The Ecology of Open-Source Software Development

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Abstract

Open Source Software (OSS) is an innovative method of developing software applications that has been very successful over the past eight to ten years. A number of theories have emerged to explain its success, mainly from economics and law. We analyze a very large sample of OSS projects and find striking patterns in the overall structure of the development community. The distribution of projects on a range of activity measures is spectacularly skewed, with only a relatively tiny number of projects showing evidence of the strong collaborative activity which is supposed to characterize OSS. Our findings are consistent with prior, smaller-scale empirical research. We argue that these findings pose problems for the dominant accounts of OSS. We suggest that the gulf between active and inactive projects may be explained by social-structural features of the community which have received little attention in the existing literature. We suggest some hypotheses that might better predict the observed ecology of projects.

Besides the Internet itself, the most distinctive and widespread development in information technology since the mid-1990s has not been a particular software application, but rather a way of writing and distributing software in general. The rapid growth of the Open Source Software (OSS) movement has astonished most observers. From modest beginnings, there are now thousands of active OSS projects, ranging in scope from simple calculators

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to entire operating systems. Open Source Software is given away for free by the developers who write it, both in the sense that it is provided at a nominal charge and that it is licensed to users without the legal restrictions typical of commercial software.[1]

Although OSS development is an important phenomenon closely linked to the growth of the Internet, we do not know much about how it works in practice, who is involved or why they participate. From a theoretical point of view, the OSS approach does not fit with standard models of software development (Sandred 2001, Vixie 1999) or formal organization more generally (Neff and Stark 2002). It is a hybrid: part social movement, with idealistic principles and goals; part formal organization, with an intensive schedule and innovative products; part volunteer network, with time and energy to donate.

In this paper, we present data from a large sample of OSS projects as a first step towards understanding the social organization of OSS development. We argue that, as a collaborative project of great size and scope, rooted in networks of volunteers and embedding innovative organizations and new markets within itself, OSS development is of strong interest to economic sociologists. We find that the social structure of OSS development, as measured by the size, composition and activity pattern of projects, differs significantly both from typical characterizations by movement "evangelists" and from broad claims by theorists of OSS.

We begin by providing some basic background about OSS and then discuss the emerging theoretical literature. We then present some hypotheses from this literature and test them against a large sample of OSS projects. A central finding is that the OSS community is spectacularly stratified on a variety of activity and participation measures. The observed structure challenges both the common image of the OSS community as a relatively "flat" network of interacting peers (Raymond 2001) and to an emerging theory of the community as an efficient router of human capital information

[1]For an accessible narrative overview of the OSS movement, including samples of the various software licenses, see Wershler-Henry (2002). For some of the foundational texts of the movement, and a sense of its internal diversity, see the essays in DiBona et al. (1999).

(Benkler 2002). It *is* consistent, however, with some recent empirical data on OSS project development (Mockus et al. 2000) and on the OSS community (Krishnamurthy 2002). In our discussion, we emphasize the strikingly consistent patterns found in the data, discuss their implications for existing theory, and suggest a number of hypotheses about the social structure of the OSS community that might explain the observed patterns.

EXISTING THEORY AND RESEARCH

Traditional software development follows a familiar pattern. A company writes a program and then tries to sell it. The program's "source code" is a trade secret, just like an auto manufacturer's blueprints for its cars. By contrast — as the name suggests — the source code in an OSS project is available to anyone who wants it. The software is developed and maintained by a community of volunteers. Essentially, anyone is free to take the results of this work and modify it, extend its capabilities, or incorporate it into their own projects (usually, but not always, on condition that they keep their own contributions "open" in a similar way).[2] It is a counterintuitive way to act in the highly competitive world of computing and information technology. And yet, although casual users are often unaware of it, many essential features of the Internet — such as sending email and serving web pages — are more often than not controlled by software created through OSS projects. Besides this "backstage" work, OSS projects like the GNU/Linux operating system and, more recently, Apple's use of OSS components in their operating system have become increasingly prominent.

[2]The precise conditions depend on the license the software is released under. There is debate within the OSS community about its appropriate form. The central innovation of the Free Software Foundation's canonical GNU General Public License (or GPL) is that it allows the licensee to make changes to the source code and freely redistribute it only on the condition that the source code for the new version is redistributed with any new version of the software. Programmers may freely use the work of others, but must make their own changes available for use in the same way. Other licenses (the Berkeley BSD license, for example) do not contain this restriction. See Sandred (2001) Ch. 3, Wershler-Henry (2002) Chs 2 and 4, Perens (1999) and Williams (2002) for further detail and different perspectives on the issues at stake.

Early surveys of the new information technologies were largely speculative and tended to focus on the transformative possibilities of new hardware (Dertouzos 1997, Gilder 1990). More recent research has put the growth of the Internet in historical perspective (Abbate 2000, Chandler and Cortada 2000) and shown how the new information technologies are changing — and being shaped by — existing legal and political institutions (Lessig 2001, Sunstein 2001). Sociologists are also examining the effect of the Internet on social inequality, political participation and cultural life generally (for a review see DiMaggio et al. 2001).

A smaller body of research focuses on the engine driving many of these changes — the OSS developers themselves and the distinctive organizational forms they have created. Evangelists for the movement have written about how it ought to work (DiBona et al. 1999), and journalists have described the movement's recent history and main figures (Moody 2001). But there are far fewer studies of the organizational structure of OSS, such as the characteristics of projects, their practical administration, the relationship between developers and users, the location and background of the developers themselves, their reasons for participating in the community, the benefits they gain from it, and so on.

Theories of OSS

The stylized image of OSS development, most often found in popular accounts of the phenomenon, is one of an egalitarian network of developers largely free of hierarchical organization and centralized control. A widely-cited essay by Eric Raymond argues explicitly that the virtues of the OSS style of development come from its flat structure. He contrasts

> two fundamentally different development styles, the "cathedral" model of most of the commercial world versus the "bazaar" model of the Linux world... Linus Torvalds's style of development — release early and often, delegate everything you can, be open to the point of promiscuity — came as a surprise. No quiet, reverent cathedral-building here — rather, the Linux community

> seemed to resemble a great babbling bazaar of differing agendas and approaches ... out of which a coherent and stable system could seemingly emerge only by a succession of miracles ... the Linux world not only didn't fly apart in confusion but seemed to go from strength to strength at a speed barely imaginable to cathedral-builders (Raymond 1998).

Efforts by economists to "theorise the the bazaar," as it were, break the problem into two parts. First is the lack of hierarchy and the apparently chaotic nature of OSS development. From an economist's point of view, it is not surprising that a distributed and disaggregated system of innovation successfully outperforms a hierarchically-organized alternative. Thus, Eric von Hippel argues that

> Complete user-centric innovation development and consumption communities can flourish when (1) at least some users have sufficient incentive to innovate, (2) at least some users have an incentive to voluntarily reveal their innovations and the means to do so, and (3) diffusion of innovations by users can compete with commercial production and distribution. When only the first two conditions hold, a pattern of user innovation and trial will occur, followed by commercial manufacture and distribution of innovations that prove to be of general interest (von Hippel n.d.).

By "user-centric innovation" von Hippel means a community of users who tend to tinker with and improve the products they use. Hobbyists often display this tendency (von Hippel first noticed it happening amongst windsurfers who improved their gear) and he argues that the OSS community is a very large and disaggregated example of this type.

A complementary account is presented in Benkler (2002). Benkler presents a transactions costs analysis (Coase 1988, Williamson 1985). The central virtue of the OSS model, he argues, is its "peer-to-peer" structure, which lowers transactions costs in particular circumstances and provides a more efficient method of allocating human capital inputs:

> [T]he primary advantage of peer production is in acquiring and processing information about human capital available to contribute to information production projects . . . [P]eer production has a systematic advantage over markets and firms in matching the best available human capital to the best available information inputs to create the most desired information products . . . [I]f peer production has a sufficient advantage in terms of its capacity to process information about who the best person is for a given information production job over firm and market based mechanisms to outweigh the costs of coordination, then peer production will outperform firms and markets (Benkler 2002).

Benkler does not say how to measure the benefits of information flow conferred by commons-based peer production. Information is not conveyed via price signals, as in markets, or via chains of command, as in firms. Instead, it "relies on decentralized information gathering and exchange to reduce the uncertainty of participants, and has particular advantages as an information process for identifying human creativity available to work on information and cultural resources in the pursuit of projects, and as an allocation process for allocating that creative effort" (Benkler 2002, 7). The "pervasively networked environment" of the OSS community allows for better information flow about who should take on particular projects. This analysis suggests a community social structure of a particular kind. In contrast to atomized agents relying on price signals to make decisions, community participants should be well-connected ("pervasively networked") and information should flow well between them. The result, according to Benkler, will be a process "matching human capital to information inputs to produce new information goods" (Benkler 2002, 73).

The second problem is a little more difficult to reconcile with a purely economic view. Why is there so much voluntary participation? Why are participants willing to develop and distribute their innovations for free? In a careful economic analysis of developer motivations, Lerner and Tirole (2000) argue that, despite initial appearances, several incentives make it rational to volunteer. Chief amongst these are the practical benefits to users of having software that works properly, the increase in reputation that comes from being associated with a successful project, and the potential for OSS projects to lead to further commercial opportunities. Lerner and Tirole argue that "the reputational benefits that accrue from successful contributions to open source projects appear to have real effects on the developers," that "there also appear be quite tangible — if delayed — rewards" to participation, that "many of the skilled Apache programmers have benefited materially from their association with the organization" and that there is "substantial evidence that open source work may be a stepping stone to securing venture capital" (Lerner and Tirole 2002, 217-18).

This perspective on OSS development is illuminating but incomplete. The motives adduced by Lerner and Tirole are plausible (and supported by evidence from a number of important OSS projects), but cannot fully account for the movement's organization. In particular, the role of the project leader is difficult to explain in economistic terms:

> Another important determinant of project success appears to be the nature of its leadership ... The key to a successful leadership is the programmers' trust in the leadership: that is, they must believe that the leader's objectives are sufficiently congruent with theirs and not polluted by ego-driven, commerical or political biases. In the end, the leader's recommendations are only meant to convey her information to the community of participants. The recommendations receive support from the community only if the leadership's goals are believed to be aligned with the programmers' interests (Lerner and Tirole 2002, 221-22).

The difficulties of the argument are apparent. Programmers are supposed to contribute to projects for self-interested reasons, but leaders can only be successful if they are "not polluted by ego-driven, commercial or political biases". Lerner and Tirole attempt to parse the project leader's authority as simply a matter of conveying information, and her success as simply dependent on congruence with the interests of her followers. But, from a sociological point of view, this is a thin characterization of the role of the charismatic leader. Indeed, they note that "leaders of open source movements may initially not have been motivated by ego gratification and career concerns" (Lerner and Tirole 2002, 213), and that "Despite the substantial status and career-concerns benefits of being a leader of an imporant open source project, it would seem that most should not resist the large monetary gains from taking a promising technology private. We can only conjecture why this is not the case" (Lerner and Tirole 2002, 215).

These gaps in the economic account of community participation suggest there is more than "simple economics" at work here. In particular, the key role of project leaders in mobilizing successful projects seems undertheorized. Empirical studies of the OSS community's social structure raise further questions about both Lerner and Tirole's and Benkler's view of OSS.

Existing empirical data

What do we know about OSS community structure? We focus on two studies in particular.[3] Mockus et al. (2000) is a case study of one of the most successful open source projects, the Apache server.[4] Taking a software-engineering perspective, they focused on the internal process used to develop Apache, asking how many people wrote code, reported problems and repaired defects. A key finding was that the Apache project was driven by about 15 core developers, who contributed about 85-90% of the code, surrounded by a larger penumbra of participants. A group larger than the core by about an order of magnitude helped fix defects, and a group larger by an order of magnitude again helped report problems (Mockus et al. 2000, 271). The authors hypothesized that this pattern would be common across successful OSS projects.

[3]Other important efforts in this direction include Lakhani and von Hippel (n.d.), Lancashire (2002) and Schweik and Semenov (2003).

[4]Apache is a piece of software that serves up web pages. Websites are powered by web servers that respond to requests from users to see a particular page on a site. More than half the world's websites are powered by the Apache server.

In one of the few survey- rather than case-study based analyses of OSS, Krishnamurthy (2002) asked whether "the community-based model of product development holds as a general descriptor of the average OSS product." Examining 100 mature projects from the Sourceforge database (see below for further discussion of this data source, also used in this paper), he found that "the vast majority of mature OSS projects are developed by a small number of individuals. In fact, the median number of developers in his sample was one. He also found that few OSS projects generated much discussion. "On average, each OSS project had 2 forums and 2 mailing lists for discussion. Ten of the 100 products had neither an online forum nor a mailing list . . . 33 out of 100 projects had 0 messages! At the same time, a few products led to great discussion with the highest number of messages over a life time of a product standing at 4,952" (Krishnamurthy 2002).

These findings suggest that a large-scale survey of OSS projects should find a clear structure. On the basis of the Apache case study, we expect that *within projects*, development activity will be strongly skewed across coding, problem-correction and problem-reporting tasks in, the manner described by Mockus et al. (2000). On the basis of Krishnamurthy's survey, we expect that *between projects*, development activity will be strongly skewed, with a small number of projects attracting most activity.

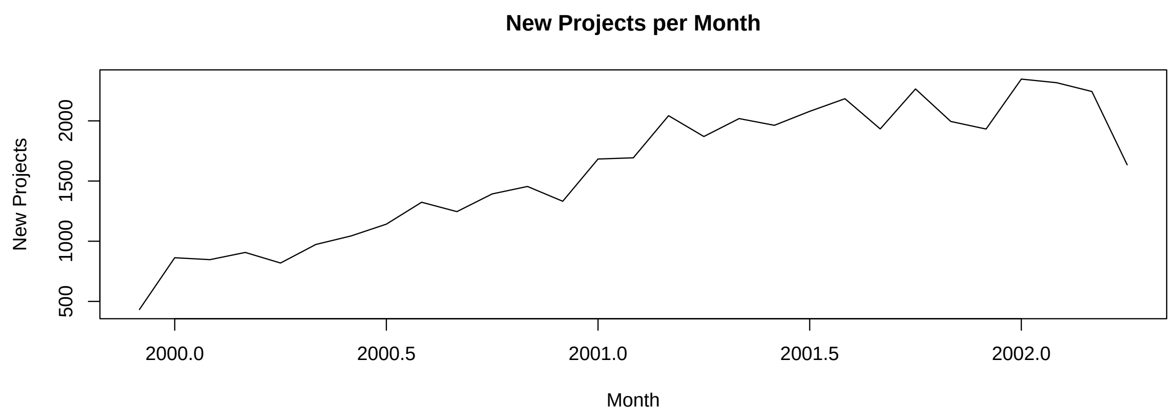
DATA AND METHODS

One reason for the lack of research in this area is that the OSS movement is large, informally structured, and geographically dispersed. It is therefore difficult to collect good data. We avoid this problem by using a copy of the Sourceforge project database in our analysis. Sourceforge (`www.sourceforge.net`) is the largest repository of Open Source projects available on the Internet. Sourceforge provides hosting services for project developers, allowing them to manage their source code, communicate with one another (via email, mailing lists and discussion forums) and make their work available for download. Although the developers themselves are located all over the world, Sourceforge's servers are where the day-to-day interaction and innovation actually happens for a very large sample of OSS projects.

Sourceforge's parent company, OSDN, provided the lead author with a summary snapshot of its project database in August of 2002. The data contain records for the 46,356 projects then hosted by Sourceforge. Fields include basic (non-confidential) information on each project and various measures of development activity. These measures include data on the number of developers, downloads, CVS[5] checkouts and commits, number of mailing lists, number of posts to mailing lists, number of unique message authors, number of site views, number of support requests open and closed, and number of bug reports opened and closed. These variables measure different aspects of a project's vitality ranging from level of general interest (site views, downloads) to intensity of development (number of developers, CVS code commits), as well as intermediate activity (bug reports, support requests).

Sourceforge does not host all OSS projects by any means. Several major projects — amongst others, the Linux Kernel, the Apache server, the GNOME and KDE desktop environments, and the XFree86 implementation of the X-Window system are all major OSS projects with their own websites, project-management groups and underlying organizational apparatus (usually some form of non-profit organization). In addition, many of the original GNU software projects are hosted by the Free Software Foundation's Savannah server rather than by Sourceforge. Nevertheless, Sourceforge is a valuable resource for researchers. It is by far the largest collection of OSS projects and has grown rapidly since its foundation in 1999, as can be seen from Figure 1.

[5]Concurrent Versioning System, or CVS, is software that allows multiple developers to work on a project over time. Developers "check out" portions of the source code in order to make modifications to it. Changes are later "committed" to the main development tree, which holds the canonical version of the code. The CVS application keeps track of what code has been checked out, and by whom, and allows project managers to reconcile code changes made by different developers into a stable release of the source code. Data on CVS checkouts and commits is therefore a measure of a project's development activity.



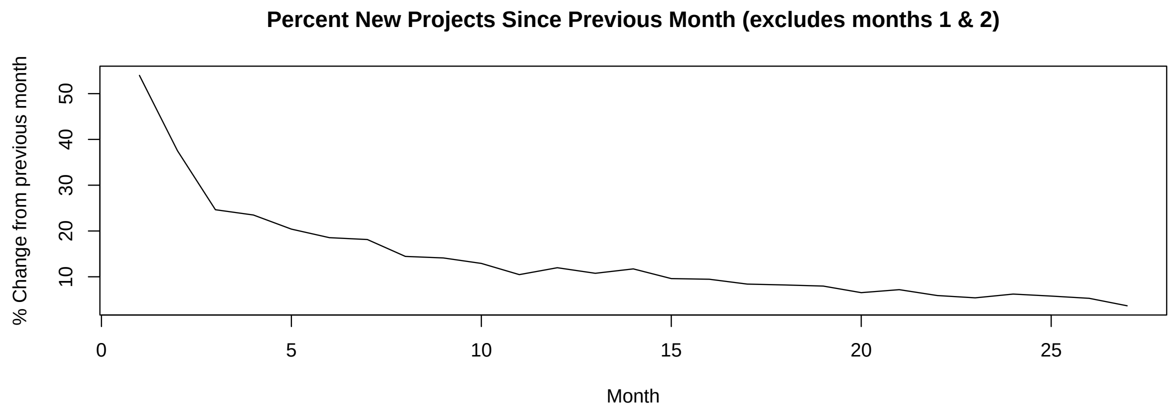


Figure 1: *New Projects on Sourceforge, Nov. 1999–Aug 2002: absolute (top) and relative (bottom) growth.*

RESULTS

We examined six measures of project activity. Detailed descriptive summaries of each measure are provided in Table 1.[6] It shows the valid N, the number of missing values and the number of unique values for each variable. Values at selected intervals between the 5th and 95th percentiles are shown beneath a small histogram. Each variable's five lowest and five highest values are also shown.

As is clear from these descriptive statistics, activity across the whole range of OSS projects is spectacularly skewed, beyond even the expectations raised by Krishnamurthy's study. The median number of developers is one. The 95th percentile is 5. Relative to the whole field, only a tiny number of projects have more than a handful of developers. The median number of CVS commits is zero. At the 75th percentile it is 1 and at the 90th percentile it is less than 100. This indicates that there is little or no programming activity taking place on more than half of the projects. Examining the number of message authors across all forums shows that only projects at the 90th percentile and above have more than two contributing message writers.

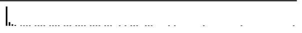
To better grasp the structure of the data, it is convenient to represent it graphically. Phenomena with highly skewed distributions often follow "power-law distributions" — roughly, the relationship between the frequency of an event and its size appears linear on a log-log scale. Zipf's law, a subspecies of power-laws, says that the size (y) of the r'th largest occurrence of an event will be inversely proportional to its rank-order: $y \approx r^{-b}$, with $b \approx 1$ (Zipf 1949).[7] Distributions of this sort are very common across a wide range of natural phenomena — the frequency of earthquakes is a stock example, with small quakes being very common compared to the few large ones. For social phenomena, power laws have been observed for city size (Krugman 1996), formal organizations such as the military and hospitals

[6]This table was produced using the `describe` function from Frank Harrell's `Hmisc` library for R (Harrell 2001, Ihaka and Gentleman 1996).

[7]Power-law distributions express a relationship between size and frequency; Zipf's law relates rank and frequency. The two are closely related. See Adamic (n.d.) for a helpful discussion of relationships of this type.

Table 1: Summary of Project Activity Measures

Developers



```
      n missing  unique    Mean     .05   .10   .25   .50   .75   .90    .95
  46356       0      43   1.688       1     1     1     1     2     3     5

lowest :  1  2  3  4  5, highest: 46 47 55 65 80
```

Downloads

```
      n missing  unique    Mean   .05   .10   .25   .50   .75   .90    .95
  46356       0    4380    2289     0     0     0     0    48   872   3116

lowest :       0       1       2       3       4
highest: 1698729 1723212 3330871 4598807 7703001
```

Site Views

```
      n missing  unique    Mean   .05   .10   .25   .50   .75   .90    .95
  46356       0    5726    1915     7    12    31   140   562   2084  4903

lowest :       0       1       2       3       4
highest:  640248  762994  821937  879960 5124577
```

Msg Uniq Auth

```
      n missing  unique    Mean   .05   .10   .25   .50   .75   .90 .95
  46356     0      70   1.237     0     0     1     1     1     2   3

lowest :   0   1   2   3   4, highest: 132 149 183 257 344
```

CVS Commits

```
      n missing  unique    Mean   .05   .10   .25   .50   .75   .90    .95
  46356       0    1649   88.89   0.0   0.0   0.0   0.0   1.0  94.0  328.2

lowest :     0     1     2     3     4
highest: 30111 31058 39669 68320 78959
```

(Mayhew and Rushing 1973, Mayhew and James 1972), and — relevant in this context — aspects of the flow of Internet traffic (Huberman 2001).[8] We find that the OSS community displays a very similar structure. The panels in Figure 2 show rank-ordered distributions for six activity measures. In each

[8]There is an under-explored link between the work of Mayhew and his associates and more recent studies of the emergent structure of Internet communities (and other social phenomena with power-law-type characteristics). Mayhew's work is strongly oriented towards the deep problem of emergent differentiation within social aggregates (Blau 1977, 1970), and thus might well provide a fruitful sociological approach to these issues. Pursuing this link in more detail is a task for future research.

case, projects are rank-ordered logarithmically on the x-axis, ordered from highest to lowest. Thus, for the 'Developers' panel, the first tick on the x-axis marks the project at the 99.995th percentile, the second the project at the 99.99th percentile, and so on. Given that each plot shows the data for more than 45,000 projects (rather than, say, a fitted line), the regularity is striking. In each case, the activity is overwhelmingly concentrated in the very upper end of the distribution. That this should be so for the number of downloads is consistent with other work the topology of the Internet (Faloutsos et al. 1999). But it also holds for the measures which more closely index actual interaction, such as the number of developers and the number of messages. Mayhew et al. (1995) found similar patterns in naturally occurring face-to-face groups.

It is interesting in and of itself that each of these measures of OSS community activity should be so consistent. Yet this is only a first step towards understanding the development of the field. The mechanisms generating these consistent rank distributions may be quite different from one another. Different kinds of activities may cluster in different sorts of projects, for instance, even though the shape of the overall distributions is the same. To illustrate this point, we compared the most active projects as measured by number of downloads (Table 2) with the most active projects as measured by number of CVS commits (Table 3). The most downloaded projects are mainly end-user applications. The most heavily developed projects are mainly "behind the scenes" system-level applications, programming environments, or utilities providing basic functionality to an Operating System.

In summary, we found power-law type distributions for all activity measures in our dataset. In each case, a tiny number of projects dominate an activity-type when measured by volume. Different projects (and different kinds of project) dominate different measures. Measures of user interest in a project — such as site views and downloads — are not closely related to measures of developer activity on a project. The OSS community presents different faces to different audiences. Most users will download a similar set of applications (the most popular ones), but most project developers will never see a user looking to download their software. Many users may con-

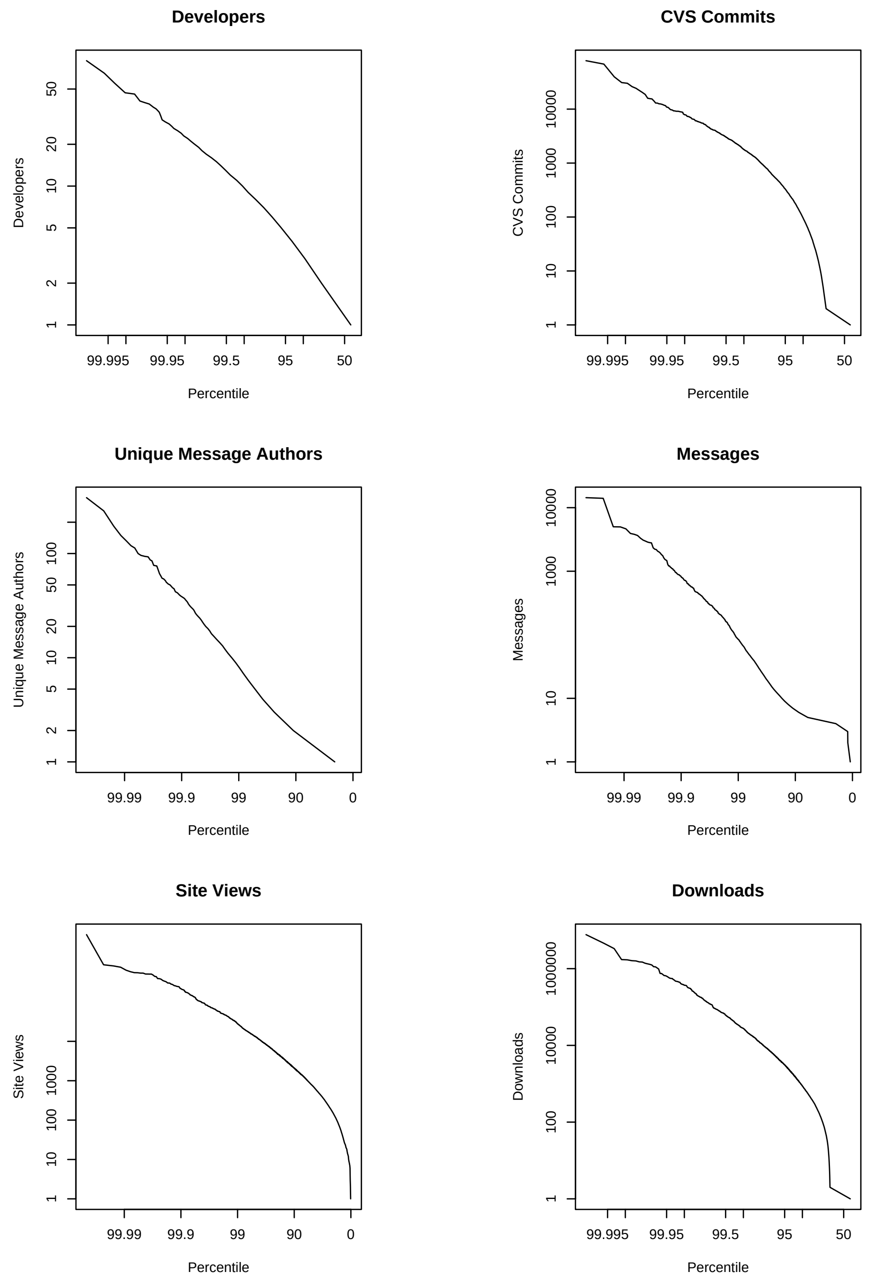


Figure 2: *Six measures of project activity.*

tribute bug reports or feature requests, but the vast majority of projects do not receive them.

DISCUSSION

These preliminary findings raise questions about the scope and accuracy of existing theories of OSS development. In particular, the highly stratified structure of project development suggests that broad generalizations about the "OSS approach" or the "OSS community" or "OSS developers" may be much too broad. Similarly, arguments about what makes OSS successful may need tempering given data on the characteristics of a typical project. So, for instance, Raymond's image of the bazaar does not capture the fact that the typical project has one developer, no discussion or bug reports, and is not downloaded by anyone. "Linus's Law," coined by Eric Raymond, states that "Given enough eyeballs, all bugs are shallow."[9] It is hard to see how it can apply to most OSS projects in our dataset, as the only eyeballs looking at the code belong to the lone developer. Similarly, the transactions costs model presented by Benkler argues that the flow of information in a pervasively networked environment tends to allocate the best human capital to the job at hand. There is little evidence of this process at work in the present sample of OSS projects, if only because there simply is so little communication registered on the vast majority of projects.[10]

What can we make of this gap between theory and data? A natural response is to argue that what is at issue here is the appropriate definition of the OSS community or the OSS field of projects. On this view, many of the projects hosted by Sourceforge have fallen dead-born from the PC. They are unlikely to develop beyond a vague plan for development, a general invitation to help out, and a version 0.001a alpha release (if even that). So perhaps we should exclude them from the pool of projects we consider when we talk

[9]An amazing three metaphors packed into seven words.

[10]We do not discuss a third strong claim often made for the OSS model, namely that it produces innovative software better than standard approaches. There is not a great deal of evidence for this claim in our data, but this is a complex issue that needs separate treatment at greater length.

Table 2: Top Ten Most Downloaded Projects

Name	Type of Application
CDex	Audio
VirtualDub	Video processing
ZSNES	Game emulator)
Back Orifice 2000	System/network admin
MySQL	Database
Dev-C++	Development
AFPL Ghostscript	Print/typesetting
MyNapster	File sharing
Tux Racer	Game
Gnucleus	File sharing

about OSS. An argument in favor of this view is that the Sourceforge data has a disproportionate number of projects that are likely to fail or have already failed. If we look instead to projects that have succeeded — the standard cases studies like Apache, or the Linux Kernel and so on — then we see the true OSS model at work.

A difficulty with this argument is that it simply restates the problem by redefining the scope of the term "OSS community." In addition, it contradicts the rhetoric that evangelists for OSS use and theorists echo. Why shouldn't the thousands of amateur developers count as part of the community? Isn't that what is supposed to characterize the phenomenon in the first place?

A better approach, we argue, is to see the highly stratified nature of OSS as an opportunity for advancing theory. It seems clear that for every successful OSS project there are thousands of unsuccessful ones. This surely raises important questions about the alleged benefits of the approach. It obviously does not mean OSS cannot work (any more than the failure of regular businesses means that capitalism cannot work), but it does mean that the scope conditions for a successful project need to be better specified. Why, for example, does Apache succeed when so many others fail? It cannot simply be because it's an OSS project, for so are the failures. There must be something else at work.

What might that be? We do not pretend to offer a full explanation here. But we do want to suggest some possible approaches, grounded in sociological approaches to organization and mobilization. Three aspects of OSS development seem particularly under-theorized. First, it is clear from the case-study literature that successful OSS projects are most often staffed (at their cores) by professional software developers. This might seem like a banal observation, but we should bear in mind how this differs from the populist image of teenage hackers in their parents' basements beavering away on new technologies. Despite the public image of hackers, the projects that matter are (more often than not) run by professionals and not amateurs. We need more research into how this group regulates itself, and what its values are. A hypothesis for future research is that *the more successful an* OSS *project, the more professional its core contributors will be*, as measured by length of practical experience, formal qualifications or both.

Second, we suggest that the data presented here, corroborated again by case studies, implies that the role of project leaders in mobilizing development is crucial. Effective project leadership seems to us one of the most likely candidates for differentiating successful projects from unsuccessful ones. The voluntary nature of participation in an OSS project makes the role of the leader vitally important. The preconditions for successful mobilization may well be best understood not via economic approaches, we argue, but via concepts borrowed from the literature on social movement organization and political action. The theoretical literature on OSS at present is dominated by ideas derived from Economics, Law and Management. These disciplines obviously have important contributions to make, but may tend to downplay or miss key aspects of the OSS phenomenon. As we said at the beginning, OSS is a hybrid — part economic project, part network organization and part social movement. The two latter aspects, and especially the last, seem the least well-understood. We suggest that *successful* OSS *projects will tend to have core participants mobilized in a way similar to core participants in successful social movement organizations.*

Third, and last, we argue that the importance of hierarchical organization to successful OSS projects is systematically underplayed in the theoretical literature. We suggest that *successful* OSS *projects will tend to have a*

Table 3: Top Ten Projects by CVS Commits

Name	Type of Application
Crystal Space 3D Engine	Graphics engine
Open CASCADE Auto Config	Development
Direct Rendering Infrastructure	Graphics development
Squid HTTP Proxy Developments	Proxy server
gkernel	Core OS development
Linux Standard Base	Core OS development
LinuxSH	Core OS development
QuakeForge	Game engine
phpGroupWare	Web groupware
Python	Programming language

strong hierarchical component, at least in the ways they manage the relations between lead (and core) developers and other contributors. This is not an original observation on our part, yet it is remarkably absent from most of the standard accounts of OSS, which tend instead to focus on the (allegedly) quasi-anarchic qualities of the development process. Jordan Hubbard, a leading contributor to the FreeBSD project, comments:

> Despite what some free-software advocates may erroneously claim from time to time, centralized development models like the FreeBSD Project's are hardly obsolete or ineffective in the world of free software. A careful examination of the success of reputedly anarchistic or "bazaar" development models often reveals some fairly significant degrees of centralization that are still very much a part of their development process.[11]

There is a lot to be said for this argument. As several case-studies have noted, core development on successful OSS projects tends to be well organized. In some cases — most conspicuously in the case of the Linux kernel — it is entirely hierarchical, with lead developer Linus Torvalds deciding which patches will be accepted to new versions of the kernel and which will

[11]Quoted in *Linux Magazine*, April 2000. `http://www.linux-mag.com/2000-04/opensource_evol_01.html`.

not.[12] We suggest that, despite the canonical image of OSS development as a free-for-all bazaar, hierarchical organization is central to the success of important projects. This hierarchy is not a formal organizational chart but rather (we conjecture) a status-based pecking order which is known to project participants and serves as a way of policing members. Following Arthur Stinchcombe's observation that contracts may have hierarchical elements (Stinchcombe 1985), we suggest that the apparently open-form, flat networks of the OSS community are in many ways strongly hierarchical. We further suggest that, contrary to the conventional wisdom, hierarchy tends to emerge as a precondition of successful project management and hypothesize that *the closer a successful project is to the core of the* OSS *community, the more hierarchy will be found in its management style.* Thus, for instance, the social organization of kernel hackers will be more hierarchical than that of developers of add-on applications for the GNOME or KDE desktop environments, because the kernel is the essence of the operating system, whereas additional text editors or desktop calculators are much less important.

In sum, we have argued that the huge gap between successful and unsuccessful (active and inactive) projects in our data is a real puzzle. We offer these hypotheses as a way of focusing attention on some aspects of the OSS community which we feel have been neglected in current theory. We have consciously formulated them in a way that focuses on aspects of OSS organization — professionalism, clear leadership, hierarchy — that are antithetical to the standard image of the community. More generally, we have argued that researchers should attend more closely to the social structure of the OSS community. The process of OSS development is embedded in particular structural and organizational contexts that theorists of OSS have so far paid little attention to. Investigating them offers a promising route for an original sociological perspective on this exciting phenomenon.

[12]This has created a significant amount of tension in the kernel hacker community. [REF]

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Fun and Software Development

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Abstract – **The FASD study gathered 1330 answers about fun and software development from open source developers as well as 114 answers from programmers working in commercial software projects. The analysis of these data proves that fun plays an important role when software developers decide to get engaged in an open source project. Moreover, the comparison of the answers gives evidence for the hypothesis that programming in an open source project is significantly more fun compared to the same activity under commercial conditions. The reasons for this fact are that open source projects are able to attract software developers with a credible project vision and that they can offer them an optimal challenge.**

I. INTRODUCTION

The continuing success of open source software has also attracted the interest of the research community. As a result of this academic interest, a number of empirical studies were carried out to account for the open source phenomenon (see for example [1] to [12]). The study about Fun and Software Development (FASD) builds on these existing studies (see [13]).

II. RESEARCH QUESTIONS

The aims of the FASD study are twofold:

First, the study aims to make a quantitative estimation of the importance of fun in order to explain the open source developers' commitment. Second, it aims to verify the hypothesis that open source developers have more fun when programming than developers of commercial software. If this hypothesis can be confirmed, the FASD study aims to identify those elements which are responsible for the fact that open source developers have more fun with their work than commercial developers.

A. Research methods

In order to achieve the aims of this study, a questionnaire for an online survey was developed. There were two versions of this questionnaire, one addressing open source developers, the other addressing programmers working in commercial software firms. The questionnaires consisted of 53 questions. The first part of the questionnaire was identical for both versions. The purpose of this part was to measure the flow software developers experience during their work. I used the flow construct introduced by Csikszentmihalyi (see [14], [15]) to operationalise the fun developers have while programming.

In the following part, I asked the open source developers about their readiness for future activities in open source projects, about how many patches and modules they have developed so far, and how much of their working hours and spare time respectively they spend on developing open source software. With these questions, the criterion variables were established, i.e. they function as a measure of the developers' commitment.

In a further part of the questionnaire, the open source developers were asked about the reasons why they initially joined an open source project or why they started one themselves. In the concluding part of the questionnaire, I gathered demographic data about the respondents and tried to elicit information about the opportunity cost they have when they work for open source projects in their spare time, e.g. by asking them how much spare time and how many hobbies they have.

In the questionnaire for the developers in commercial software firms, I asked them about their willingness to work overtime and about how many checkins they did in the past few days in order to get an impression of their commitment. In a further part of the survey, these developers were asked about their relation to their employer, i.e. how proud they are of their employer and how well they can develop personally and professionally at their workplace. I further asked them how frequently they feel deadlines, about the project visions behind the software projects they work in and about the project managers' formal authority and professional competence. Again, gathering demographic data concluded this questionnaire.

The questionnaire I used was a standardised questionnaire that contained no open questions. About 80% of the questions were formulated as statements; the respondents then indicated their agreement with the statements from “completely unimportant” to “very important” and “is never the case” to “is always the case” respectively on a six point Likert scale.

This study design allows answering the questions formulated in the beginning and to test the hypothesis. I used a simple model which combines the open source developer's commitment as a dependent variable with the explanatory variables consisting of the fun (i.e. flow) and the opportunity cost of time (i.e. the availability of spare time). Using statistical methods like regression and variance analyses, it is possible to test the connection between fun and spare time one the one hand and commitment on the other. The proportion of the variance that can be explained with this model can be used as a measure of the importance of fun for the motivation of open source developers.

By directly comparing the answering behaviour of open source developers and programmers working for commercial firms, it is possible to test the hypothesis that the two groups differ significantly concerning the experience of flow. And by asking the commercial developers about deadlines, project visions and formal authority - all characteristic elements of the commercial software development model which distinguish it from the open source model - I am able to identify the factors responsible for a potential difference between them.

The open source version of the questionnaire was launched on May 3, 2004. I sent a mail to the mailing lists of the various projects hosted by SourceForge, GNU/Savannah and BerliOS. This questionnaire was open during 53 days until June 25, 2004 and was filled in by 1330 respondents. For the second questionnaire, I found six software companies in Switzerland ready to collaborate with the FASD study. The questionnaire for the developers working for these companies was open from September 20 until November 10, 2004. 114 software developers filled in this version of the questionnaire.

III. RESULTS

A. General results

The study participants come from 74 countries, 19.1% thereof come from the USA, 18.9% from Germany, 5.1% from France and 4.6% from Great Britain. The remaining contributors come from other European countries, from South America, Australia and a few African and Asian countries. Only 1.9% of the contributors are female and only 22.3% have children. Nearly 60% of the respondents are full time employed, only 3.3% declared to be out of work and 28.1% are students. More than half of the contributors are between 20 and 29 years old, almost 28% are between 30 and 39 years old, the youngest is 12 and the oldest is 65 years old. Most of the contributors have only been actively engaged in developing open source software (OSS) for a relatively short period of time. The median is 3 years, the mean 4.8 years. Individual contributors have been active for over 40 years, so that the OSS experience varies to a great extent. The majority of the developers have reached the role of project leader as their highest position (64.6%). This can be explained by the fact that numerous of the existing OSS projects worldwide are one-person projects; therefore, this person must inevitably be the project leader. In contrast to this figure, the proportion of developers (27.2%), bug fixers (3.3%) and persons only registered in mailing lists (3.9%) is relatively small.

B. Use of time for OSS in general

The contributors spend an average of 12.15 hours per week on OSS activities. 7.32 hours thereof are spent during spare time and 4.82 hours during working hours. This statistical analysis corroborates the impression that the commitment for open source projects mainly happens in the spare time. Yet, the share of development of open source projects during working time amounts to considerable 41%.

C. Use of time in dependence on the project role

As expected, the time invested in OSS varies according to the contributor's role within the open source project. Project leaders spend a total of 14.13 hours per week on average on OSS (8.51 hours in spare time), developers devote 11.10 hours (5.87 hours in spare time), bug fixers 5.6 hours (3.6 hours in spare time) and the remaining users about five hours per week (ca. 2.5 hours in spare time). The amount of time committed to OSS therefore increases with the importance of the contributor's role. An F-test confirms a significant difference of the means (significance level $\alpha = 1\%$), though this is only true for the first three categories.

D. Use of time in dependence on time constraints

When analysing the commitment of time for OSS in dependence on the developer's number of hobbies, it turns out that maximal commitment occurs with programmers who have one additional hobby besides OSS. However, the difference between a person having two and a person having three pastimes (including programming) is only weakly significant (significance level $\alpha = 10\%$). When the free time invested in OSS is analysed in dependence on the programmer's degree of employment, an expected tendency is confirmed: The lower the degree of a developer's employment, the more he programs in his free time.

The difference between a fully employed person, who spends 6.5 hours per week on OSS, and a student spending a total of 8.2 hours per week, is statistically significant ($\alpha = 5\%$), as well as the difference between a student and a jobless person, who spends 17.7 hours per week on OSS ($\alpha = 1\%$). However, the difference between people who are employed 100% and people who are employed 70% (9.56 hours per week) is not significant. The latter group only consisted of 15 people, though.

IV. FLOW COMPONENTS

By means of a factor analysis, I was able to investigate the decisive factors which underlie the 28 questions concerning flow experience. Interestingly, this analysis resulted in two different sets of factors for the two versions of the questionnaire. The factor analysis with the answers of open source developers led to the following six factors: *Concentration* (7 items), *clearness of the task* (6 items), *flow/fun* (5 items), *immersion* (4 items), *attention* (2 items) and *reversed wording* (2 items) (see Table I).

The factor analysis of the questionnaires filled in by commercial software developers resulted in the following five factors: *Flow/fun* (6 items), *concentration* (6 items), *immersion* (5 items), *clearness of the task* (4 items) and *challenge* (3 items). The results of the two factor analyses correspond in four of five relevant factors. But whereas challenge is of great importance to commercial developers, it seems that this factor is less important to open source developers.

The reduction of the 28 variables concerning the experience of flow to a few basic factors sets up the basis for further evaluations.

A. Commitment and experience of flow

To what extent does the joy of programming correlate with the commitment for OSS?

In the analysis of the open source developers' commitment in dependence on their experience of flow, some significant correlations can be observed. The amount of time an open source developer is prepared to spend for open source projects correlates highly significant with the experience of flow/fun, immersion, the concentration the developer can devote to the activity, as well as the clearness of the task and the control he can exert on it. The more fun the developer has while programming and the more he is wrapped up in the activity, the more time he spends on open source projects. Table II clearly shows that the experience of flow has its strongest effect on the time spent on OSS during spare time.

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