Brooks' Versus Linus' Law: An Empirical Test of Open Source Projects

Charles M. Schweik
Department of Natural Resources Conservation, National Center for Digital Government
University of Massachusetts Amherst
Amherst, MA 01003, USA
cschweik@pubpol.umass.edu

Robert C. English and Meelis Kitsing
National Center for Digital Government
University of Massachusetts Amherst
Amherst, MA 01003, USA
bobengl@gmail.com
mkitsing@polsci.umass.edu

Sandra Haire
Department of Natural Resources Conservation
University of Massachusetts Amherst
Amherst, MA 01003, USA
shaire@nrc.umass.edu

ABSTRACT
In this paper, we investigate collective action in open source software development, where both volunteers and paid professionals essentially produce a public good. By using a large dataset, our logistic regression shows that adding more programming staff to the software projects increases their probability of success. This finding contradicts some dominant theories on software development as well as on the provision of public goods. As governments worldwide increasingly rely on open source software, our analysis has concrete implications for the public sector in contributing to the success of these projects.

Keywords
Open source software, collective action, public goods, software development, government, public sector

1. INTRODUCTION
Government agencies worldwide are both using more Free/Libre and Open Source Software (FOSS), and are showing interest in FOSS as a development paradigm for software products developed in their own shops or by contractors. Their IT managers see clear benefits in open standards, interoperability of software and data, and the avoidance of vendor "lock in." More concretely, FOSS technologies provide possibilities for sharing software solutions between agencies and governments, the transparency of code (which in some domains, such as in voting systems, could be quite important), the reuse of software modules, a reduction in software acquisition costs, and the sharing of programming staff and resources across agencies or even governments toward some common goal [1], [2].

However, one common concern over the use FOSS solutions is the longer-term support of the projects. If there is no specific firm or organization that owns the software, many wonder how can it be assured that the software will continue to be maintained and supported. This is a concern voiced by IT managers in all sectors. The central question relates to the concern of "project abandonment" and what factors may ensure that it doesn't occur. From an operational standpoint, government IT managers interested in FOSS have only two options that might help avoid project abandonment. They can contribute some of their own programming staff to a help the project move along, and to ensure in-house expertise, or, they can contribute financially to support programmers not on staff who are working on or interested in working on the project. Either option tends to increase the number of developers on the project.

2. RESEARCH PUZZLE
This brings us to the key research question for this paper. *Are FOSS projects more likely to be successful if additional programming support is added to the project*? There are two competing theories – Brooks' Law and Linus' Law – that predict opposite relationships between the number of developers on a team and project success. Brooks argued that "adding manpower to a late project makes it later" [3]. Contributing factors to lateness include the communication complexities with new team members, coordination costs, and the training needed to bring them up to speed. These arguments connect directly to "collective action" theory, where groups of people work to create public goods. Mancur Olson's seminal work argued that "the larger the group, the less likely it will further its common interests" [4].

On the other hand, it has been argued that Brooks' law does not translate directly to FOSS communities [5], [6]. In an influential early work on FOSS, Eric Raymond presented "Linus' Law": "Given enough eyeballs, all bugs are shallow" [7]. In other words, with a relatively large testing and developer community, a problem in software code will be identified quickly and a solution will be produced. Lastly, Jones' [6] findings allow us to question the applicability of Linus' Law from a different perspective. In most FOSS projects, a few dedicated programmers do the majority of the code writing. The others contribute bug fixes or a "few hundred lines of code" here or there. In short, the idea of "more eyes" doesn't typically play out in FOSS. But this can be tested empirically. In general, if small core teams do most of the work, then projects with larger teams shouldn't be more successful than projects with small teams.

3. RESEARCH METHODS
This paper empirically tests these competing theories by building upon our previous work [8] developing a success/abandonment measure for projects stored on the FOSS project hosting site Sourgeforge.net (SF). The result is a dataset of 107,747 FOSS projects, including developer count data, that we classified as successful, abandoned or indeterminate [8]. We test three competing hypotheses about team size and FOSS project success:
The Brooks' Law Hypothesis: FOSS projects with larger teams will face added coordination costs, which will hinder FOSS development. Consequently, they will be less successful.
The Linus' Law Hypothesis: FOSS projects with larger development teams will be more successful.
The "Core Team" Hypothesis: The size of the development

team won't have any effect on FOSS project success, because the core developer groups are almost always small teams.

In order to operationalize the concepts of successful, abandoned and indeterminate, we point out that FOSS projects go through two main longitudinal stages: "Initiation" and "Growth." We define the *Initiation Stage* as the period where a project is active but there has yet to be a first public release of code. The *Growth Stage* is the period after the first public release of code.

4. FINDINGS

We used simple logistic regression using Developer Count as a single independent variable against our dichotomous dependent variable "Abandoned in the Growth Stage (0) and Successful in the Growth Stage (1)". In our dataset, 46,374 projects fell in these two categories. 30,592 were abandoned projects and 15,782 were successful projects. The results show that the number of developers on a project is statistically significant in explaining variability in the data (Model L.R. $P<0.02$) and the coefficients have significant explanatory power ($P<0.02$ based on Wald Z). . The odds ratio for the Developer Count coefficient is 1.24. This indicates that for each developer added to a project, the odds that the project will become successful in the growth stage increases 1.24 times. We calculated the actual percentage of Successful in the Growth Stage projects in our dataset. All projects with greater than 86 developers have a predicted and an actual probability of 1. We qualified our interpretation of the model in the context of its ability to discriminate differences in response ($C=0.638$), and also conducted an evaluation of goodness of model fit.

We fully recognize that the simple univariate regression model does not fully explain the factors that lead FOSS projects to success or abandonment. Obviously, the argument can be made that simply adding people to a project won't, by itself, likely make a project successful. What is needed is a multivariate model that includes other theoretically-driven covariates. We're currently working toward this goal. But the major point of this paper is that even this simple model does provide evidence for choosing one hypothesis over another. Our findings suggest that adding more programmers improves the chances that a FOSS project will be successful, consistent with Linus' Law. Our finding demonstrates a correlation, not necessarily a causal relationship. Do more developers lead to project success? Or is it that successful projects attract more developers, in part because of the economic motivations that drive some programmers to participate (e.g., signaling programming skill to a broad community, self-learning through reading others' programs and peer-review). The fact the rise in success rate holds strongly for projects with smaller numbers of developers tends to favor the idea that more developers produces success; however, we can't conclusively answer this question with the dataset we have, because it represents generally one point in time. But even with the above limitations acknowledged, the findings above lend support to the argument that the relatively flat, modular system of coordination in FOSS projects allows the addition of programmers without too many coordination costs. The real concern in FOSS appears to be not slowing projects down when adding more programmers, but rather, given that most projects have small developer teams, how to get "more eyeballs" contributing to these projects.

5. CONCLUSION AND IMPLICATIONS

We see at least two implications for public sector organizations. First, from a FOSS user perspective, it may be worth checking the project website to see how many developers are participating before choosing a particular product. If there is a relatively large number of developers, that's a good sign. Of course, that shouldn't be the sole criteria; there will still be lots of successful small projects. But development team size should be one of many selection criteria. Second, our research suggests that adding programmers to help an existing FOSS projects is beneficial. It also suggests that in situations where a new project is being initiated using public sector programming or contractual staff, it might be worthwhile to actively look for other development partners within the agency or even externally (other agencies or governments), who might have programming staff to contribute to the project, as long as some consideration is made related to the architecture (e.g., modularity) of the project. Finally, the findings here may have broader implications in how governments may wish to organize work in the future. Recently, we are seeing the emergence of "open source like" collaborations in other public sector work. While more research is needed, our findings suggest that flatter hierarchies and modularity create advantages in the way some work can be accomplished.

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