Hacking Alone?
The Effects of Online and Offline Participation on Open Source Community Leadership

Siobhán O'Mahony
Harvard Business School
somahony@hbs.edu

Fabrizio Ferraro
IESE Business School
fferraro@iese.edu

September 1, 2004

This research has been supported by the Stanford Center for Work, Technology and Organization, the Stanford University Technology Ventures Program, the Social Science Research Council and the Harvard Business School Division of Research. The data collection and processing efforts of John Sheridan, Vikram Vijayaraghavan and Daniel Berch and editorial support provided by Clare Flaherty were much appreciated. All errors or omissions are our own. Neither author has any financial interest in Linux or open source companies. Both authors contributed equally to this work

Abstract

Research on computer mediated communication has examined how a lack of social presence affects participation, communication and leadership in online groups, but until recently, has not examined offline relations or emergent social structures. The few studies examining these issues have not been integrated with research on open source communities. Online communities producing open source software face even greater problems of governance than affinity or interest based online communities, as leadership responsibilities extend beyond mailing list management to managing release dates, public relations, and collaborations with firms. With data from one open source community's online and offline networks over three consecutive years, we assess factors affecting voting participation and leadership. We find that the more developers one has met face to face, the more likely one was to vote in a leadership election. Controlling for contributions of code, developers are more likely to hold a top leadership position when they participate more in online discussions. However, online participation in technical discussions did not affect leadership as much as occupying a structurally advantaged position in the community's social network. We conclude with theoretical implications that consider the dynamics of online and offline networks for governing distributed online communities.

Words = 197

Over the past twenty years, we have learned much about how computer mediated communication (CMC) affects status, participation, communication and leadership within online groups. Initial theories that focused on the lack of social presence or reduced social cues associated with computer mediated communication have matured to discover that these attributes are not necessarily a feature of a particular medium. Much of this research was conducted in laboratories with dyadic or small student groups working on structured tasks for set periods of time (Straus and McGrath 1994; Lebie et al 1996; Bouas and Arrow 1996) or in field studies with clearly identified sponsors in settings guided by employment or student relations (e.g. Hinds and Kiesler 1995). While the role of CMC in distributed work attracted the interest of many scholars, particularly in the fields of social psychology (e.g. Sproull and Kiesler 1991) and organizational behavior (e.g. DeSanctis and Fulk 1999), much less attention has been devoted to online communities and the role of CMC in the organization, leadership and governance of voluntary activities, communities and social movements (Iacono and Kling 2001; Diani 1999).

This research examines the face-to-face network of an open source community that began online and, ten years later, still operates primarily in cyberspace: the Debian Linux distribution project. Debian is the largest and most well known non-commercial Linux distribution. A "distribution" of the Linux operating system contains the standard Linux Kernel and a number of other packages developed to ensure the correct functioning of the system across different hardware platforms and peripherals. Like RedHat, Debian packages the Linux kernel (developed by Linus Torvalds and his lieutenants) with other software that often includes custom features. Unlike RedHat, Debian is not a firm, but a voluntary online community that happens to produce an operating system. While Debian does not sell its wares, third parties may. By analyzing Debian's online and offline participation networks over three consecutive years, we show how face to face engagement influences voting participation and leadership of the project. We find that even in online communities managed by the most sophisticated and

talented of programmers, where the value of one's technical contribution is paramount, that face-to-face interaction plays a critical role in determining leadership. After reviewing what we know about status, participation and leadership in online groups, we explore how these findings translate for online communities in the 'wild' to gain insight into factors that might affect leadership of an open source project. We conclude by theorizing how offline networks may affect the evolution and governance of online communities.

Status, Participation and Leadership in Online Groups

Several theories have tried to explain how computer mediated communication affects the dynamics of working groups. Social presence theory argues that media offering less paralinguistic information (information carried by the sender's presence or tone) will be low in social presence and that media with greater social presence should increase our ability to communicate and influence others (Short et al 1976). Thus, tasks that are highly interdependent, ambiguous or equivocal (like programming) tasks should require richer media (Daft and Lengel 1986). However, several studies have found evidence of precisely the opposite effect. The fewer the social cues carried by the medium, the more people attended to the message rather than the messenger (Chaiken and Eagly 1983). This indicates that people may be better able to concentrate on the message without social presence.

This theory was modified by Kiesler and colleagues with the reduced social cues approach which posits that media with fewer social cues will de-emphasize social norms, thus encouraging less inhibited behavior (1984). Since electronic mail carries less social context information, those communicating with it may be less inhibited and more risk seeking (Kiesler et al 1984; Sproull and Kiesler 1991). The strength of this approach lay in explaining two contrasting types of phenomena – more equal participation and less inhibited behavior. Reduced self monitoring and awareness could lead to greater equality of participation and fewer power and status stratification effects, as well as flaming and lack of

etiquette. While flaming is a well known phenomenon in the programming community in general (Raymond 1999), it has not seemed to impede the productivity of open source projects. By all informal accounts, many open source projects have survived, using primarily text based medium to coordinate their activities.

There has been healthy debate over the status-equalizing effect of computer mediation. Numerous studies examining the effects of communication modality on group participation have found that CMC equalized participation in groups relative to their traditional face to face counterparts (Kiesler and Sproull 1992; Dubrovsky et al 1991; Poole, & DeSanctis 1988; Sproull and Kiesler 1986; Kiesler et al 1984), but overall support for the reduced cues hypothesis has been inconsistent. Other research shows that status differences can persist even in groups that work completely online without physical contact (Dubrovsky et al 1996; Weisband et al 1995; Spears and Lea 1994). In one study, mixed status groups made poorer decisions and did not gain access to critical information held by lower status members (Hollingshead 1996). Weisband also found that high status members participated more in group discussions than low status members when using electronic mail and face to face communication (1994).

These effects may be attributed to differences in the setting or the technology but more likely there are other variables to consider. For example, groups that continually spend a great deal of their time online, such as open source programmers, may design their own social cues into the medium. Recent research suggests that prior relationships (McGinn and Keros 2003); time spent developing the relationship prior to (Moore et al 1999; McGinn et al 2003) or while interacting with the media (Weisband 2002) may also be important. In their experimental study of a single issue, two party negotiation that crossed friends and strangers with three different types of media (face, telephone, and email), McGinn and Keros found media effects for friends, but not for strangers.

McGinn and Croson reconcile some of these contradictory findings by proposing that where social perceptions and intimacy are already established, the limitations of low efficacy, single channel media such as email may have less effect on behavior (2004: 10). They point out that underlying much of this research is the assumption that media properties affect the degree of consciousness and attention to others and introduce the concept of social awareness as a property, derived not from the medium itself, but constructed by parties to an interaction (McGinn and Croson 2004). Thus, strong long term relationships may attenuate potentially negative effects from communicating with media that transmits less paralinguistic or social context information. Indeed, in a recent study of short term distributed teams working on a deadline, team members that created and reinforced awareness about themselves performed better than teams that did not (Weisband 2002).

Approaches that rely on social cues as a trigger mechanism also do not account for the persistence of roles and relationships independent of such cues (Spears and Lea 1994). The enactment of roles is an essential part of group life online or offline and people's attitudes can change depending on the role they occupy (Lieberman 1956). This is particularly relevant for online groups that are not based on short tasks but have a sustained focus or mission and longevity over time. In an online group that is producing software over a ten-year period, the roles contributors play could be stable and well known. Furthermore, these roles may tie contributors to networks both off and online that affect determinants of leadership. Online communities may have a longer lifespan and thus offer greater opportunity to evaluate how effects of the medium and role or network structure interact.

Online Communities in the Wild

We define online communities in the wild as distributed groups of people voluntarily contributing to a common social information space supported by networked communication outside of their employment, residence or educational institutional context. Such communities are often organized

around a core common interest or demographic attribute, but unlike communities organized by territory, they are not bound by geography and their structure emerges independent of the institutional constraints that mark other types of online communities supported by organizations. Our understanding of how findings from early research on computer mediated communication hold with respect to online communities 'in the wild' is still in the early stages (e.g. Cummings, Butler, and Kraut 2002; Cummings, Kiesler and Sproull 2002; Butler et al in press; Butler 2001), but the strength and nature of the relationship of online communities vis a vis traditional communities has been debated since Howard Rheingold coined the world 'virtual community' in 1993 to represent community without propinquity (Hampton and Wellman 2003: 277).

Early explorers of online or 'virtual' communities have found that participation in such forums offers individuals another form of community experience, not alternative to traditional community life, but complementary to it (Hampton and Wellman 2003; Koku, Nazer and Wellman 2000; Wellman and Gulia 1999; Wellman et al 1996; Rheingold 1993). Rheingold's early work showed how people with shared interests and affiliations could develop strong bonds and share mutual support through internet communities (1993). Wellman and Gulia argue that Internet based groups can support existing communities and enable the construction of new forms of community organizations, since "the Net supports a variety of community ties, not only weak ties and intimate secondary relationships, but strong, intimate ties" (1999: 13).

Sociological research in this area generally concurs with earlier social psychological research on the equalizing effects of computer mediated communication, but for different reasons. Because online communities are likely to develop only where interests are shared, interactions are less likely to be focused on social or ascribed characteristics and their associated status implications (Wellman et al 1996: 231). Online communities may subsequently bring people together with divergent social circles who might not otherwise meet. Thus, the focus is on what mobilizes people to come together online versus

offline as opposed to features of the medium. These in depth interpretive studies of online communities offer a very different picture of online groups than survey research which tends to find online social relationships weaker than offline relationships (Cummings, Butler, and Kraut 2002; Parks and Roberts 1998). Cummings, Kiesler and Sproull (2002) characterize most online social support groups as weak ties, primarily because the cost of entry and exit is low (e.g. Pickering and King 1995) and because there is a high degree of turnover or churn (Butler 2002).

Research on communities in the wild diverges from earlier literature on the effects of computer mediated communication in groups by explicitly recognizing the interplay between online and offline interaction (Butler et al in press). For example, in Parks and Floyd's study of 24 Usenet groups, nearly two-thirds of relationships that began on newsgroups were at some point supplemented by mail, telephone, or face to face interaction (1996: 92). This finding was replicated in Parks and Robert's study of users in real time text based virtual environments known as MOOs (Multi-User Dimensions, Object Oriented) (1997). As opposed to comparing online and offline interaction as competing modalities, this stream of research presumes that both modalities coexist and examines moderating and mediating relationships. Thus, offline behavior may be a factor that affects online community members' social awareness of each other.

A second source of divergence from earlier research on computer mediated communication in groups is the renewed attention paid to the emergent structure of online communities – a necessary condition for communities to become self sustaining. Online groups in the wild do not sustain themselves by technology alone, but require management of social and technical resources in order to continue to attract members particularly as they scale (Butler 2001). "Underlying many claims about the consequences of a computer-mediated social infrastructure is the belief that information technology has the potential to drastically reduce the negative consequences of size, leading to social structures that are either larger or not dependent on internal structure" (Butler 2001: 349-350). Butler's resource based

model of social structure sustainability posits that as an online community grows in membership, it is better positioned to provide more resources but less able to convert those resources into valued benefits for members (2001). Managing this tension may be the one of the primary functions that leaders in online communities perform. In fact, since neither physical distance nor hierarchical authoritative relations can constrain online interactions, influencing the normative and formal social structures that can guide action are even more critical.

Open Source Software Communities

One type of online community that has experienced unprecedented growth since the word open source was coined in the spring of 1998, are open source software communities. An open source software project faces even greater problems of governance than typical online communities, as leaders have responsibilities that extend beyond mailing list and account management to managing release dates, representing the project to the public and collaborating with firms. In addition, most early open source communities were initiated online by people who did not know each other and thus knew very little of other members' social context. Open source communities typically rely on text based media to coordinate their activities - project mailing lists supplemented by real time interaction on IRC channels. With the emergence of a commercial market for open source, corporations have begun to sponsor more conferences, trade shows and travel which has likely enhanced opportunities for face to face interaction. However, the role of face to face interaction in the open source community has been under examined.

Scholarly analysis of open source software projects has examined the motivation (Lakhani and Wolf 2003; Dalle and Jullien 2003; Hertel et al 2003; Lerner and Tirole 2002); contribution patterns (Mockus, Fielding and Herbsleb 2000; 2002); normative and legal practices (O'Mahony 2003); membership and joining processes (von Krogh, Spaeth and Lakhani 2003; O'Mahony and Ferraro forthcoming); relations with firms (West 2003; O'Mahony 2002) and knowledge creation and innovation

(Lee and Cole 2003; von Hippel and Krogh 2003; Kogut and Meitu 2001), without connecting to literature on computer mediated groups or online communities. As a result, these two literatures have not informed each other. We aim to remedy this here.

Unlike internet communities focused on hobbies, fantasy, gaming or social support, these online communities are more like distributed project teams in a production environment. There is a high degree of interdependence as eventually members' contributions must be integrated into one software build, but typically a modular structure also offers opportunity for independent work (Baldwin and Clark 2003). Unlike studies of distributed teams sponsored by firms (e.g. Hinds and Bailey 2003), participants do not share a common employment context and thus lack authoritative mechanisms and profit goals. Unlike student task groups, open source projects have sustained longevity and multi-vocal linkages with the offline world through user groups, conferences and trade shows every year (O'Mahony 2002).

Despite the growth of interest in open source projects, little has been done to understand how these projects are governed or how online or offline social networks shape project dynamics. In this paper we follow a more relational approach (Wellman and Berkowitz 1988) to unveil how real life interaction can influence a critical decision for any community: the election of their leader. First, we look at the leader election process, a process not likely to be found in most commercial software projects, but one that is becoming more common among open source communities. Second, we examine what affects the likelihood of becoming a member of the top management team.

Voting Participation. We predict that participation in online and offline forums are likely to influence the degree of commitment to community governance and thus the propensity to vote in the project's leadership election. By indicating one's choice of leader, one shows a measure of commitment to the project's future. Controlling for the amount and quality of code a developer contributes, we predict that developers who participate more in online discussions will be more likely to vote.

H1: The greater the amount of participation in online discussions, the more likely developers will be to vote in project leader elections.

Offline social ties can also reinforce or enhance participation in online communities. In a study of scholarly networks, Koku, Nazer and Wellman found that scholars who see each other often or work near each other; email each other more often (2000). The more Internet listserv members people knew in the offline world, the more time they spent doing community building work in their online communities (Butler et al 2000). A later survey of participants in an online self-help group dedicated to hearing loss found that participants benefited more when their online support leveraged their real world support[1] (Cummings, Kiesler and Sproull 2002). In Hampton and Wellman's study of wired and nonwired home residents, online access facilitated the formation of a greater number of real world weak ties (2003). Thus, participation in offline networks may help reinforce the shared purpose of the project and thus enhance commitment and participation in the project's governance.

H2: The more developers have met others on the project, they more likely they will be to vote in project leader elections.

Leadership. Given this understanding of electoral participation, we can also make some predictions about which developers are more likely to become a member of the top leadership team. Most researchers of open source communities have stated that open source communities operate in a meritocratic manner (Lee and Cole 2003; Kogut and Meitu 2001). One interpretation is that all developers maintain a relatively equal social status, with recognition for the merits of their technical contributions. Alternatively, meritocratic can be interpreted as allocating positions of leadership and status only to those who have contributed more critical and/or greater quantities of code. We consider the degree to which a project is meritocratic a matter of empirical investigation. In doing so, we take an

[1] Over 40% of the sample of 64 list participants had real world family and friends participating in their support group (Cummings, Kiesler, and Sproull, 2002): 80.

inverse approach from Butler et al's research examining how leadership roles affect participation in an online community (in press). Instead we explain how different forms of participation affect who becomes a leader.

Controlling for the amount and criticality of code contributed, we predict that participation in online and offline forums will affect which developers become leaders. As Ahuja and Carley discovered, an online community can operate without formal hierarchy, but influential players can still become more central than others and affect the flow of communication (1999). Thus, developers who maintain a greater online presence in technical discussions may be more likely to become a member of the top leadership team.

> H3: The greater the amount of participation in online discussions, the higher the probability that a developer will be on the leadership team.

Ahuja and Carley's research on the network structure of virtual organizations (1999) also suggests that one's position in the network may also affect who becomes a leader. Brokers of unique ties can influence the flow of information across and within boundaries of technical organizations (Allen 1977; Tushman 1977) and, in traditional organizations, have been found to have enhanced career mobility and promotion prospects (Burt 1992). Participation on technical committees can also help individuals move to positions of authority and influence within their respective firms (Rosenkopf et al 2001). Fleming and Waguespack's hazard models predicting leadership on Internet Engineering Task Force (IETF) committees found that there was a strong threshold for technical contributions, after which collaborations with other high status contributors became important (2004). Meeting other developers face to face and occupying a structurally advantaged position in the social network may thus increase the likelihood of becoming a leader.

> H4: The higher the betweeness centrality of a developer in the project's face to face network, they more likely they will be on the leadership team.

Data and Methods

Dependent Variables. Every year Debian developers have the opportunity to elect their project leader for a one-year term. Candidates may nominate themselves and post a leadership platform on the website outlining their goals for the project nine weeks before the end of the term. An excerpt from a winning candidate's platform is provided below.

> Would I be a good project leader? Frankly I don't know. I do not intend to be as dictating and vocal as X was, but neither as silent as Y was the last year. Both have done a good job, but things are not what they were. Debian has grown to be too big for X's style of leadership, and Y has laid a great foundation for a new period by giving us the constitution. This also means the role of project leader as now very different: most functions have been delegated, leaving the leader to act as a kind of benevolent overseeing person who nudges the project in a good direction (*Third Elected Leader Platform, Debian Election*)

As this candidate points out, the role a leader should fulfill on this project was evolving as the project scaled. At this stage in the project, some administrative functions that used to be under the leader's control were delegated to committees[2]. In designing a Constitution, project members wanted the role of leader to be more defined and limited. The Constitution guides leaders "to make decisions which are consistent with the consensus of the opinions of the Developers" and leaders are encouraged to avoid overemphasizing their own point of view when making decisions (Debian 2003). Thus, the concept of leader is firmly based on consensus building as opposed to authoritarian rule.

Platforms are debated and followed by a three week polling period that provides ample time for members from all time zones to participate. A long polling period is also important so that volunteers who don't work on the project every day, or even every week, have a chance to check in and vote. Developers submit ranked votes via email and the results are tabulated using a variation of the Condorcet method. This method makes full use of all the data submitted by simulating run-off

[2] For more information on the challenges of managing and leading Debian over time, see O'Mahony, Siobhan, "Managing Community Software in a Commodity World", forthcoming in *Ethnographic Reflections on the New Economy* Edited by Gregory Downey and Melissa Fisher.

elections among pairs of candidates. Debian developers voted to use this method to allow three or more candidates to run without risking the possibility of electing a leader that lacked the support of the majority. Participating voters and election results are posted on the website, but usually the identity and vote is kept private. We used data on participating voters as a measure of participation to test H1 and H2.

To test H3 and H4, we created a dependent variable representing the top leadership team which included the elected project leader, release coordinator, developer accounts manager, and members of the technical committee. Release coordinators and developer accounts manager are volunteers for indefinite appointments. Release coordinators shepard the project to closure and developer account managers are responsible for allocating account rights to the code repository. The technical committee is chosen by the project leader and has the constitutional right to resolve technical disputes. We viewed these positions as providing critical leadership for the project.

Independent Variables. To obtain a measure of developers' contribution to email discussion, we downloaded all the interactions from the main mailing list of the project, called debian-devel. Using this data we measured the number of messages each developer posted the year before the elections. To construct measures of face-to-face interaction, we took advantage of an interesting practice that members of the project adopted. The Debian project began using public key encryption as a way to build trust and authenticate member identities in 1994. To make public-key cryptography useful, a real-world identity must be linked to a public key. One authenticates the link between individual identity and key ownership by signing another person's key. This is an expression of trust: the signer has reviewed government identification and believes that the public key they sign belongs to the person who claims it. Developers sign keys at "key signing parties" or post their need to have their key signed on the project website. That way, when developers are traveling they can meet up with each other. This method became, in the spring of 2000, a condition for becoming a project member. Since each key signing is

dated and requires a face to face meeting, these data indicate when individual project members met each other. The data we collected from the Debian keyring consist of gpg and pgp keys signed by dyads between 2000 and 2002. We used these data to measure the degree centrality of each developer, which is the number of other developers each one of them has met face-to-face.

Likewise, we measured betweenness centrality using the keyring data, in order to synthetically capture the structural position of developers in the social network and each individual's ability to potentially broker information and exert social influence. In the keyring file, every developer has access to who has signed the key of every other developer. If a developer does not know who they are interacting with, they can view the keyring file and see if they know anyone else who has met this person and signed his key. In this context, betweenness centrality is a measure of an individual's ability to link disconnected parts of the network through face-to-face interaction. Betweenness centrality measures the extent to which an actor can broker communication between other actors (Freeman, 1979; Marsden, 1982; Wasserman and Faust, 1994). The index can be computed as follows:

$$C_B(n_i) = \frac{\sum_{j<k} \frac{g_{jk}(n_i)}{g_{jk}}}{\frac{(g-1)(g-2)}{2}}$$

Where g_{jk} is the number of geodesics linking two actors, $g_{jk}(n_i)$ the number of geodesics linking two actors that contain actor I, and $g_{jk}(n_i)/g_{jk}$ the probability that actor is involved in the communication between two actors. By standardizing its value by the number of pairs of actors not including n_i, $(g-1)(g-2)/2$, the index will take values from 0 to 1.

Control Variables. To control for the amount and quality of technical contribution, tenure, and geographical location, we collected data from various project databases. From the project developer database, we identified the continent of residence for each developer (country was not available) and leadership positions, if any, held over time. As a measure of each developer's contribution to the

project, we collected data from the project's bug tracking database on the number of software packages each developer maintained in 2001 and 2002 (the only years available). We also computed a measure of package popularity, indicating how often packages maintained by a developer are installed and used. Since early 2003, Debian users could install a "popularity-contest package" that automatically calculates the number of people that use a particular package regularly. We computed the raw sum of the votes for all packages maintained by individual developers as a measure of the criticality of their contributions for others. For each year we computed a measure of developer project tenure, counting the months since they first signed a key.

In order to understand this data in the context of the project's evolution, 80 informants from the open source community at large were interviewed, six of them in leadership positions within Debian. Online documentation such as mailing list archives, meeting notes, and other formal project documents offered an additional source of data. To show how contribution to the mailing list and developers' centrality affected the likelihood of voting in the election and the likelihood of achieving a leadership position, we estimated a series of logit models which are appropriate for dichotomous dependent variables (Long 1997).

Results

Descriptive statistics and correlation tables for 2000 and 2001 are presented in Tables 1 and 2. Table 3 presents the logit coefficients for the model predicting voter participation in the 2001 project leader election[3]. The voting participation rate was 42% out of 739 members eligible to vote. We included membership in the leadership team the year before, the number and popularity of code packages maintained, tenure (in months), geographic location (by continent), amount of participation in

[3] To help the interpretation of the logit coefficients, the odds ratios are reported in parentheses. Odds ratio are computed by taking the antilogarithm of the logit coefficient, thus for the effect of degree centrality on voting in 2001, we can take the coefficient from model 3 in table 5, and simply compute: $e^{.042}=1.043$. Values exceeding 1 indicate and increased likelihood of becoming a member of the NMC, while value less than 1 indicate decreased odds.

online discussions the year before, and the number of ties (degree centrality) of developers as independent variables. In the base model, which does not include contributions to online discussions nor degree centrality, there is a significant positive effect for being a member of the leadership team the year before the election and for the number of software packages maintained. However, the popularity of one's software package is not significant. Tenure negatively affected the likelihood of voting.

Adding postings to online discussion improves the fit of the model. We find significant support for Hypothesis 1: posting ten more messages to the online discussion increases the probability of voting by 11% (odds ratio is 1.011). With the inclusion of degree centrality, the fit of the model is further improved and provides support for Hypothesis 2. While the number of packages maintained, tenure and contribution to online discussions are still significant, meeting one more person increases the likelihood of voting by 4.3% (odds ratio is 0.04). Furthermore, if developers get their key signed at a designated keysigning party, they are likely to sign many keys. Thus, this effect could be magnified for those attending key signing parties. If a developer met ten people at a key signing party, then he would be 43% more likely to vote in the project leader election.

Table 4 reports the logit coefficients and the odds ratios for a series of models predicting the achievement of leadership positions in 2000, and the full models for the years 2001 and 2002. Among the control variables in model (1) only package popularity and tenure are statistically significant in a positive direction. The raw number of software packages one maintains is never significant in predicting leadership. Regardless of the model or the year, the quantity of effort one devotes to Debian has no effect on the propensity to become a member of the leadership team[4]. However, the criticality of the code one maintains has a small significant effect, but only in 2000. Adding postings to online discussions to the model (2) increases its fit and the coefficient is statistically significant. We find significant support for Hypothesis 3: posting ten more messages to online discussions increases the

[4] It is important to note that not all packages are equal – some may be more complex than others.

probability of becoming a member of the top leadership team by 9% (odds ratio is 1.009). Considering that the measure is computed over a year of postings, it is evident that this is an effect of considerable magnitude.

Including degree centrality in model (3) does not improve the fit of the model and therefore there is no evidence that having met more developers increase the likelihood of becoming part of the leadership team of the project in 2000. Betweenness centrality, on the other hand, significantly increases the fit of the model. With a one percent increase in betweenneess centrality, a developer is 1.7 times more likely to achieve a leadership position (odds ratio = 1.73). This supports hypothesis 4. In the full model both the popularity of the packages maintained and developers' contribution to online discussions are still significant, but tenure does not seem to have an effect. Similar results are obtained in models (5) and (6) which were estimated on data from 2001 and 2002.

Discussion

Despite public fascination with the placeless and distributed nature of open source communities, we find large and significant effects for the importance of face to face contact in predicting participation in project governance. In a community that values technical contributions more than any other (Levy 1994; Raymond 1999; Stallman 1999), we were surprised to find that the amount and criticality of software packages one maintained did not have a larger effect on engagement in project governance. Given Fleming and Waguespack's finding that a 1 s.d. increase in an IETF draft publication resulted in a 23% increase in the probability of earning a leadership appointment, we would have expected stronger results for code contributions (2004). The relative unimportance of the number of code packages that a person maintains may be of particular interest to open source researchers. What was significant in predicting voter turnout for leader elections was participation in online discussions and social networking. Developers who participated more in online discussions were more likely to vote in a

leader election and more likely to be on the leadership team. The importance of online technical discussion to leadership is not however unexpected.

Although descriptions of the meritocratic principles of open source projects have emphasized contributions of code, it is not a stretch to imagine that online postings would also be important. Postings to the project mailing list provide another type of technical contribution essential to the livelihood of the community, whether developers are offering technical assistance, posting bugs and fixes, or asking questions. As Orlikowski and Yates argue, when an online mailing list is the primary vehicle for distributed groups to communicate, mailing list contributions "are no longer merely an aspect or organizational work, rather, they *are* the organizational work" (1994: 573). As many informants confirmed, there are many ways in which people can make a contribution to the project and contributions can be made without programming per se. Some members in our sample did not maintain packages at all, while others maintained 80 or more. One implication is that online discussions may play a critical role in fostering a community of practice, where members learn by doing through engagement with others (Brown and Duguid 1991).

What is surprising is the significant result we find for social networking: meeting other developers face to face. This may have provided a base level of social awareness helpful in sustaining collaboration in a primarily text based world for over a decade. The more developers one met in person, the more likely one was to vote in an election. While meeting additional developers did not affect the probability of joining the leadership team, a developer's structural position in the social network did significantly affect the probability of being on the leadership team. In fact, this effect is larger than participation on the project mailing list. As a research setting, Debian offers a very conservative test of the role of face to face interaction in online communities. Most project work occurs online where developers are comfortable developing social relations in a computer supported text based environment, in fact this may be a trait of hackers (Levy 1995). With over 1,000 developers in 40 countries and no

travel budget, the opportunity for face to face interaction would seem to be constrained. Given that the data we used only represented *one* face to face meeting, the strength of this finding may be under estimated. That is, people may have met multiple times, but only signed their keyring once. In other research settings, the effect of social networking on online community relations might be stronger.

Mechanisms. Several mechanisms may be responsible for these findings. Face to face interaction may serve to reinforce commitment to the project and thus enhance interest in its governance and electoral process. Relative to text based communication, face to face interaction has been found to enhance reciprocity (McGinn, Thompson and Bazerman 2003), cooperation and rapport building. Many contributors to Debian are volunteer. It takes time to understand the different leader platforms and the strengths and weaknesses of each and it takes time to vote. Contributors who have met other people on the project may feel not just greater commitment, but greater reciprocity to do their part to manage the project. Thus, people may feel more accountable to the project once others on the project become aware of their presence. In the past, survey research has found negative associations between high Internet use and commitment to online communities (Wellman et al 2001). Larger online social networks that are more sparsely connected by weak ties could make normative control more difficult (Wellman et al 2001) and lead to the kind of uninhibited behavior that Kiesler and colleagues theorized about (1984). Debian's strong sense of purpose and normative and institutional controls may mitigate against this effect from taking hold.

For a leader to become elected by a community that ultimately rejects traditional models of hierarchy and restricts the authority of their leader, they must undoubtedly earn the trust of project members. Perhaps members are more confident that their leader will not abuse the little authority entrusted to them if they occupy structurally advantaged positions in the social network. Relative to text based communication, face to face interaction can enhance disclosure and mutual trust (McKinn and Keros 2003; Valley, Moag and Bazerman 1988). In Iacono and Weisband's study of trust in 14

distributed teams, continuous and frequent interaction facilitated trust (1997). They theorize that trust in distributed teams is less about relating than it is about doing – engaging in continuous patterns of interaction (Iacono and Weisband 1997). In this research, we do not examine repeated interactions, but the effect of a single meeting. Developers could have interacted online for many years without ever meeting. If trust is the mechanism behind the significant effects that we find, then trust must derive from the simple power of finally connecting the interactions associated with a name to a live person.

Fleming and Waguespack's longitudinal analysis of careers within the IETF found that the most common path to leadership required both brokerage and sustained commitment to the community. Technical skills, physical presence (at IETF meetings) and structural position were necessary to bind the community together (2004). However, attendance at IETF meetings alone had little effect and brokerage without legitimacy earned by contribution to IETF drafts handicapped prospects for leadership (2004). Our results confirm their finding that interaction with others in person may not dictate evaluations of trust, but may, in conjunction with technical contributions, offer distributed technical communities the opportunity to triangulate on their evaluations of trust.

Implications and Extensions. There is much about the Debian project that is unique to it. Most open source projects do not have a Constitution nor an electoral process as sophisticated as the one Debian designed. Debian is also unique in its leadership turnover: at least six different leaders have managed the project over the past ten years. Debian's success in managing this turnover is evidence of the institutionalization of leadership. While each new leader constructs this role differently, the institution has successfully been decoupled from the person (Selznick 1957). In fact, the founder of the project, in an interview with the first author, claimed not to understand the current voting system and had little hand in designing either the Constitution or the election rules. Other large, successful open source projects such as Linux, Gnome and Apache still have their founders at the helm, so there are fewer leadership dynamics to evaluate.

Most organizations do not let their employees vote on their choice of team leader. However, introducing voting processes to projects in which professionals from diverse occupations must contribute (e.g. software development, construction, entertainment productions and product design) may not be so far fetched. As more porous organizational boundaries foster an ever enlarging body of constituents and specialists relevant to decision making, decision systems that support a plurality of distributed professionals are likely to be important. Future research should examine how the various decision mechanisms with which open source projects have experimented have affected their technical and social evolution. For example, the Apache project requires three positive votes and no vetoes for the acceptance of a code patch.

While Debian may be a unique case, it provides insight as to how leaders emerge in communities that have no obvious basis of authority - and this is relevant to the management of professional expertise in many contexts. Practitioners argue that the ability to create and manage virtual communities will be a distinguishing feature of successful businesses (Williams and Cothrel 2000; Armstrong and Hagel 1996). In so doing, firms should not consider online communities as distinct from offline spheres of socio-economic activity. Putnam's analysis of the declining trend in social capital (2000) did not fully examine new forms of coordinated action that are complementary to traditional forms. This research builds upon Putnam and Feldstein's most recent work (2003) examining new forms of communities that are less territorial, but no less powerful in their ability to exercise and lead coordinated action. However, while online communities are capable of more rapid and large scale coordinated action than their offline counterparts, they cannot collectively hold resources without a form recognized by the offline world (O'Mahony, 2002). If stocks of social capital are cumulative and self-reinforcing (Putnam 2000), than our research approaches must not only consider the reciprocal dynamics among online and offline networks, but how these flows affect established institutions or create new ones.

References

Ahuja, M.K. & Carley, K.M. 1999. Network structure in virtual organizations. *Organization Science.* **10**, 741-757.

Allen, T.J. 1977. *Managing the flow of technology transfer and the dissemination of technological information within the R&D organization*, Cambridge, Mass: MIT Press.

Armstrong, A. & Hagell, J. 1996. The Real Value of On-Line Communities. *Harvard Business Review*. May 1996. 134-141.

Baldwin, Carliss Y., & Clark, Kim B. 2003. "The Architecture of Cooperation: Does Code Architecture Mitigate Free Riding in the Open Source Development Model?" Harvard Business School Working Paper Series, No. 03-209.

Brown, J.S. & Duguid, P. 1991. Organizational learning and communities-of-practice: toward a unified view of working, learning, and innovation. *Organization Science*. **2**, 40-57.

Burt, R.S. 1992. *Structural holes the social structure of competition*. Harvard University Press, Cambridge, Mass.

Butler, B., Sproull, L., Kiesler, S. & Kraut, R. Community Effort in Online Groups: Who Does the Work and Why? In: Weisband, S.A.L., (Ed.) *Leadership at a Distance*. Erlbaum, In Press.

Butler, B.S. 2001. Membership Size, Communication Activity, and Sustainability: A Resource-Based Model of Online Social Structures. *Information Systems Research.* **12**, 346-362.

Chaiken, Shelly, & Eagly, Alice H.1983. "Communication Modality As a Determinant of Persuasion: The Role of Communicator Salience." *Journal of Personality and Social Psychology.* **45** (2): 241-56.

Cummings, J., Kiesler, S.B. & Sproull., L. 2002. Beyond Hearing: Where Real-World and Online Support Meet. *Group Dynamics.* **6**, 78-88.

Cummings, J.N., Butler, B. & Kraut, R. 2002. The Quality of Online Social Relationships. *Communications of the ACM.* **45**, 103-108.

Dalle, J.-M. & Jullien, N. 2003. 'Libre' software: turning fads into institutions? *Research Policy.* **32**, 1-11.

Debian (2003) Debian Constitution. http://www.debian.org/devel/constitution.

DeSanctis, G. & Fulk, J. 1999. *Shaping organization form: communication, connection, and community,* Thousand Oaks, Calif: Sage.

Diani, Mario. 1999. Social Movement Networks Virtual and Real. *Conference "A New Politics", CCSS, University of Birmingham, 16-17 September.*

Fleming, L. & Waguespack, D. 2004. Penguins, Camels and Other Birds of a Feather: The Emergence of Leaders in Open Innovation Communities. (UnPub)

Freeman, L.C. 1979. Centrality in Social Networks Conceptual Clarification . *Social Networks.* **1**, 215-239.

Hampton, K., & Wellman, B. 2003. Neighboring in Netville: How the Internet Supports Community and Social Capital in Wired Suburb. *City and Community.* **2** (4), 277-311

Hertel, B., Niedner, S. & Herrmann, S. 2003. Motivation of software developers in Open Source projects: an Internet-based survey of contributors to the Linux kernel. *Research Policy*. **32** (7).1159.

Hinds, P. & Kiesler, S. 1995. Communication across boundaries Work, structure, and use of communication technologies in a large organization. *Organization Science.* **6** (4):373-393. 1047-7039.

Hinds, P.J. & Bailey, D.E. 2003. Out of Sight, Out of Sync: Understanding Conflict in Distributed Teams. *Organization Science.* **14**, 615-632.

Hollingshead, A.B. 1996. Information suppression and status persistence in group decision making: The effects of communication media. *Human Communication Research*. **23**, 193-219.

Iacono, S. & Kling, R. 2001. Computerization Movements: The Rise of the Internet and Distant Forms of Work. In: Yates, J. and Maanen, J.V., (Eds.) *Information Technology and Organizational Transformation: History, Rhetoric, and Practice*. 93-136.

Kiesler, S., Siegel, J. & McGuire, T. 1984. Social psychological aspects of computer-mediated communication. *American Psychologist*. **39**, 1123-1134.

Kiesler, S. & Sproull, L. 1992. Group Decision Making and Communication Technology. *Organizational Behavior and Human Decision Processes.* **52**, 96-123.

Kogut, B. & Metiu, A. 2001. Open-Source Software Development and Distributed Innocation. *Oxford Review of Economic Policy.* **17**, 248-264.

Koku, Emmanuel, Nazer, Nancy & Wellman, Barry. 2000. Netting Scholars:online and offline. *American Behavioral Scientist.* **44** (10); 1752-1778.

Lakhani, K. & Wolf, B. 2003. Why Hackers Do What They Do: Understanding Motivation and Effort in Free/Open Source Software Projects. MIT Sloan Working Paper No. 4425-03.

Lee, G. & Cole, R.E. 2003. From a Firm-Based to a Community-Based Model of Knowledge Creation: The Case of the Linux Kernel Development. *Organization Science.* **14**, 633-649.

Levy, S. 1994. *Hackers: Heroes of the Computer Revolution*, New York: Penguin Books.

Lieberman S. 1956. The effects of changes in roles on the attitudes of role occupants. *Human Relations.* **9**, 385-402.

Marsden, P.V. 1981. Introducing Influence Processes into a System of Collective Decisions. *American Journal of Sociology.* **86**, 1203-1235.

McGinn, K.& Croson, R. 2004. What do communication media mean for negotiations: A question of social awareness. In Michele, J. Gelfand, and Jeanne M. Brett (Eds) *The Handbook of Negotiation and Culture*: Stanford University Press. 334-349.

McGinn, K. & Keros, A. 2003. Improvisation and the logic of exchange in embedded negotiations. *Administrative Science Quarterly.* **47**. 442-473.

McGinn, K., Thompson, L. & Bazerman, M. 2003. Dyadic Processes of Disclosure and Reciprocity in Barga ining with Communication. *Journal of Behavioral Decision Making*. **16**(1), 17-34.

Mockus, A., Fielding, R.T. & Herbsleb, J.D. 2002. Two Case Studies of Open Source Software Development: Apache and Mozilla. *ACM Transactions on Software Engineering and Methodology*. **11**, 309-346.

O'Mahony, S. 2002. Community Managed Software Projects: The Emergence of a New Commercial Actor. Unpublished Dissertation, Stanford University.

O'Mahony, S. 2003. Guarding the Commons: how community managed projects protect their work. *Research Policy*. **32** (7); 1179-1198.

OMahony, Siobhan & Ferraro, Fabrizio. Managing the Boundary of an Open Project, in *Market Emergence and Transformation*, W. Powell and J. Padgett, Eds., Santa Fe Institute, forthcoming.

Orlikowski, W.J., Yates, J., Okamura, K. & Fujimoto, M. 1995. Shaping electronic communication: the metastructuring of technology in the context of use. *Organization Science*. **6**, 423-444.

Parks, M.R. & Roberts, L.D. 1997. Making MOOsic: The Development of Personal Relationships On-line and a Comparison to their Offline Counterparts. *Journal of Social and Personal Relationships*. **15** (4): 517-537

Parks, M.R. & Floyd, K. 1996. Making Friends in Cyberspace. *Journal of Communication*. **46**, 80-97.

Pickering, J.M. & King, J.L. 1995. Hardwiring weak ties Interorganizational computer-mediated communication, occupational communities, and organizational change. *Organization Scienc*. **6** (4): p. 479-486

Putnam, R. D. 2000. *Bowling Alone: The Collapse and Revival of American Community*, New York: Simon and Schuster.

Putnam, R.D., & Feldstein, L. 2003. *Better Together: Restoring American Community.* New York: Simon and Schuster.

Raymond, E.S. 1999. *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*, Sebastopol, CA: O'Reilly & Associates.

Rheingold, H. 1993. *The Virtual Community: Homesteading on the electronic frontier*. Cambridge, MA: The MIT Press.

Rosenkopf, L., Metiu, A. & Varghese, P.G. 2001. From the Bottom Up? Technical Committee Activity and Alliance Formation. *Administrative Science Quarterly.* **46**, 748-772.

Selznick, P. 1957. *Leadership in administration a sociological interpretation,* Evanston, Ill: Row, Peterson.

Short, J., Williams, E. & Christie, B. 1976. *The social psychology of telecommunications.* London : John Wiley and Sons.

Sproull, L. & Kiesler, S. 1986. Reducing Social Context Cues: Electronic Mail in Organizational Communication . *Management Science.* **32**, 1492-1513.

Sproull, L. & Kiesler, S.B. 1991. *Connections new ways of working in the networked organization*. Cambridge, Mass: MIT Press.

Stallman, R. 1999. The GNU Operating System and the Free Software Movement. In: DiBona, C., Ockman, S. and Stone, M., (Eds.) *Open Sources*, Sebastopol, CA: O'Reilly

Straus, Susan G., & McGrath, Joseph E. 1994. "Does the Medium Matter? The Interaction of Task Type and Technology on Group Performance and Member Reactions." *Journal of Applied Psychology*.**79** (1): 87-97.

Tushman, M.L. 1977. Special Boundary Roles in the Innovation Process. *Administrative Science Quarterly* **22**. 587-605.

von Hippel, E. & von Krogh, G. 2003. Open Source Software and the "Private-Collective" Innovation Model: Issues for Organization Science. *Organization Science.* **14**, 209-223.

von Krogh, G., Spaeth, S. & Lakhani, K.R. 2003. Community, Joining, and Specialization in Open Source Software Innovation: A Case Study. *Research Policy*. **32**, 1217-1241.

Wasserman, S. & Faust, K. 1994. *Social network analysis: Methods and applications*, New York: Cambridge University Press.

Weisband, S.P., Schneider, S.K. & Connolly, T. 1995. Computer-mediated communication and social information: Status salience and status differences. *Academy of Management Journal.* **38**, 1124-1151.

Weisband, S.P. 2002. "Maintaining awareness in distributed team collaboration: Implications for leadership and performance". In P.Hinds & S.Kiesler (eds), *Distributed Work*. Cambridge MA. MIT Press. 311-333.

Wellman, Barry & Berkowitz, S.D. 1988. Structural Analysis: from method and metaphor to theory and substance. In *Social Structures: A Network Approach.* Edited by Barry Wellman and S. D. Berkowitz. Cambridge: Cambridge University Press.

Wellman, B., Salaff, J., Dimitrova, D., Garton, L., Gulia, M. & Haythornthwaite, C. 1996 Computer Networks as Social Networks: Collaborative Work, Telework, and Virtual Community. *Annual Review of Sociology.* **22**, 213-238.

Wellman, Barry & Gulia, Milena. 1999. Net Surfers Don't Ride Alone: Virtual Communities as Communities. In *Networks in the Global Village.* Edited by Barry Wellman. Boulder, CO: Westview.

West, J. 2003. How Open is Open Enough? Melding Proprietary and Open Source Platform Strategies. *Research Policy*. **32** (7); 1259-1285.

Williams, R.L.& Cothrel, J. 2000. Four Smart Ways to Run Online Communities. *Sloan Management Review*. **41**, 81-91.

Table 1. Descriptive statistics and correlation table 2000.

Variable	Obs	Mean	Std. Dev.	Min	Max	Leader	# packages	Pck popularity	# postings	Degree centrality	Betweenness centrality	Tenure	USA	Other
Leader	299	0.02	0.15	0.00	1.00	1.00								
# packages	299	7.31	10.55	0.00	81.00	0.05	1.00							
Pck popularity	299	411.77	1011.76	0.00	7898.00	0.25	0.37	1.00						
# postings 1999	299	44.74	87.75	0.00	615.00	0.33	0.22	0.23	1.00					
Degree centrality	299	3.66	4.68	1.00	45.00	0.32	0.06	0.08	0.39	1.00				
Betweenness centrality	299	0.55	1.63	0.00	16.30	0.41	0.05	0.08	0.31	0.83	1.00			
Tenur e	290	17.41	11.89	0.40	67.77	0.13	-0.10	0.05	0.02	0.34	0.34	1.00		
USA	299	0.30	0.46	0.00	1.00	0.05	-0.04	0.01	0.09	-0.09	-0.05	-0.14	1.00	
Other	299	0.12	0.33	0.00	1.00	0.01	0.14	0.07	-0.01	-0.11	-0.08	-0.15	-0.24	1.00

Table 2. Descriptive and correlation table 2001.

Variable	Obs	Mean	Std. Dev.	Min	Max	Vote	Leader	Leader 2000	# postings 2000	# packages	Pck popularity	Degree centrality	Betweenness centrality	Tenure	Europe	USA	Other
Vote	534	0.41	0.49	0.00	1.00	1.00											
Leader	534	0.01	0.11	0.00	1.00	0.07	1.00										
Leader 2000	534	0.02	0.13	0.00	1.00	0.13	0.75	1.00									
# postings 2000	534	24.29	58.23	0.00	545.00	0.27	0.48	0.49	1.00								
# packages	534	6.67	9.00	0.00	81.00	0.29	0.02	0.05	0.29	1.00							
Pck popularity	534	298.84	808.37	0.00	7898.00	0.18	0.14	0.23	0.38	0.38	1.00						
Degree centrality	534	4.56	6.57	1.00	75.00	0.16	0.26	0.25	0.32	0.14	0.12	1.00					
Betweenness centrality	534	0.39	1.30	0.00	21.49	0.14	0.36	0.32	0.34	0.09	0.13	0.80	1.00				
Tenure	515	18.58	15.53	0.13	79.97	-0.05	0.16	0.14	0.10	0.01	0.15	0.28	0.24	1.00			
Europe	534	0.47	0.50	0.00	1.00	0.07	-0.04	-0.04	0.00	0.09	-0.02	0.20	0.13	-0.01	1.00		
USA	534	0.31	0.46	0.00	1.00	-0.01	0.03	0.04	0.05	-0.07	0.02	-0.11	-0.07	-0.09	-0.63	1.00	
Other	534	0.12	0.33	0.00	1.00	0.05	0.01	0.00	0.02	0.08	0.04	-0.07	-0.04	-0.05	-0.35	-0.25	1.00

Table 3: Logistic regression predicting voter participation 2001.

	(1)	(2)	(3)
	vote	vote	vote
Leader in 2000	2.277**	1.706	1.537
	(9.749)	(5.509)	(4.652)
Number of packages	0.084***	0.069***	0.064***
	(1.087)	(1.071)	(1.067)
Package Popularity	0.000	0.000	0.000
	(1.000)	(1.000)	(1.000)
Tenure in the project (in months)	-0.011*	-0.012*	-0.017**
	(0.989)	(0.988)	(0.984)
North America[a]	0.000	-0.027	0.027
	(1.000)	(0.974)	(1.028)
Other Continent[a]	0.228	0.270	0.324
	(1.256)	(1.310)	(1.382)
Number of postings (Year t-1)		0.011***	0.010***
		(1.011)	(1.010)
Degree centrality (Year t-1)			0.042**
			(1.043)
Intercept	-0.810***	-0.887***	-0.976***
Log-likelihood ratio for model estimated:			
vs. null model (df)	62.45††	78.99††	84.02††
	(6)	(7)	(8)
vs. previous model (df)		16.54††	5.03†
		(1)	(1)
N	515.00	515.00	515.00
Pseudo R-squared	0.09	0.11	0.12

Odds ratios in parentheses
[a] Compared to developers located in Europe
*=p<0.l, **=p<0.05, ***=p<0.01 (one tailed tests)
† χ^2 significant at the level (p = <.05)
†† χ^2 significant at the level (p = <.01)

Table 4: Logistic regression predicting leadership 2000 - 2002.

	(1)	(2)	(3)	(4)	(5)	(6)
	Leader 2000	Leader 2000	Leader 2000	Leader 2000	Leader 2001	Leader 2002
Number of packages	0.006	-0.017	-0.023	-0.032	-0.085	-0.046
	(1.01)	(0.98)	(0.98)	(0.97)	(0.919)	(0.955)
Package Popularity	0.001***	0.000**	0.001**	0.001**	-0.001	-0.000
	(1.0005)	(1.0005)	(1.005)	(1.005)	(0.999)	(1.000)
Tenure in the project (in months)	0.076**	0.080**	0.063	0.028	0.084**	0.104***
	(1.08)	(1.08)	(1.07)	(1.03)	(1.088)	(1.110)
North America[a]	1.253	1.267	1.660	1.347	0.667	1.589
	(3.53)	(3.58)	(5.31)	(3.845)	(1.948)	(4.900)
Other Continent[a]	0.770	0.996	1.581	1.406	1.517	1.405
	(2.17)	(2.72)	(4.89)	(4.080)	(4.558)	(4.074)
Number of postings (year t-1)		0.009***	0.007**	0.008**	0.020***	0.014
		(1.009)	(1.007)	(1.008)	(1.021)	(1.014)**
Degree centrality (year t-1)			0.097			
			(1.10)			
Betweenness (year t-1)				0.549**	0.632*	0.670*
				(1.731)	(1.882)	(1.955)
Intercept	-6.491***	-7.358***	-7.544***	-6.785***	-8.852***	-10.724***
Log-likelihood ratio for model estimated:						
vs. null model	13.55†	23.75††	25.68††	29.22††	43.14††	35.93††
(df)	(5.00)	(6.00)	(7.00)	(7.00)	(7.00)	(7.00)
vs. previous model		10.22††	1.93	5.38†		
(df)		(1.00)	(1.00)	(1.00)		
Observations	289.00	289.00	289.00	289.00	514.00	646.00
Pseudo R-squared	0.21	0.36	0.39	0.44	0.58	0.53

Odds ratios in parentheses
[a] Compared to developers located in Europe
*=p<0.l, **=p<0.05, ***=p<0.01 (one tailed tests)
† χ^2 significant at the level (p = <.05)
†† χ^2 significant at the level (p = <.01)