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Abstract

Control of open source projects is problematic because of the very nature and ideology of the open source paradigm. In contrast to commercial software projects, there are no formal control mechanisms in place and participation is generally voluntary in open source projects. However, despite this apparent lack of control of the project, open source software development has become a viable and cost effective way of developing high quality software. This paper reports on a quantitative study which tested the impact of informal control on the effectiveness of the core group of software developers in open source projects. The findings indicate that clan control and self control impact positively on the various dimensions of the group effectiveness of the core group of software developers in open source projects.

Keywords: open source projects; informal control; clan control; self control; group effectiveness; project output;, group cohesion; benefits to group members.

INTRODUCTION

Open source software has gained much attention in recent years due to the success of a number of large scale software projects, such as Linux and Apache. There is no doubt that there are an increasing number of good quality open source software packages available for a wide range of business applications. However, despite the obvious success of open source software as an alternative development approach, the dynamics of the open source software development approach are still not well understood. How can a group of software developers geographically dispersed across the globe deliver high quality software in relatively short time frames when there are no formal control mechanisms in place to manage an open source project? In this research project we were interested in finding out how informal control can lead to effective group behaviours and outcomes from the core groups of software developers in open source projects.

This paper is structured as follows. First, open source software as a development approach is discussed, and it is argued from the existing literature that it is a viable alternative way to develop cost effective software. Then control theory and open source projects are discussed in terms of how informal control over an open source project is achieved. Next, effectiveness of the core group of software developers in open source projects is discussed in terms of Hackman's (1990) group theory. The research hypotheses are outlined and the method used to collect empirical data and test these research hypotheses is described and justified. The results of the data analysis are presented and discussed in relation to the research hypotheses. Finally, conclusions and implications of this study for research and practice are discussed and suggestions are made for future work.

Open source software as a viable and alternative development approach

The open source software movement has caught the attention of the software industry and IT industry in general because of its ability to produce high quality software at low cost, and in short time frames, using virtual groups of software developers geographically dispersed (Good 2002; Perens 2004; Wheeler 2005). The global infrastructure of the Internet enables software developers to work together efficiently and effectively in a networked and collaborative manner to develop software. The open source approach creates a dynamic synergy allowing virtual teams of software developers who have never met face-to-face to form communities based on self-interest to develop new software and to improve on existing software products (President's Information Technology Advisory Committee 2000).

The open source movement is a major paradigm shift in the way that software applications will be developed in the future (O'Reilly 2004; Perens 2004). The open source movement is driven by three significant trends in the software industry: commoditisation of software; collaborative development enabled through Internet infrastructure; and software customisability and delivery of software as web services over the Internet (O'Reilly 2004; Perens 2004). The culmination of these three trends will see software and ICT become increasingly a utility which can be developed, refined and delivered using the Internet infrastructure (Carr 2003; Flashline Inc 2004; O'Reilly 2004; Perens 2004). Table 1 shows, through a comparison of open source against conventional software development approaches, that there are significant advantages to be gained from the open source development approach.

Table 1 Comparison of the open source development approach with conventional software development approaches (Source adopted from Perens 2004)

Paradigm	Efficiency	Failure Rate	Distributes Cost	Distributes Risk	Protects Customer Differentiation	Protects Vendor Differentiation	Required Market Size
Retail	less than 10%	50%	Late, sometime after sales start.	No.	No.	Yes.	100,000 and up.
In-House and Contract	60% to 80%	50%	No	No.	Yes.	Maybe	1
Consortium and Non-Open-Source Collaboration	60% to 80%	Perhaps 90%, unacceptably high.	Yes	Yes	Maybe	Maybe	5 and up.
Open Source	60% to 100%	50%	Early, during development	Yes	No	No	5 and up.

Open source software development is gaining acceptance and respectability as a viable way to develop high quality and innovative software (Good 2002; Perens 2004; Wheeler 2005; Open Source Initiative 2005). The global market place is now demanding open standards as the Internet continues to evolve into the global operating system on which all business applications will need to run in the future. Software development can be classified into non-differentiating software such as retail/packaged software and open source to which everyone has access and differentiating software which is developed in-house or by contract and gives an organisation a competitive advantage in the market place. Only 10 percent of software needs of an organisation are in differentiating software (Perens 2004). Hence, open source software is a viable, cost effective alternative for the rest of an organisation’s software needs (Good 2002; Perens 2004; Wheeler 2005).

However, the dynamics of open source software development as a process are not well understood. The existing literature suggests that open source software is developed out of a combination of extrinsic and intrinsic motivations by software developers (Osterloh, Frost & Frey 2002) and that informal control plays a key part in governing the effective participation of open source developers (Gallivan 2001; Stewart & Gosain 2002; Choudhury & Sabherwal 2003; Basnet 2004; Lattemann & Stieglitz 2005). These are quite powerful controls because building and maintaining a reputation is a prime motivation for participating in an open source project. Although the process of open source software development is much less structured than traditional approaches, it still follows a rigorous path. There are a number of checks and controls, such as version and configuration management and mechanisms, which ensure that only high quality code is released (Cubranic & Booth 1999; Healy & Schussman 2003).

Control theory and open source projects

The dynamics of controlling participation in open source projects is not well understood and there is little empirical research beyond a meta-analysis of existing literature on control of open source projects (Gallivan 2001; Basnet 2004). Control can be viewed in a behavioural sense (Kirsch 1996, 1997), based on standards expected from past experience (behavioural control). Control can be viewed through an assessment of output-based predetermined goals (output control). Control can also be viewed as social governance based on conformity to certain moral and cultural rules (social control) (Choudhury & Sabherwal 2003; Lattemann & Stieglitz 2005). This form of control provides a much better fit with the structure and processes of open source projects (Sharma, Sugumaran & Rajagopalan 2002) In the context of open source projects, informal control can be viewed as endeavouring to ensure individuals act in a manner that is consistent with achieving the desired objectives of an open source project and in line with the ideology of the open source movement. The existing literature suggests that informal controls are more likely to be dominant forms of control in open source projects.

Informal controls can be classified into two types: clan control and self-control. Clan control is implemented through mechanisms that minimize the differences between controller’s and controllee’s preferences (Eisenhardt 1985) by ‘promulgating common values, beliefs, and philosophy within a clan in other words a common set of beliefs and ideology, which is defined as a group of individuals who are dependent on one another and who share a set of common goals' (Kirsch 1996, p. 217), or by identifying and reinforcing acceptable behaviours through shared experiences, rituals, and ceremonies (Kirsch 1996, Ouchi 1980). However, clan control may be difficult to achieve in open source projects unless they are part of a long term alliance, such as is the case with the core software developers (Das & Teng 1998, 2001; Carmel 1999). Like clan control, self-control relies on the controllee engaging in behaviour consistent with the best interests of the controller without formal controls. However, there is an important distinction: unlike clan control, in which control stems from sharing norms and values (open source ideology) within a group, self-control is a function of individual objectives and standards and intrinsic motivation (Kirsch 1996, p. 218).

With self-control, the controllee determines both the goals and the actions through which they should be achieved (Henderson & Lee 1992), as in self regulated teams (Cummings 1978, Manz & Sims 1980). Mechanisms supporting self-control are primarily implemented by the controllee. Such mechanisms may include the controllee identifying and establishing standards for their own behaviour, or establishing a timetable for project milestones and monitoring progress against these milestones. However, as several authors (e.g. Von Glinow 1983, Kirsch 1996) have noted, the controller can also encourage or enable the controllee to exercise self-control. 'Controllers, who do not directly exercise self-control over others, nevertheless can encourage others to exercise self control. For example, controllers can train and mentor controllees in appropriate techniques (Brief & Aldag 1981) or ensure that tasks are clearly defined for discernable boundaries for an open source project (Cummings 1978; Kirsch 1996). Controllers can also institute performance evaluation schemes that reward autonomy and self management' (Kirsch et al. 2002, p. 486). In self-control, the individual, independent of formal organizational mechanisms or group norms, institutes the rewards (Kirsch 1996). Finally, in clan control rewards and sanctions depend on whether the individuals act according to group values, norms, and objectives (Kirsch et al. 2002). However, rewards may be implicit in clan control, with no need for formalised rewards mechanisms. According to Kirsch et al. (2002), in clan control, 'Unlike behaviour and outcome control situations, there is no need for explicit incentives to align the goals of controllers and controllees because of the existence of shared goals' (p. 486).

Group effectiveness of open source projects

Groups in an open source project context are defined as an assortment of individuals where each individual contribution to the project is summated and produces a successful comprehensive project as the result of group effort (Furst, Blackburn & Rosen 1999). Performance evaluation and accountability for a group will occur at the individual, rather than the collective, level. Then, group members are collections of individuals who interact extensively to produce a deliverable, who are then evaluated based on the team outcome, and are accountable as a team for team outcomes (Sundstrom et al. 1990). While there may be many members of an open source project, the software development group is really confined to the core group of software developers who make and monitor work contributed to the project.

The effectiveness of free/open source projects was viewed through the theoretical lens of Hackman's (1990) group effectiveness theory which consists of three dimensions: group output, group cohesion and psychological benefits to group members. Hackman's (1990) model of group effectiveness is a comprehensive model depicting three variables associated with group effectiveness. This model proposes that group effectiveness is a multidimensional construct consisting of three dependent variables or factors: (1) The degree to which the group's products or services meet the standards of quantity, quality and timeliness of those who receive, review and/or use the output—project output; (2) The degree to which the group's work processes enhance the capability of members to work together interdependently in the future—group cohesion; and (3) the degree to which the group's experience contributes to the growth and personal well being of team members—benefit to members (Hackman et al. 1986)

Project output is an important dependent factor or variable of group effectiveness of open source projects. Productive output can be achieved by ensuring that the group's products or services meet the standards of quantity, quality and timeliness of those who receive, review and/or use the output (Hackman 1987). Evaluating whether a project team has been effective in reaching shared goals; whether the quality of the software created from this project is high; and whether the project tasks are completed on time are some examples of project output factors which measure the group effectiveness of the open source projects.

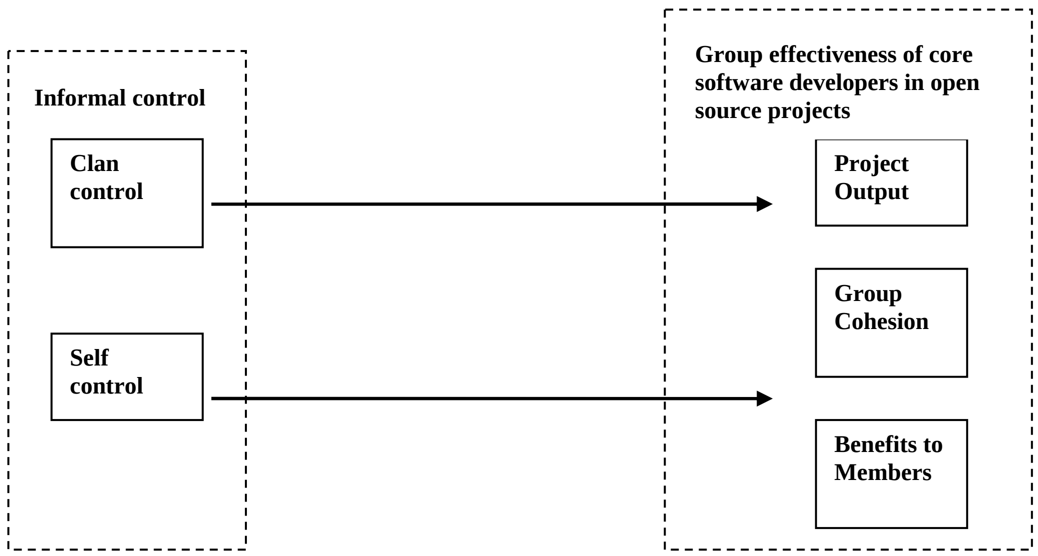
In obtaining the maximum outcome of the projects, the group cohesion factor effectively plays an important role through an extensive interaction among group members and reflects the diversity of ideas generated by the group (Nemeth 1992), member involvement (Lawler 1986), and increased group efficiency and productivity (Hammer & Champy 1993). Prior literature discusses group members' urge for cohesive behaviour in a developer community, including establishing a group identity that encourages group members to put group goals before individual goals (Gaertner et al. 1989), building trust among group members (Mayer, Davis & Schoorman 1995) and generating co-operation among heterogeneous group members (Nemeth 1993; Tusi, Egan & O'Reilly 1992; Watson, Kuman & Michaelson 1993).

In an environment like open source projects, the life span of each project is limited. Hence, the group members look for benefits, including expanding their social networks within developer communities, the work methods of developer community teams can become an important part of the organization's knowledge repository, acquisition of new skills by contributing himself, professional growth and development, etc. Such benefits would play an important role and a dependent factor in determining the group effectiveness of open source projects

Therefore, this research paper will report on the impact of informal control on the group effectiveness of open source projects as part of a larger empirical study. The measures of the three dimensions of group effectiveness were adapted to the context of the core group of software developers in open source projects by refining a number of existing scales from previous empirical studies which examined various dimensions of group effectiveness (Denison 1996; Janz 1999; Carless & De Paola 2000; Lurey & Raisinghani 2001; Stewart & Gosain 2002, 2002; Pescosolido 2003).

Research hypotheses and method

In this paper we investigate the impact of informal control on the effectiveness of virtual communities in free/open source projects. In particular, we are concerned with the impact of clan control and self control dimensions of informal control on the group effectiveness of software developers in open source projects (Basnet 2004). Figure 1 is the theoretical conceptualisation of the proposed research model which we tested empirically using multiple regression analysis.



Hypotheses tested to confirm the relationships between the two dimensions of the independent variable informal control and the three dimensions of the dependent variable, group effectiveness in open source projects are:

H1: Clan control positively influences group effectiveness of open source projects:

H1a: Clan control positively influences project output.

H1b: Clan control positively influences the group cohesion.

H1c: Clan control positively influences the benefits to group members.

H2: Self control positively influences group effectiveness of open source projects:

H2a: Self control positively influences project output.

H2b: Self control positively influences the group cohesion.

H2c: Self control positively influences the benefits to group members.

The research method employed to collect and analyse data to test the hypotheses was quantitative. An online survey was sent by email to 5000 members of Source Forge (www.sourceforge.net). SourceForge.net is the dominant open source development portal, with over 100,000 registered open source projects currently in different phases of the project life cycle (http:www.sourceforge.net). The sample was obtained by selecting the core software developers from the most active projects in the five categories of the project life cycle. An open source project is classified in Sourceforge.net into five distinct project life cycle phases: (1) pre alpha; (2) alpha; (3) beta; (4) production stable; and (5) mature—which are used to categorise open source projects in their stages of development. The survey instrument was developed by adapting and refining scales from existing empirical studies which had measured the constructs of interest in this study. The targeted respondents were asked to focus on a particular current and recent free/open source project when answering the online questionnaire. In all, 785 responses were received, of which there were 635 usable responses. The effective response rate was approximately 18 percent after the sample size had been adjusted for ineligible and unreachable email addresses. This was considered a reasonable response rate for an online survey. The number of cases in sample size was more than adequate to conduct factor analysis and three sets of multiple regression analyses with three independent variables and three dependent variables.

Discussion of data analysis results

Firstly, the data items measuring informal control and group effectiveness were examined for normality by examining the graphical distribution of the data sample for each measurement item, the mean, standard deviation, and the skewness and kurtosis for each measurement item. All of the data items were found to be representative of a normal distribution as the skew and kurtosis values were within the acceptable range of the absolute value of 2 (Hair et al. 1998; Coakes 2005).

RESULTS OF FACTOR ANALYSIS AND RELIABILITY ANALYSIS FOR INDEPENDENT AND DEPENDENT VARIABLES

Factor analysis and reliability analysis were conducted together to ensure the measurement items for the two dimensions of informal control and the three dimensions of group effectives in open source projects were valid and reliable measures. Table 2 shows that the factor analysis of the two dimensions of informal control resulted in a three factor model of informal control: clan control, and two distinct dimensions of self control: autonomy and personal goals.

Table 2 Results of factor analysis and reliability analysis for independent variable—informal control

Independent variables	**Factor loadings**	**Item to total correlation**
Clan Control		
1. I am willing to put in extra effort for this project to be successful	(dropped)	
2. My values and that of other members of this project are similar	.674	.477
3. This project and its members inspire my programming effort	.677	.505
4. Members of this project are one big family	.745	.534
5. Free/OSS programmers should help each other out	,549	.384
6. The members of this project have common set of values, beliefs, norms about open source software	.728	.520
Variance explained 30.93% Cronbach Alpha 0.724		
Self Control through Autonomy		
2. I have significant freedom over what work I do in this project	.744	.559
3. I have significant freedom over how I do work in this project	.813	.612
4. Meeting my goals in this project gives me a feeling of accomplishment	.817	.629
Variance explained 11.395% % Cronbach Alpha 0.76		
Self control through personal goals		
1. I am responsible for setting my own goals for project work	.729	.498
5. Meeting my goals in this project contributes to my professional growth	.857	.641
6. Meeting my goals in this project improves my self-esteem	.788	.563
Variance explained 16.732% Cronbach Alpha 0.74		
Total Variance Explained = 59.06 %; Kaiser-Meyer-Olkin measure of Sampling Adequacy = 0.787 Bartlett test of sphericity = 1752.680; Significance = 0.000		

One item, clan control (clan control item 1), cross loaded on two dimensions of informal control and have factor loadings of 0.31 and 0.37 which are less than the recommended minimum 0.5 (Hair et al. 1998). After reviewing the wording of the clan control item 1 statement and considering the results of the factor analysis, it was decided to drop this item. The remaining items measuring the three dimensions of informal control displayed adequate discriminant and convergent validity as indicated by the factor loadings, which are all above recommended minimum 0.5. The Cronbach alpha scores from the scale reliability analysis for these three dimensions are all above the recommended 0.7, indicating that these items are reliable measures of these dimensions (Nunnally 1979; Hair et al. 1998).

Factor analysis and scale reliability analysis were also conducted for the three dimensions of the group effectiveness to ensure that the measurement items were valid and reliable. Table 3 shows that the factor analysis of the items measuring the three dimensions of group effectiveness resulted in a three factor model.

Table 3 Results of factor analysis and reliability analysis for dependent variable group effectiveness in open source projects

Dependent variables	**Factor loadings**	**Item to total correlation**
Project Output		
1. Project team has been effective in reaching shared goals	.787	.624
2. Feedback indicates that project output is useful	.683	.476
3. Members will continue to meet project goals	.797	.656
4. Software created from this project is high quality	.636	.495
5. Project output is greater than individual contributions	Dropped	
6. Knowledge and information have been produced in this project	Dropped	
7. Project tasks are completed on time	.605	.453
Variance explained 15.69% Cronbach Alpha 0.78		
Group Cohesion		
1. I try to help any member with difficulties they are having with project tasks	.787	.488
2. The blame for mistakes made in this project shared amongst members	.788	.416
Group Cohesion continued		
3. I look forward to continuing as a member in this project	.496	.355
4. : Based on my experiences on this project, I would be interested in participating in other Open Source Software projects in the future	Dropped	
Variance explained 9.53% % Cronbach Alpha 0.6		
Benefits to group members		
1. I developed new skills while working on this project	.859	.693
2. I learned things in this project that I will use in other projects	.810	.689
3. I am highly satisfied with my professional growth and development in this project	.814	.745
4. I get a feeling of worthwhile accomplishment from being involved in this project	.709	.633
Variance explained 34.76% Cronbach Alpha 0.85		
Total Variance Explained = 59.99 %; Kaiser-Meyer-Olkin measure of Sampling Adequacy = 0.829 Bartlett test of sphericity = 2528.455; Significance = 0.000		

The factor loadings were all above the recommended 0.5, except for measurement item 3 for group cohesion which was 0.496 and was retained as the factor loading was significant given the large data sample size of 635 valid responses. Two items were dropped from the project output dimension of group effectiveness as the factor loadings for these items were lower than the recommended 0.5 level (Hair et al. 1998). Additionally, after reviewing the statements for items 5 and 6 it was felt that these items were somewhat ambiguous and not clear statements which are representative measures of project output. All remaining items measuring the three dimensions of group effectiveness displayed adequate discriminant and convergent validity. The Cronbach alpha score for 5 items retained for project output which was above the recommended 0.7 level indicated these items were a reliable measure of project output (Nunnally 1979). One item was dropped from the group cohesion dimension because of the low factor loading. The Cronbach alpha score of 0.6 indicated that the 3 items retained may not be a reliable measure of group cohesion but, given the exploratory nature of this research, it was decided to retain group cohesion despite its less than adequate reliability (Hair et al. 1998). All four measurement items were retained for benefits to group members as the factor loading were above the recommended 0.5 level and indicated adequate discriminant and convergent validity. The Cronbach alpha score of 0.85 was above the recommended 0.7 level and indicated that the 4 items were a reliable measure of the benefits to group members.

RESULTS OF MULTIPLE REGRESSION ANALYSIS FOR THREE DEPENDENT VARIABLES

In order to run the three sets of multiple regression models, it was important to ensure that the underlying assumptions of multiple regression analysis were met by examining the multiple regression models for linearity, homescedasticity, independence of the residuals and normality. Linearity was assessed by analysing the residuals and partial regression plots. The multiple regression models were found to be linear after examining the residual plots and no non linear pattern was found after examining the partial plots for the each of the independent variables. After examining the residual plots the constancy of the residuals across the independent variables indicated homescedasticity in independent variables. The independence of the residuals was evaluated using the Durbin Watson test and for all of the three multiple regression models the range was within 1.5 and 2.5 required for independent observations. The normality of the error terms was examined using the normality probability plots of the residuals. Since all of residual values fell along the diagonal with no substantial or systematic departure, residuals are considered to represent a normal distribution.

Table 4 Multiple Regression Model 1 Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.383(a)	.147	**.143**	.91472114	**1.915**

a Predictors: (Constant), Autonomy, Personal Goals, Clan Control b Dependent Variable: Project Output

Table 5 ANOVA(b) for Multiple Regression Model 1

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	91.033	3	30.344	**36.266**	.000(a)
Residual	527.967	631	.837		
Total	619.000	634			

a Predictors: (Constant), Autonomy, Personal Goals, Clan Control b Dependent Variable: Project Output

Table 6 Coefficients(a) for Multiple Regression Model 1

	Unstandardized Coefficients		Standardized Coefficients	T value	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-1.277E-16	.036		.000	1.000		
Clan Control	**.379**	**.037**	**.380**	**10.331**	**.000**	1.000	1.000
Personal Goals	.006	.037	.006	.166	.868	1.000	1.000
Autonomy	.052	.037	.052	1.427	.154	1.000	1.000

a Dependent Variable: Project Output

Tables 4, 5 and 6 show the results of the multiple regression analysis for the dependent variable project output. Overall three independent variables explain 14.3 percent of the variance in the dependent variable project output, which is highly significant given the F value of 36.266 in the Anvoa table. The tolerance and variance inflation factor values are low and indicate that multicollinearity is not a problem in this multiple regression model. Clan control is the only significant positive indicator of open source group effectiveness in terms of project output with a beta coefficient of 0.38and a T value of 10.331 which is statistically significant at 0.01 level. The other informal control factors, personal goals and autonomy, are not significant indicators of open source group effectiveness in terms of project output

Table 7 Multiple Regression Model 2 Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.345(a)	.119	.115	.92969970	1.864

a Predictors: (Constant), Autonomy, Personal Goals, Clan Control b Dependent Variable: Group Cohesion

Table 8 ANOVA(b) for Multiple Regression Model 2

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	73.600	3	24.533	28.384	.000(a)
Residual	545.400	631	.864		
Total	619.000	634			

a Predictors: (Constant), Autonomy, Personal Goals, Clan Control b Dependent Variable: Group Cohesion

Table 9 Coefficients(a) for Multiple Regression Model 2

	Unstandardized Coefficients		Standardized Coefficients	T Value	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-5.357E-17	.037		.000	1.000		
Clan Control	**.320**	**.037**	**.321**	**8.588**	**.000**	1.000	1.000
Personal Goals	**.101**	**.037**	**.101**	**2.699**	**.007**	1.000	1.000
Autonomy	.076	.037	.076	2.027	.043	1.000	1.000

b Dependent Variable: Group Cohesion

Tables 7, 8 and 9 show the results of the multiple regression analysis for the dependent variable group cohesion. Overall three independent variables explain 11.5 percent of the variance in the dependent variable group cohesion which is highly significant given the F value of 28.384 in the Anvoa table. The tolerance and variance inflation factor values are low and indicate that multicollinearity is not a problem in this multiple regression model. Clan control is again the most significant positive indicator of open source group effectiveness in terms of group cohesion, with a beta coefficient of 0.321 with a T value 8.588 which is statistically significant at 0.01 level. The personal goals dimension of self control is also positive indicator of open source group effectiveness in terms of group cohesion with a beta coefficient of 0.101 with a T value 2.699 which is statistically significant at the 0.01 level. The other informal control factor autonomy dimension of self control is not a significant indicator of open source group effectiveness in terms of group cohesion.

Table 10 Multiple Regression Model 3 Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.488(a)	.238	.234	.86470626	1.880

a Predictors: (Constant), Autonomy, Personal Goals, Clan Control b Dependent Variable: Benefits to Group members

Table 11 ANOVA(b)

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	147.191	3	49.064	65.618	.000(a)
Residual	471.809	631	.748		
Total	619.000	634			

a Predictors: (Constant), Autonomy, Personal Goals, Clan Control b Dependent Variable: Benefits to Group Members

Table 12 Coefficients(a)

	Unstandardized Coefficients		Standardized Coefficients	T Value	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	3.427E-16	.034		.000	1.000		
Clan Control	**.256**	**.035**	**.257**	**7.390**	**.000**	1.000	1.000
Personal Goals	**.103**	**.035**	**.103**	**2.965**	**.003**	1.000	1.000
Autonomy	**.401**	**.035**	**.401**	**11.552**	**.000**	1.000	1.000

b Dependent Variable: Benefits to Group Members

Tables 10, 11 and 12 show the results of the multiple regression analysis for the dependent variable benefits to group members. Overall three independent variables explain 23.4 percent of the variance in the dependent variable benefits to group members which is highly significant given the F value of 65.618 in the Anvoa table. The tolerance and variance inflation factor values are low and indicate that multicollinearity is not a problem in this multiple regression model. Clan control is again a significant positive indicator of open source group effectiveness in terms of benefits to group members with a beta coefficient of 0.257 and a T value 7.390 which is statistically significant at 0.01 level. The personal goals dimension of self control is a positive indicator of open source group effectiveness in terms of benefits to group members with a beta coefficient of 0103 and T value 2.965 which is statistically significant at 0.01 level.. The autonomy dimension of self control is the strongest positive indicator of open source group effectiveness in terms of benefits to group members with a beta coefficient of 0.401 and a T value 11.552 which is statistically significant at 0.01 level.

DISCUSSION OF DATA ANALYSIS RESULTS

Table 13 Summary of the results of hypotheses testing

Hypotheses (***) indicates 0.01 significant level	**Supported/not supported**
Clan control positively influences group effectiveness	
H1a: Clan control positively influences project output.	Supported (***)
H1b: Clan control positively influences the group cohesion.	Supported (***)
H1c: Clan control positively influences the benefits to group members.	Supported (***)
Self control positively influences group effectiveness (Self control was split into two dimensions personal goals and autonomy)	
H2a: Personal goals positively influences project output.	Not supported
H2b: Personal goals positively influences group cohesion.	Supported (***)
H2c: Personal goals positively influences benefits to group members	Supported (***)
H3a: Autonomy positively influences project output	Not supported
H3b: Autonomy positively influences group cohesion	Not supported
H3c: Autonomy positively influences the benefits to group members.	Supported (***)

Of the nine hypotheses tested in three sets of multiple regression models, six hypotheses were supported at the 99 percent significant level. Clan control, as suggested by the existing literature, plays a prominent role in maintaining control over the core developers in open source projects and would appear to positively influence project output and cohesion of the core developers and the benefits they obtain. The output of an open source project evolves over time depending on what each core developer group member chooses to work on (Osterloh, Rota & Kuster 2002). Thus, clan control ensures that despite individual differences, the core developers of an open source project share something in common – the shared goals and ideology of the open source project (Kirsch 1996).

When the core developers participate in open source development approved activities such writing and sharing code, sharing knowledge, and providing help and support to others programmers they are both intrinsically and extrinsically rewarded by the clan (Ouchi 1979;Kirsch 1996). The intrinsic rewards are in the form of personal benefits to group members. In the core developer groups of open source projects this ideology includes the norms, values and beliefs of the hacker culture. Therefore if members identify strongly with the shared ideology of the group, then the level of group cohesion increases (Ouchi 1979; Kirsch 1996). Furthermore, when clan control is operating, members are rewarded for their commitment towards the clan, which in turn strengthens group cohesion.

Self control through the personal goals of core developers also plays a prominent role in maintaining over the core developers and would appear to positively influence the cohesion and benefits obtained by the group of core developers in open source projects. Thus, it is the member's responsibility to self-monitor, self-reward, and self-sanction their activities to achieve their personal goals (Kirsch 1997). Achieving personal goals through self control can lead to feelings of accomplishment, personal growth and development, and increased self-esteem (Lawler & Hall 1970).

Self control through autonomy does not appear to play a major role in maintaining control over the core developers in open source projects, but does appear to positively influence benefits obtained by the group of core developers. One of the strongest attractions to open source development is the freedom to choose what work one does, and how they go about doing this work (Osterloh, Rota & Kuster 2002). This finding supports the view of Markus, Manville and Agres (2000) who believe that intrinsic motivation and self-management of autonomous knowledge workers plays a pivotal role in the success of open source projects. Personal goals and autonomy do not appear to positively influence project output. Personal goals and autonomyt appear more likely to directly benefit individual core developers and increase the cohesion within the group of core developers, resulting in positive indirect benefits for open source projects.

CONCLUSIONS AND IMPLICATIONS

The results of the multiple regression analysis reported in this paper show that clan control plays a significant part in informally controlling the behaviour and outcomes of the core group of software developers in open source projects by having a positive influence on the project output, group cohesion and benefits obtained by the members of the core group of software developers. The two sub dimensions of self control—personal goals and autonomy—also play a significant part in informally controlling the behaviour and outcomes of the core group of software developers in open source projects by having a positive influence on the group cohesion and benefits obtained by the members of the core group of software developers. Overall, clan control appears to be the dominant factor in exerting informal control over the core group of software developers in open source projects. Furthermore, autonomy appears to be the most significant dimension of the self control factor for the core group of software developers through the benefits which can be gained individually and by maintaining the cohesion of the core group of developers for an open source project.

Overall, the findings of this study have important implications for the management of personnel in software projects. The success of open source projects emphasise the importance of a collective and constructive mindset in groups of developers and the need to also motivate developers at the individual level by allowing them to pursue personal goals and maintain a certain level of autonomy in their work.

The findings of this study are based on the analysis of a very large quantitative data sample. Therefore, we believe that our findings regarding the three factor model of informal control and its impact on the group effectiveness of open source projects are relatively robust, valid and reliable. Open source software is increasingly seen as a viable and effective way to develop software. Gaining a better understanding of the dynamics of such an approach through better understanding how control is exerted over the core group of software developers in such an open, fluid and virtual development environment has many important lessons for the software industry and indeed for industry in general.

However, we do believe this study was the first serious attempt to quantify the measurement of informal control and group effectiveness of the core group of software developers in open source projects and that further work is required to improve and establish the validity and reliability of these constructs. A qualitative study of these constructs would help to clarify and validate the dimensions of these constructs and identify other dimensions which should be included in the measurement of informal control and group effectiveness for virtual groups of software developers in open source projects.

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