**Essays on Value Creation in the Open Source Phenomenon: Unde****rstanding the Influence of Work Structures, Team Composition, and Community Ideologies**

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# Introduction

In the current digitally enabled collaborative environment, free (libre) and open source software (FLOSS) projects have become ubiquitous. Founded on the principles of openness and co-operation, FLOSS has over time come to refer to software in which the source code is available to the general public for use and modification from its original design. Since the 1980s, which saw the formalization of the concept of FLOSS through the creation of licenses and institutions that protected its principles, open source has been transforming the information technology (IT) organizational landscape. The decade that followed its formalization, saw the first release of Linux, Apache webserver, and Python; projects which would go on to become the poster children for the FLOSS movement. In the 2000s, motivated by the success of FLOSS projects, IT organizations started cautiously embracing the phenomenon. In 2001, IBM opened the source code of several of its software tools (estimated at $40 million) to the public domain, creating the Eclipse open source project [[1]](#footnote-1). The current decade, the 2010s, has seen the phenomenon sustain its exponential growth - both in terms of contributors coming together on collaborative development platforms like GitHub, as well as in terms of organizations supporting and taking ownership of FLOSS projects. The importance of the FLOSS model of development for the future of IT organizations was made evident in June 2018, when Microsoft announced that it was purchasing GitHub for an estimated $7.5 billion[[2]](#footnote-2).

The transformation of FLOSS from an ideology in the 1980’s to a phenomenon that has become central to the strategic decision of IT organizations leads to the question - what does it have in store for the future? A clue for answering this question comes from Microsoft’s GitHub acquisition announcement, where they [Microsoft] state the bright future for FLOSS and collaborative development.

“Computing is becoming embedded in the world, with every part of our daily life and work and every aspect of our society and economy being transformed by digital technology. Developers are the builders of this new era, writing the world’s code. And GitHub is their home…

… In short, developers will be at the center of solving the world’s most pressing challenges. However, the real power comes when every developer can create together, collaborate, share code and build on each other’s work.”(Microsoft News Center 2018)

With digital transformations (e.g. 3D printing, blockchain, digitally enabled development platforms etc.) making industries increasingly information oriented, new opportunities have emerged to adopt practices that have been successful in the IT industry. Predictably, the FLOSS model of development has attracted considerable attention from other disciplines. Specifically, the allure of being able to tap into the vast reserves of skills spread across the globe, enabling the creation products and services of high quality and functionality at a low cost can be appealing for many organizations and industries. For example, with life sciences increasingly becoming an information orientated science, it has been suggested that what worked for FLOSS development might be an answer to the spiraling cost of drug R&D (Munos 2006). Although some initiatives (e.g. MMV , DNDi , CAMBIA ) have looked towards adopting an open source approach for drug discovery, they have been successful at adopting it only in the early phases, where ideas and solutions are crowdsourced from the community. While many organizations are considering the FLOSS approach for developing their products, migrating to a model of development that does not conform to traditional contractual, governance mechanisms, and organizational boundaries can seem daunting. Practically, organizations are seeking to benefit from the strengths of open collaboration but are unsure about how to integrate it with their own strengths and practices that they have painstakingly built over time. As information systems (IS) researchers, we are in a unique position to enrich the theories surrounding the FLOSS artifact and inform organizations on how they can facilitate value by adopting a FLOSS approach to development.

The theoretical enquiry of the value creation mechanisms associated with the FLOSS model of development starts at the information technology artifact, the actual software developed, which creates value through its use in the community. And fundamental to building the complex FLOSS artifact is the unique work orchestration mechanisms that emerge to motivate and coordinate task work of geographically distributed individuals and organizations (Howison and Crowston 2014; Lindberg et al. 2016). Hence, replicating the FLOSS model of development requires careful understanding of the work structures that provide the framework for effectively organizing task work, the mechanisms through which it can facilitate value, and the boundaries of its applicability. Gathered around the FLOSS artifact, is the team of contributors comprised of both individuals and organizations who collaborate to build the software. In the absence of formal management and governance practices like requirements and release management, communities of practice sustain themselves by nurturing informal network governance mechanisms like – access restrictions, collective sanctions, macroculture, and reputation (Jones et al. 1997). Understanding how project owners can foster informal network governance mechanisms in order to protect social exchanges and overcome coordination challenges is an important element of sustaining collaboration in open source teams. Encompassing both the work structures and teams are the ideological undercurrents that shapes the objectives and motivations of the FLOSS community (Daniel et al. 2018). Given its effect on the motivation of the contributors, ideological changes are expected to moderate the value creation mechanisms associated with different FLOSS attributes, like the project’s work structures. Therefore, harnessing the full potential of the FLOSS phenomenon would require a clear understanding of the ideologies that shape the community and ensuring a seamless fit between the ideological needs and the different project attributes. The three essays of this dissertation explore the value creation mechanisms associated with – work structures, teams and governance structures, and community ideologies. An important aspect of this dissertation is to expand our knowledge regarding organizational participation in FLOSS projects. Organizational participation in FLOSS projects can result in a trade-off between openness (increasing autonomy and stimulating innovation, creativity, and organizational growth) and control (over platform activities, efficient development practices, and intellectual property right appropriation (Engeström 2007; Jarvenpaa and Lang 2011). The trade-off manifests as a boundary management problem that, if effectively managed, can directly influence the innovative and absorptive capacity of the FLOSS community (Teigland et al. 2014). Each essay in this dissertation explores the implications of the trade-off between openness and control in the context of the value creation mechanism being studied.

Specifically, my dissertation has three essays, which address each of the following broad research questions:

1. How does superposed *work structures* tasks influence the success of FLOSS projects?
2. How does *informal governance mechanisms* that emerge in FLOSS *teams* influence the survival of FLOSS projects?
3. How have the *ideological shifts* invoked by (a) the emergence of permissive licenses, and (b) the shift towards organizational ownership, transformed the influence of FLOSS work structures on project outcomes?

## Structure of The Dissertation

The dissertation is structured as three similarly themed but separate essays exploring the value creation mechanisms associated with FLOSS projects. The three essays have separate theoretical underpinnings and implications contribute to different aspects of FLOSS research and practice. To collect data for our analysis, we selected FLOSS projects started in GitHub in early 2014 and followed them for a period of two years.

The first essay, examines how the unique nature of FLOSS work which is dominated by the sequential layering of individual tasks, referred to as superposition, acts as an antecedent to the project’s success. Building on the theory of collaboration through open superposition (Howison and Crowston 2014), the essay theorizes the motivational mechanisms that operate within superposed work structures and unearths the contextual conditions that may limit the influence of superposition on FLOSS project value. Furthermore, given the increasing usage of FLOSS by organizations, the study investigates the specificities brought to these motivational mechanisms when FLOSS projects are owned by organizations. Using an innovative operationalization of the work structures of FLOSS projects, this essay finds support for a non-linear relationship between the degree of superposition and the success of the project. Further, this relationship is moderated by the type of ownership of the project. Overall, the first essay advances our understanding of work structures, motivation, and organizational participation in FLOSS environments. It also provides FLOSS practitioners with valuable insights for modeling the project’s task work to facilitate their success.

While the first essay establishes the importance of task-work organization in FLOSS projects, the second essay expands the inquiry into the role of team composition in the project’s success. Building on the theories of coordination (Malone and Crowston 1994) and network governance (Jones et al. 1997), this essay studies the influence of source code access restrictions imposed on team members in mitigating coordination challenges. The study also investigates the changes brought to the coordination mechanisms when open source projects are owned by organizations. Using a Cox proportional hazard model (Hosmer et al. 2008), the study demonstrates that the relationship between the proportion of contributors who are given write access to the source code in the team and the survival of the project, is moderated by the nature of project ownership. Interestingly, the observed moderation is a crossover interaction effect that changes from negative for individual owned projects to positive for organization owned projects. Overall, the second essay advances our understanding about contributor roles, access restrictions, and organizational participation in open source environments. The findings provide open source researchers and practitioners with fresh insights for better understanding and modeling project teams to facilitate their success.

The third essay pursues an overarching view of the FLOSS community by examining the ideological underpinnings of the FLOSS community and studies its influence on project success. The essay scrutinizes two ideological shifts seen in the FLOSS community that have altered the beliefs of ‘openness’ and ‘prevention of commercial appropriation’, on which the open source phenomenon was founded. First, the emergence of ‘permissive FLOSS licenses’ that allow commercial appropriation of the collaboratively developed code, and second, ‘organizational ownership’ of FLOSS projects. Rooted in self-determination theory (Ryan and Deci 2000), this essay theorizes the mechanisms through which ideological changes influence the pathways through which work structures in FLOSS projects are related to their success. Using an instrument variable approach, this essay finds that the ideological shift pertaining to license type has a significant influence on the relationship between the work structures and project success for both individual and organization owned projects. Overall, the third essay advances our understanding of the important role that ideologies play in shaping the relationship between work structures and success of the FLOSS projects.

Each essay is self-contained in terms of literature review, hypotheses development, and implications for research and practice. The essays together contribute to different aspects of literature on FLOSS. The theoretical foundation and research hypotheses for all the three essays are summarized in Table 1-1. Further, Table 1-2 presents the research questions, methods & variables, and important findings from all the three essays at a glance.

Table 1.1: Three essays at a glance: Theoretical foundation and research hypotheses

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| **Essay** | **Theoretical Foundation and Hypotheses** |
| **1** | **Theoretical foundation:**   * Theory of collaboration through open superposition (Howison and Crowston 2014) * Self-determination theory (Ryan and Deci 2000) * Affective events theory (Weiss and Cropanzo 1996)   **Hypotheses:**   * Hypothesis 1. In the context of FLOSS projects, the degree of superposition has a nonlinear relationship with project popularity such that project popularity increases with an increase in the degree of superposition up to a particular value (the turning point). Beyond this optimal degree of superposition, any further increase reduces the popularity of the project. * Hypothesis 2a: In the context of FLOSS projects, the project ownership type moderates the relationship between the degree of superposition and project popularity such that the degree of superposition has a significantly lower influence on the popularity of the project for organization-owned projects than for individual-owned projects. * Hypothesis 2b. In the case of organization-owned projects, the degree of superposition at which project popularity is at a maximum (the turning point) is significantly lower than for individual-owned projects. |
| **2** | **Theoretical foundation:**   * Coordination theory (Malone and Crowston 1994) * Theory of network governance (Jones et al. 1997)   **Hypotheses:**   * Hypothesis 1: A greater proportion of core contributors in a project will lead to a lower chance of survival of the project * Hypothesis 2: Organizational ownership mitigates the negative influence that the proportion of core contributors has on project survival * Hypothesis 3: The average code contributions per core contributor decreases in the case of organization owned project as compared to individual owned projects. |
| **3** | **Theoretical foundation:**   * Theory of collaboration through open superposition (Howison and Crowston 2014) * Self-determination theory (Ryan and Deci 2000)   **Hypotheses: First Ideological shift, license choice**   * Hypothesis 1a: The type of license moderates the relationship between the degree of superposition and the popularity of FLOSS projects, such that, for projects with restrictive licenses an increase in the degree of superposition tends to have a higher positive influence on the popularity of the project than for projects with permissive licenses. * Hypothesis 1b: The type of license moderates the relationship between the degree of superposition and the survival of FLOSS projects, such that, for projects with restrictive licenses, an increase in degree of superposition tends to have a higher positive influence on the survival of the project than for projects with permissive licenses.   **Hypotheses: Second Ideological shift, organizational ownership**   * Hypothesis 2a: For organization owned projects, the moderating influence of license type on the relationship between the degree of superposition and the popularity of FLOSS projects is less in comparison to individual owned projects. * Hypothesis 2b: For organization owned projects, the moderating influence of license choice on the relationship between the degree of superposition and the survival of FLOSS projects is less in comparison to individual owned projects. |

Table 1.2: Three essays at a glance: Three essays at a glance: Research questions, methods, variables and main finding

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| **Essay (Research Questions, Method)** | **Essay (Main Findings)** |
| **Essay 1: Work structures of FLOSS projects**  **Research questions:**   * How does the extent of task superposition influence FLOSS project success? * How do organization-owned FLOSS projects differ from individual-owned FLOSS projects in terms of task superposition, and does this difference influence project success?   **Empirical model:** OLS, Negative binomial model  **Unit of analysis:** Project level of analysis  **Dependent variable:**   * Project popularity measured as the number of stars that a project has received   **Independent variable:**   * Degree of superposition operationalized as the ratio of number of versions to number of tasks in the project * Ownership type of the project | **Main findings:**   * Empirical analysis of a large sample of FLOSS projects hosted on Github indicates that the emergence of sequentially layered and individual task work, referred to as the superposed organization of work, exhibits an inverted-U shaped relationship with the popularity of a project. * For individual-owned projects, as the degree of superposition increases from 0 to its turning point, the popularity, is found to increase by more than five times, from 11.53 to 71.79, holding everything else constant, while for organization-owned projects it is found to increase from 28.26 to 38.08 * For individual-owned projects, the popularity of the project is found to decrease from 71.79 to 37.12 as the degree of superposition increases from its turning point to its highest value of 1, keeping everything else constant, while this number decreases from 38.08 to 20.78 for organization-owned projects |

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| **Essay (Research Questions, Method)** | **Essay (Main Findings)** |
| **Essay 2: Team Composition and Governance of Open Source Projects**  **Research questions:**   * What role does contributor access restrictions have in influencing the survival of FLOSS projects? * How does organizational ownership moderate this relationship?   **Empirical model:**   * Cox-proportional hazard model * Hierarchical linear model   **Unit of analysis:**   * Project level of analysis – Hypotheses 1 and 2 * Contributor level of analysis – Hypothesis 3   **Dependent variables:**   * Hazard rate: Likelihood a project becomes inactive at time t given that it has survived till time t * Average code contributions per core contributor   **Independent variables:**   * Proportion of contributors with write access * Contributor type (core or peripheral contributor) * Ownership type of the project | **Main findings:**   * Based on the survival analysis of a large sample of FLOSS projects owned by individuals and a wide range of organizations, this study finds that the proportion of contributors who are given write access to the source code exhibit opposing effects on project survival, which is conditional on the ownership of the project. * For individual owned projects, as the proportion of core contributors increases from 0 to 1, the hazard rates increases by 0.96 , which translates to a 21% increased chance of survival. * For organization owned projects, as the proportion of core contributors increases from 0 to 1, the hazard ratio decreases by 0.34 which translates to a 10% decreased chance of survival. |

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| **Essay (Research Questions, Method)** | **Essay (Main Findings)** |
| **Essay 2: Team Composition and Governance of Open Source Projects**  **Research question:**   * How have the ideological shifts invoked by (a) the emergence of permissive licenses, and (b) the shift towards organizational ownership, transformed the influence of FLOSS work structures on project outcomes?   **Empirical model:**   * Cox-proportional hazard model * Hierarchical linear model   **Unit of analysis:**   * Project level of analysis – Hypotheses 1 and 2 * Contributor level of analysis – Hypothesis 3   **Dependent variables:**   * Hazard rate: Likelihood a project becomes inactive at time t given that it has survived till time t * Average code contributions per core contributor   **Independent variables:**   * Proportion of contributors with write access * Contributor type (core or peripheral contributor) * Ownership type of the project | **Main findings:**   * Based on the survival analysis of a large sample of FLOSS projects owned by individuals and a wide range of organizations, this study finds that the proportion of contributors who are given write access to the source code exhibit opposing effects on project survival, which is conditional on the ownership of the project. * For individual owned projects, as the proportion of core contributors increases from 0 to 1, the hazard rates increases by 0.96 , which translates to a 21% increased chance of survival. * For organization owned projects, as the proportion of core contributors increases from 0 to 1, the hazard ratio decreases by 0.34 which translates to a 10% decreased chance of survival. |

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| **Research Questions** | **Problem formulation:**   * Need for a deeper theoretical enquiry into the dominant way of organizing FLOSS task work which is characterized by the sequential layering of individual tasks, referred to as superposition. * Enrich the theory of collaboration through open superposition by unearthing the boundaries describing the influence of task superposition on FLOSS project success. * Understand if the assumptions and mechanisms that form the basis of the theory of superposition are also applicable to the context of organizational ownership of FLOSS projects.   **Research questions:**   * How does the extent of task superposition influence FLOSS project success? * How do organization-owned FLOSS projects differ from individual-owned FLOSS projects in terms of task superposition, and does this difference influence project success? | |
| **Hypotheses** | **Theoretical foundation:**   * Theory of collaboration through open superposition (Howison and Crowston 2014) * Self-determination theory (Ryan and Deci 2000) * Affective events theory (Weiss and Cropanzo 1996)   **Hypotheses:**   * Hypothesis 1. In the context of FLOSS projects, the degree of superposition has a nonlinear relationship with project popularity such that project popularity increases with an increase in the degree of superposition up to a particular value (the turning point). Beyond this optimal degree of superposition, any further increase reduces the popularity of the project. * Hypothesis 2a: In the context of FLOSS projects, the project ownership type moderates the relationship between the degree of superposition and project popularity such that the degree of superposition has a significantly lower influence on the popularity of the project for organization-owned projects than for individual-owned projects. * Hypothesis 2b. In the case of organization-owned projects, the degree of superposition at which project popularity is at a maximum (the turning point) is significantly lower than for individual-owned projects. | |
| **Methodology** | **Dependent variable:**   * Project popularity measured as the number of stars that a project has received   **Independent variable:**   * Degree of superposition operationalized as the ratio of number of versions to number of tasks in the project * Ownership type of the project   **Empirical model:**   * OLS, Negative binomial model   **Unit of analysis:**   * Project level of analysis | |
| **Analysis** | **Main findings:**   * Empirical analysis of a large sample of FLOSS projects hosted on Github indicates that the emergence of sequentially layered and individual task work, referred to as the superposed organization of work, exhibits an inverted-U shaped relationship with the popularity of a project. * For individual-owned projects, as the degree of superposition increases from 0 to its turning point, the popularity, is found to increase by more than five times, from 11.53 to 71.79, holding everything else constant, while for organization-owned projects it is found to increase from 28.26 to 38.08 * For individual-owned projects, the popularity of the project is found to decrease from 71.79 to 37.12 as the degree of superposition increases from its turning point to its highest value of 1, keeping everything else constant, while this number decreases from 38.08 to 20.78 for organization-owned projects |  |
| **Implications** | * This essay advances the existing literature on motivation (e.g. Ke and Zhang 2010, von Krogh et al. 2012, Ryan and Deci 2000) and work structures (e.g. Howison and Crowston 2014, Lindberg et al. 2016) in FLOSS projects, as it takes a significant step in establishing the role of work organization as a key driver for contributors’ motivations and also as an antecedent to project success * It advances the literature surrounding organizational participation in FLOSS projects (Capra et al. 2011; Fitzgerald 2006; Spaeth et al. 2015; Stewart et al. 2006; Wagstrom 2009) by enhancing our understanding of how organizational participation influences FLOSS projects in general and their work structures in particular * Lastly, this essay introduces a clear construct for the concept of superposition using which the boundary conditions associated with the construct was identified | |

Table 1.2: Essay 2 - Team Composition and Governance of Open Source Projects

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| **Research Questions** | **Problem formulation:**   * Need for a deeper understanding of the mechanisms associated with FLOSS team composition determined by the proportion of contributors who are given write access to the source code * Establish the important role played by informal network governance mechanisms in sustaining collaboration in open source communities * Understand how informal network governance mechanisms interact with formal governance mechanisms when organizational takes ownership of FLOSS projects and introduces project management practices   **Research questions:**   * What role does contributor access restrictions have in influencing the survival of FLOSS projects? * How does organizational ownership moderate this relationship? |
| **Hypotheses** |  |
| **Methodology** | **Dependent variables:**   * Hazard rate: Likelihood a project becomes inactive at time t given that it has survived till time t * Average code contributions per core contributor   **Independent variables:**   * Proportion of contributors with write access * Contributor type (core or peripheral contributor) * Ownership type of the project   **Empirical model:**   * Cox-proportional hazard model * Hierarchical linear model   **Unit of analysis:**   * Project level of analysis – Hypotheses 1 and 2 * Contributor level of analysis – Hypothesis 3 |
| **Analysis** | * Based on the survival analysis of a large sample of FLOSS projects owned by individuals and a wide range of organizations, this study finds that the proportion of contributors who are given write access to the source code exhibit opposing effects on project survival, which is conditional on the ownership of the project. * For individual owned projects, as the proportion of core contributors increases from 0 to 1, the hazard rates increases by 0.96 , which translates to a 21% increased chance of survival. * For organization owned projects, as the proportion of core contributors increases from 0 to 1, the hazard ratio decreases by 0.34 which translates to a 10% decreased chance of survival. |
| **Implications** | * This essay advances the existing literature on contributor roles and team composition in FLOSS projects (Rullani and Haefliger 2013; Sagers 2004; Setia et al. 2012), as it unearths the complex role of access restrictions in mitigating the coordination challenges and the variance in contributors expectations and goals * By studying the moderating impact of organization ownership, this essay contributes to the debate of openness vs. control in FLOSS environments. The findings add an interesting dimension to this debate by theorizing that control (through project management practices) and openness (by providing access to the source code) can complement each other under certain conditions. * This essay is one of the first to study the antecedents to the sustenance of FLOSS projects which is an important, yet underdeveloped dimension of FLOSS project success. |

Table 1.3: Essay 3 - Ideologies in Open Source Communities

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| **Research Question** | **Problem formulation:**   * Need for a deeper understanding of how community ideologies shape the motivational needs of the contributors * Study ideological shifts that have shaped the FLOSS community as we know off today and study their influence on the dominant structures of work introduced in essay 1 of this dissertation   **Research question:**   * How have the ideological shifts invoked by (a) the emergence of permissive licenses, and (b) the shift towards organizational ownership, transformed the influence of FLOSS work structures on project outcomes? |
| **Hypotheses** | **Theoretical foundation:**   * Theory of collaboration through open superposition (Howison and Crowston 2014) * Self-determination theory (Ryan and Deci 2000)   **Hypotheses: First Ideological shift, license choice**   * Hypothesis 1a: The type of license moderates the relationship between the degree of superposition and the popularity of FLOSS projects, such that, for projects with restrictive licenses an increase in the degree of superposition tends to have a higher positive influence on the popularity of the project than for projects with permissive licenses. * Hypothesis 1b: The type of license moderates the relationship between the degree of superposition and the survival of FLOSS projects, such that, for projects with restrictive licenses, an increase in degree of superposition tends to have a higher positive influence on the survival of the project than for projects with permissive licenses.   **Hypotheses: Second Ideological shift, organizational ownership**   * Hypothesis 2a: For organization owned projects, the moderating influence of license type on the relationship between the degree of superposition and the popularity of FLOSS projects is less in comparison to individual owned projects. * Hypothesis 2b: For organization owned projects, the moderating influence of license choice on the relationship between the degree of superposition and the survival of FLOSS projects is less in comparison to individual owned projects. |
| **Methodology** | **Dependent variables:**   * Project popularity measured as the number of stars that a project has received * Hazard rate: Likelihood a project becomes inactive at time t given that is has survived till time t   Independent variables:  Instrument variable for the choice of license:  **Empirical model:**  **Unit of analysis:**   * Project level of analysis |
| **Analysis** | **Main findings:** |
| **Implications** | * This essay provides a novel way to understand the influence of license type on project outcomes ideological beliefs of FLOSS. The findings from this essay supports the moderatin that the choice of license type exhibits a moderating influence on the relationship between superposed work structures and the project popularity and survival, which is conditional on the type of project ownership |

# Essay 1

# Essay 2

# Essay 3

1. http://www.nytimes.com/2001/11/05/technology/05OPEN.html?pagewanted=all [↑](#footnote-ref-1)
2. <https://www.theverge.com/2018/6/4/17422788/microsoft-github-acquisition-official-deal> [↑](#footnote-ref-2)