motivating potential of status (Raymond 1999). Four scale items capture the extent to which participants are motivated by status considerations to make contributions.

Finally, consistent with the literature on motivation (Lepper & Henderlong 2000), we operationalized *intrinsic* motivation in terms of the motivating potential of the task itself. That is, intrinsic motivation is the extent to which participants make code contributions because developing software is an activity they enjoy and one that satisfies their needs for competence, control or autonomy. We measured *intrinsic* motivation ($INTRINSIC_{t_2}^2$) using four scale items designed to capture the extent to which OSS participants are motivated by aspects of the task itself to make contributions.

Following Anderson & Gerbing (1988) we assessed the psychometric properties of the motivation measurement scales used in this study for content, convergent, and discriminant validity as well as for reliability. Overall, the tests provide strong support for the reliability and validity of the motivation measures used in this study.[4]

**3.3.2 Participation.** While OSS volunteers provide many different kinds of valuable services to their respective projects (Shah 2003), a principal participation behavior consists of authoring and maintaining the software, *i.e.*, writing lines of software code. Insider accounts regarding OSS project organization and operation suggest that it would be improbable for participants to advance in the Apache meritocracy without substantive and sustained software code contributions.[5] Thus, we measured participation based upon the number of source code contributions submitted and accepted by the project. A potential concern with this measure is whether accepted source code contributions equal submitted contributions, that is, does consideration of only accepted contributions underestimate participation. To investigate whether this concern is salient for the Apache projects in our study, we investigated all contributions submitted by a randomly selected 10% of the contributors in our sample. Because Apache does not distinguish or track the number of "accepted" versus "rejected" submissions, we searched through email archives to follow the history of each

[4] The online Appendix lists the measurement scale items and their sources for each measure of motivation. Results from the reliability and validity analyses are also reported in the online Appendix.
[5] Personal exchange with Dr. Fielding.

participant's interactions with the Apache community. We found that the participation behavior of these contributors was more similar to a "revise and resubmit" process than to an "accept or reject" process. As described by other OSS researchers, the participants in our sample first engaged in getting-to-know behavior by analyzing the source code and/or participating in discussions on message boards; Von Krogh *et al*. (2003, p. 16) have characterized this behavior as "a significant period of observation (lurking)". Often, the contributors' submissions were accepted without modification. Sometimes, contributors were asked to make changes before their submissions were accepted. This "revise and resubmit" procedure is similar to that described by Raymond (1999) and Markus *et al*. (2000). None of the code submissions for our random sample of Apache contributors was rejected outright. This suggests that our measure of participation as code submitted *and* accepted provides a reasonable estimate of the level of participation for contributors.

To capture the immediate and subsequent effects of motivations on behavior, our measure of participation ($\text{PARTICIPATION}_{t_2}^{3}$) is derived using contribution-based metrics for periods 2 and 3 – the period covering the survey and the following period. As a check of robustness, we derived several alternative measures of contributions. The first measure is simply the cumulative number of patches submitted and accepted into the software revision control system for the particular year. The number of lines of software code written or changed is a commonly used productivity metric in software development organizations (Boehm *et al*. 2000); thus, our second measure is the cumulative number of lines of code submitted and accepted for the given year. Finally, to account for potential productivity differences between programming languages of the Apache subprojects under consideration, each contribution is converted to a common function point metric using industry standard language conversion factors (Boehm *et al*. 2000). Our primary analysis uses the function point metric as the measure of contributors' participation. Lastly, to control for project level idiosyncrasies that may influence participation, we operationalized each measure of participation as the deviation of the measure from the applicable subproject mean.

**3.3.3 Performance.** To operationalize individual performance we leveraged the fact that Apache operates as a meritocracy (Fielding 1999). Promotion to a higher rank within the Apache hierarchy is awarded after one or more cycles of contribution followed by a positive peer review and thus, is an

acknowledgement of an individual's substantive contributions to the project. This operationalization of performance is consistent with the literature in psychology; as Mitchell & Daniels (2003) explain, performance is an "outside standard that is … usually assessed by others" (p. 227). Measuring performance as rank advancement in the Apache meritocracy satisfies the important criteria that someone other than the individual being evaluated is making the rating. In addition, meta-analysis studies in psychology suggest that measuring performance over time using measures of promotional progress is one of the most reliable ways to measure performance, and that measures of promotional progress also have higher validity than other types of performance measures (Meyer 1987). Rank advancement in the Apache meritocracy is clearly an indicator of promotional progress, and thus should be a reliable and valid measure of performance.

We operationalized our performance measure ($\text{PERFORMANCE}_{t_3^4}$) as the number of the changes in ASF rank experienced from period 3 to period 4 – the period after our measures of motivation and participation. This temporal distinction between our measures of motivation, participation and performance is consistent with the general model of motivation and performance in psychology (*e.g.*, Mitchell & Daniels 2003) in which the relationship between motivation, behavior and performance is properly considered as a sequence and not as simultaneous events. As we did for our measure of participation, we control for possible subproject differences in our performance measure by operationalizing respondent performance as a deviation from the subproject mean performance.

**3.3.4 Contributor's Knowledge, Skills and Abilities**. The literature on performance has identified individual characteristics such as knowledge and skills as antecedents of participation. As described earlier, these characteristics are difficult to measure, and are frequently assessed through the use of proxies, such as the level of education and experience. Following the extant research (*e.g.*, Ang *et al*. 2002), we measured these constructs using demographic survey items in which respondents reported their years of education ($\text{EDUCATION}_{t_2^2}$), and their total years of work experience ($\text{EXPERIENCE}_{t_2^2}$).

## 4. Analysis and Results

Our theoretical model stipulates measurements in various time periods. Motivation is an antecedent of participation, and participation is an antecedent of performance. Naturally, the data underlying these

constructs has to reflect this sequence. In our research design this requires the collection of data of participation and performance of up to two years *after* the measurement of the motivation constructs. Using past performance as an antecedent of motivation requires data collection of up to two years *prior* to the measurement of the motivation constructs. Including past performance in this model reduces the number of data points due to 'late entry' into the Apache career. Hence, we follow a two-step estimation strategy. In the first step we estimate the motivation – participation – performance relationships with all respondents, thereby utilizing the maximum number of available data points. To test the past performance – motivation relationships of H7 and H8, we augment our primary model with our measure of past performance, analyzing data only from those respondents who had started their Apache careers as of period 1.

**4.1 Model and Estimation**

In order to test our hypotheses, we specified the following structural equations in a simultaneous equation model (SEM):[6]

$$\text{PERFORMANCE}_{t_3^4} = \alpha_o + \alpha_1 * \text{PARTICIPATION}_{t_2^3} + \varepsilon_1$$

$$\text{PARTICIPATION}_{t_2^3} = \beta_o + \beta_1 * \text{INTRINSIC}_{t_2^2} + \beta_2 * \text{EXTRINSIC}_{t_2^2} + \beta_3 * \text{USE VALUE}_{t_2^2} + \beta_4 * \text{STATUS}_{t_2^2} + \beta_5 * \text{EDUCATION}_{t_2^2} + \beta_6 * \text{EXPERIENCE}_{t_2^2} + \varepsilon_2$$

$$\text{INTRINSIC}_{t_2^2} = \gamma_0 + \gamma_1 * \text{EXTRINSIC}_{t_2^2} + \gamma_2 * \text{USE VALUE}_{t_2^2} + \gamma_3 * \text{STATUS}_{t_2^2} + \{\gamma_4 * \textit{PERFORMANCE}_{t_1^2}\} + \varepsilon_{3t}$$

$$\text{USE VALUE}_{t_2^2} = \eta_0 + \eta_1 * \text{EXTRINSIC}_{t_2^2} + \{\eta_2 * \textit{PERFORMANCE}_{t_1^2}\} + \varepsilon_{4t}$$

$$\text{STATUS}_{t_2^2} = \phi_0 + \phi_1 * \text{EXTRINSIC}_{t_2^2} + \{\phi_2 * \textit{PERFORMANCE}_{t_1^2}\} + \varepsilon_{5t}$$

Our analysis approach follows the factor analytic (FA) simultaneous equation model (SEM) (*i.e.*, FASEM) approach most commonly used to evaluate path analysis models with latent variables (Anderson & Gerbing 1988). Due to non-normality in our data (Normalized Mardia's Coefficient = 11.32), we estimated our model using elliptically re-weighted least squares (ERLS). ERLS has been shown to be superior to maximum likelihood when estimating models where data exhibit even moderate departures from multivariate normality (Sharma *et al*. 1989).

[6] Lagged PERFORMANCE (for periods 1 and 2) is in equations for INTRINSIC, USE VALUE and STATUS *only* to test H7 & H8.

We evaluate model fit using a two-index comparison strategy. Following Hu & Bentler (1997), we judged the adequacy of the hypothesized models by first examining the $\chi^2$ for significance and the $\chi^2$/df ratio for a value less than 3. Then, we compared the model SRMR to a cutoff value of 0.08 and either a CFI "close to" 0.95 or an RMSEA where the 90% confidence interval includes a value of 0.07 or less.

**4.2 Results**

We assessed model performance against several standard model instantiations (Marsh 1994).[7] The first is a saturated model where all possible paths between structural model variables, both manifest and latent, are estimated. The saturated model provides a basis for subsequent model comparisons as all other models containing the same variables will be nested within this model. The second is the null or independence model where all covariances between structural variables are set to 0 and are thus unrelated. The null model is the base model for the computation of relative fit indices such as the CFI or the NNFI as well as the theoretical model's $\chi^2$. We computed $\chi^2$ difference statistics ($\Delta\chi^2$) between the theoretical and alternative models under consideration as well as a comparison of model fit indices (Bentler & Bonett 1980).

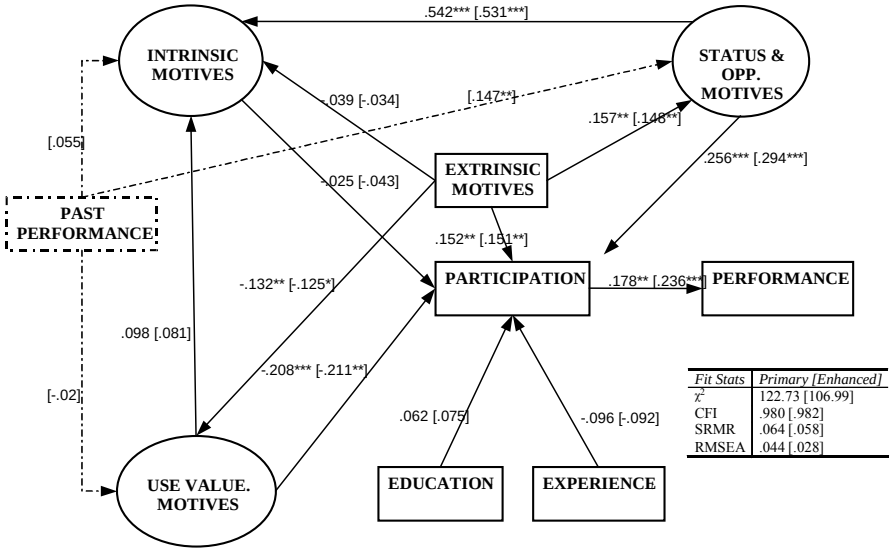
Our hypothesized model fits the data very well. The theoretical model's overall $\chi^2$ statistic is significant. The $\chi^2$/df ratio is well within acceptable range with a $\chi^2$/df = 1.28. Model fit is judged acceptable using the SRMR (0.06) in combination with the CFI (0.98). Taken together, these statistics indicate that our hypothesized model provides a highly acceptable fit to the data. Utilizing the $\chi^2$ difference test, we compared the performance of the hypothesized model with that of the alternative models. The hypothesized model performance is clearly superior to that of the independence model on measures of fit. Compared to the saturated model, the hypothesized model performs quite favorably as well ($\Delta\chi^2 = 1.22$, $\Delta$df = 12, $p < .001$). In this case, the hypothesized model can be viewed a constrained version of the saturated model where 12 of the model paths are constrained to zero. Thus constrained, the hypothesized model achieves a statistically indistinguishable level of performance from the fully saturated model. Consistent with the $\Delta\chi^2$, relevant model fit statistics are unaffected by the additional constraints placed on the model.

[7] The means, standard deviations, correlations and covariances for the variables in our model and a summary of model fit evaluation results are reported in the online Appendix.

Figure 2 shows the estimated standardized path coefficients and model fit statistics for both our primary and enhanced models.[8] H1a, H1b and H1c predicted a negative relationship between strictly *extrinsic* motivations and *intrinsic* motivations, and between the internalized extrinsic motivations (*use value* and *status*) and *intrinsic* motivations. These hypotheses are not supported. The paths from USE VALUE$_{t_2}^{2}$ to INTRINSIC$_{t_2}^{2}$ and from EXTRINSIC$_{t_2}^{2}$ to INTRINSIC$_{t_2}^{2}$ are not significant in our model. The path from STATUS$_{t_2}^{2}$ to INTRINSIC$_{t_2}^{2}$, while significant, is positive, thus in the opposite direction than predicted ($\gamma_3$ = .542, $p < .01$). H2a and H2b predicted positive relationships between being paid to contribute to Apache and contributors' *status* and *use value* motivations. These hypotheses are partially supported. The path from EXTRINSIC$_{t_2}^{2}$ to STATUS$_{t_2}^{2}$ is positive and significant ($\phi_1$ = .157, p = .04), providing support for H2b. However, the path from EXTRINSIC$_{t_2}^{2}$ to USE VALUE$_{t_2}^{2}$, while significant, is in the opposite direction than predicted by H2a ($\eta_1$ = -.132, p = .05). H3 relates the strictly *extrinsic* motivation of being a paid Apache developer to participation. This hypothesis is supported, as the path from EXTRINSIC$_{t_2}^{2}$ to PARTICIPATION$_{t_2}^{3}$ is positive and significant ($\beta_2$ = .152, p = .02). H4a and H4b relate the *use value* and *status* motivations to participation. These hypotheses are partially supported, as the path from STATUS$_{t_2}^{2}$ to PARTICIPATION$_{t_2}^{3}$ is significant and in the hypothesized direction of H4b ($\beta_4$ = .256, $p < .01$). However, the path from USE VALUE$_{t_2}^{2}$ to PARTICIPATION$_{t_2}^{3}$, while significant, is in the opposite direction than predicted by H4a ($\beta_3$= -.208, $p < .01$). H5 relates participants' *intrinsic* motivations to their level of participation. This hypothesis is not supported as the path from INTRINSIC$_{t_2}^{2}$ to PARTICIPATION$_{t_2}^{3}$ is not significant. Finally, H6 relates participation to changes in performance ranking. The path from PARTICIPATION$_{t_2}^{3}$ to PERFORMANCE$_{t_3}^{4}$ is positive and significant ($\alpha_1$ = .178, p = .02), supporting H6.

[8] The results for cumulative number of patches and cumulative number of lines of code are consistent with the reported results and are available upon request from the authors.

**Figure 2 - Model Results: Standardized Path Coefficients**




Notes: Coefficients are shown for both Primary and Enhanced models. Coefficients for Enhanced Model appear in [ ].
*** p <.01, ** p=.05, * p=.10.

To test H7, H8a, and H8b, we enhanced our primary model by adding measures of participants' past performance and paths to relate them to the participants' intrinsic motivations and internalized extrinsic motivations (*use value* and *status*), respectively. We then re-estimated the enhanced model including the original paths and variables and the newly added paths and variables. The enhanced model, like the primary model, exhibits an excellent fit to the data. The model's overall $\chi^2$ statistic is significant with a $\chi^2$/df ratio of 1.2, well within acceptable range. Model fit is judged acceptable using the SRMR (0.06) in combination with the CFI (0.98). Again, all $\Delta\chi^2$ were computed between the hypothesized and alternative models. In all cases, the $\Delta\chi^2$ indicated in favor of the hypothesized model; thus, the hypothesized model was retained as the best fitting model and serves as the basis for the examination of our remaining hypotheses.

H7 positively relates past performance to *intrinsic* motivations. We find no support for H7, as the path from $PERFORMANCE_{t_1^2}$ to $\text{INTRINSIC}_{t_2^2}$ is not significant. H8a and H8b positively relate past performance to the *use value* and *status* motivations. These hypotheses are partially supported. Although the path from past $PERFORMANCE_{t_1^2}$ to $\text{USE VALUE}_{t_2^2}$ is not significant, the path from past $PERFORMANCE_{t_1^2}$ to $\text{STATUS}_{t_2^2}$ is positive and significant, as we had predicted ($\phi_2$ = .147, p = .05).

## 5. Discussion

This study has examined the inter-relationships between the motivations, participation and performance of OSS developers. Our first finding reveals that contributors have multiple motivations to participate in OSS projects, and that while some motivations are complementary, others are not. Although the previous OSS literature suggests that participants have multiple motivations for contributing, these motivations are thought to be "mutually reinforcing" (*e.g.*, Markus *et al*. 2000). However, our findings suggest that this is not always the case. Specifically, and contrary to our expectations, we find no evidence of extrinsic motivations crowding out strictly intrinsic motivations.

However, our results do suggest associations among some motivations. Status motivations actually enhance intrinsic motivations. In addition, being paid to contribute positively relates to participants' status motivations. A potential explanation for these complementarities is offered by Sansone and Smith (2000) who suggest that extrinsic motivations can boost, regulate and maintain interest in doing a task. For example, contributors' desires to further their careers may enhance their inherent interest in making code contributions because making contributions can also help them to achieve higher status or to obtain better career opportunities. On the other hand, we find that being paid to contribute is negatively associated with participants' use value motivations. In hindsight, this may not be too surprising. Extrinsically motivated developers may be more likely to view their contributions as part of their employment relationship and thus may have less personal use value for the Apache software. An alternative explanation is that a contributor who receives an extrinsic incentive for his or her use value motivated contribution will likely require such incentives in the future for submitting contributions that increase use value. In this sense, we do observe a crowding out effect, not of an intrinsic motivation, but of an internalized extrinsic motivation.

Our second finding suggests that not all motivations affect OSS participation equally or in the same way. Some studies identify participants' most "dominant" motivations for engaging in OSS projects (*e.g.*, Ghosh *et al*. 2002). However, these studies do not identify how differences in actual participation levels are associated with different motivations for participating. As we predicted, being paid to contribute and status motivations are related to above average participation levels. However, contrary to our predictions, we find

no significant relationship between intrinsic motivations and participation levels. At first glance, this finding is puzzling. Studies of OSS contributors have revealed that contributors do enjoy participating; indeed, developers have reported flow states and losing track of time when working on OSS projects (Lakhani & Wolf 2005). Why do these feelings of enjoyment in programming not translate into higher levels of code contributions? The literature on motivation and performance offers some potential explanations. Researchers have identified some disadvantages associated with intrinsic motivation (Osterloh & Frey 2000). Intrinsically motivated contributors tend to be more autonomous and self-directed, which may lead them to exhibit less desirable behaviors. In addition, Lepper & Henderlong (2000) suggest that intrinsic motivation may not be associated with better performance if the aspects of the activity that make it interesting come at the expense of attention toward some outcome – in this case, being intrinsically motivated may not positively affect participation levels. Since OSS contributors are self-directed, it is possible that their intrinsic motivation is not fully aligned with the mission of the OSS community. For example, a potential contributor may be intrinsically motivated to work on perfecting one feature of the code that performs a relatively minor function, and may spend inordinate amounts of time perfecting the single feature rather than implementing a large number of contributions. Also contrary to our predictions, use value motivations are associated with below average contribution levels. This result could be explained by reconsidering the nature of use value motivations. Developers who contribute because they are motivated by use value want to solve a particular bug that is causing them trouble or to add a particular feature that they need to use. Once they have solved the immediate problem or added the particular feature, they may lose interest in making future contributions if there are no further salient problems or issues to motivate them. This is consistent with the argument put forth by Sansone & Smith (2000) who assert that, without motivations that help to sustain interest, individuals could lose interest over time, even in activities they have previously found motivating. This finding has important implications for those interested in sustaining the participation of contributors to OSS projects; contributors who are primarily motivated by use value considerations may need subsequent incentives to sustain their level of participation.

Our third finding suggests that the Apache meritocracy is operating effectively, and that promotions within the community are indeed based on actual contributions to the Apache projects. This is especially important for a community like Apache that depends on shared leadership and the contributions of participants for its success.

Finally, we have found that past performance rankings enhance some motivations for participating but not others. We expected that an increase in ranking would boost contributors' subsequent intrinsic and extrinsic motivations. Our findings support this expectation for status motivations, as an increase in performance ranking is associated with a subsequent increase in contributors' status motivations to participate. This finding is consistent with the notion of incentive motivation where receiving a reward increases motivation for an individual to perform previously rewarded activities. As Lerner & Tirole (2002) have noted, a promotion in rank enhances a contributor's status in the OSS community and increases incentive motivation. Thus, an increase in status due to an advance in rank should amplify the contributor's subsequent status motivations to participate. However, we find no significant associations between rank increases and intrinsic motivations or use value motivations. Our results suggest that a rank increase within the Apache community is neither considered controlling and thus diminishing intrinsic motivation, nor is it viewed as informative on competence and thus enhancing intrinsic motivation. This could be the result of the performance evaluation itself; rank increases are not typically accompanied by detailed reports and feedback on performance, but rather just announced. Thus, it may not be clear to the contributor exactly what aspects of his or her performance are superior.

## 6. Conclusions

Our study makes several important contributions to the OSS literature. First, our theoretical model and empirical evaluation increase the understanding of how motivations, participation and performance *interrelate* in OSS projects. While some studies have examined particular aspects of motivation or participation, we are not aware of any study that has examined the *system* of inter-relationships between motivations, participation and performance. Yet, one must consider the motivational system in order to understand how successfully an OSS community is functioning in terms of attracting and sustaining

participation. To our knowledge, this is also the first study that investigates how past performance affects subsequent motivations in OSS communities. Understanding this relationship provides insight into the motivational effectiveness of feedback in the OSS setting.

As a whole, our results have several implications for attracting and sustaining participation in OSS communities. First, our results suggest that OSS communities should largely welcome commercial efforts by companies. While extrinsically motivated contributors have lower use value motivations, they also exhibit greater status motivations, and being paid to contribute is associated with a higher level of contributions to the source code. More importantly, in our setting, we could not detect any crowding out of (strictly) intrinsic motivations by extrinsic motivations. This is perhaps more important, as many successful OSS projects (*e.g.*, Apache, Linux, SendMail, Mozilla, *etc*.) experience increased attention from leading software producers who pay employees to contribute to these projects. Second, developers with higher status motivations appear to be the more substantive contributors. An implication is that OSS communities may want to nurture such motivations, perhaps by devoting distinct website space to recognize distinguished developers or by promoting involvement in OSS communities as leverage in the labor market. Third, the positive relationship between past performance and status motivations indicates that a feedback system provides a valuable service to the OSS community by increasing these motivations. However, the current feedback system, which primarily is an announcement of a rank increase, fails to enhance intrinsic motivations. Feedback that indicates personal competence should increase intrinsic motivation (Pittman *et al*. 1980; Ryan *et al*. 1983). Hence, one direct implication of our results is that OSS communities should capture a competence component in the feedback system that stresses the competence of the contributor and that provides detailed information and feedback on performance. This could, for example, include a listing of achievements and extraordinary contributions.

Our study has several strengths and limitations. We have drawn upon the extensive literature on motivation in psychology and on the OSS literature to develop theoretically driven hypotheses. Our research design leverages multiple data sources, matching subjective survey data on motivations with objective measures of participation and performance. This approach helps to triangulate findings and mitigate common

method and source biases. In addition, we leverage archival data to capture participation and performance measures over a four-year period. This longitudinal approach allows us to tease out potential causality relationships between motivations, participation and performance and between and past performance and motivations. Our study focuses only on projects within the Apache OSS community. While this potentially limits our findings in a strict sense to the Apache OSS community, we believe that our results could be applicable to other successful OSS communities such as Linux, Perl, and Mozilla that share an interesting relationship between the intrinsic and extrinsic motivations of contributors. Our approach does offer some persuasive advantages. Focusing on one OSS community enables us to link developers to their actual code contributions, and to link these code contributions to objective performance evaluations by others in the Apache community. This approach enables us to cleanly capture the past performance – motivation – participation – performance relationships. In addition, eliciting broad participation in our study within one community rather than limited participation across many communities helped us to obtain a representative sample. Hence, our research design increases the internal validity, external validity and statistical conclusion validity of our results (Campbell & Cook 1979).

Our study opens up several important avenues for further research in the OSS arena. In our study, we were guided by the previous literature in psychology and open source software development to identify the most likely factors leading to OSS participation. However, it is possible that other factors could be salient. For example, some researchers have suggested an obligation/community-based intrinsic motivation (Lindenberg 2001) for contributing to OSS projects. This motivation has certain similarities with the use value motivation we have examined as use value is internalized based on identification with the OSS community. Our results for use value would suggest that obligation/community-based intrinsic motivation may be associated with below average contribution levels. However, the precise relationships between obligation motivations, participation levels and performance would need to be examined in future research. Investigating the inter-relationships among motivations, participation and performance in other OSS communities is another important research extension. In addition, most of the literature in psychology on intrinsic and extrinsic motivation is validated via carefully designed and controlled experiments. An

experimental approach could be especially useful in revealing the processes by which extrinsic motivations for contributing to OSS projects are internalized and the mechanisms by which different internalization processes lead to differences in participation. Experiments could also be helpful for designing feedback mechanisms to maximize the effect of past performance on future motivations. Further research on the motivational mechanisms underlying participation and performance is vital for effectively leveraging the advantages of "costless" OSS development.[9]

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