# 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 releases 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 community 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 became 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 in non-IT organizations to adopt practices that have been successful in the IT industry. Predictably, the FLOSS model of development has attracted considerable attention from other disciplines. 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 appeals to many organizations and industries (Coverity Inc. 2013). 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 a FLOSS 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. Herein lies my long terms research objective, for which, this dissertation is the first step - to unearth the value creation mechanisms associated with the FLOSS model of development and understand how these mechanisms can be replicated more widely across IT and non-IT organizations

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 these work structures 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 in distributed teams is an important element of sustaining collaboration in FLOSS projects. Encompassing both the work structures and teams of contributors are the ideological undercurrents that shape 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.

Given the importance of the aforementioned three aspects of FLOSS, the three essays of this dissertation explore the value creation mechanisms associated with – work structures, team composition and governance, and community ideologies. Conceptually, the three essays are grounded in theories from information systems and organization studies. The essays enrich these theories by not only addressing some of the existing theoretical gaps, but also by clarifying some of the assumptions on which these theories are founded (Alvesson and Sandberg 2011). The following subsections briefly introduces the theoretical background and the motivation for the three essays.

**Work structures:** Drawing from commercial software development practices, early research on the task characteristics of FLOSS projects indicates the importance of codebase architecture (e.g., modularity; Baldwin and Clark 2006) and of coordination mechanisms (e.g., Chua and Adrian 2010, Crowston et al. 2005, Mockus et al. 2002) for ensuring successful collaboration. While this large body of research provides an excellent understanding of FLOSS task work from an architectural perspective, rather less is known about the sociotechnical nature of work organization during the production process and its implication on FLOSS project outcomes. Recognizing this gap, recent works of Howison and Crowston (2014) and Lindberg et al. (2016), have called attention to the characteristics of the software artifact, such as the emergent structures of work —which may be instrumental in overcoming the challenges related to FLOSS task work orchestration. These studies have observed the emergence of unique routines in the work structures of FLOSS projects that are surprisingly effective at establishing the delicate balance between —managing developers’ contributions, and sustaining the contributors’ needs for openness and autonomy. In this context, Howison and Crowston (2014), observed and conceptualized superposition of tasks as the dominant work orchestration mechanism in FLOSS projects, wherein motivationally independent tasks are incrementally layered to create the software. This work orchestration mechanism is different from that observed in the case of traditional software development, where the focus is towards co-work and concurrent task development through a modular task design. Although the dominance of the superposed orchestration mechanism in FLOSS projects has been attributed to its ability to satisfy the psychological needs of the intrinsically motivated contributors, it is still unclear if this motivational influence, theorized using self-determination theory (SDT; Ryan and Deci 2000), could be scaled up to the project level. This calls for a deeper theoretical enquiry to better understand if and how these unique ways of organizing task work influence project success. Following this line of enquiry, essay 1 attempts to enrich the theory of collaboration through open superposition (Howison and Crowston 2014) by unearthing the boundaries describing the influence of task superposition on FLOSS project success. This leads to the broad research question that essay 1 addresses:

*How does work structures influence the success of FLOSS projects?*

**Team composition and governance:** FLOSS project contributors are often classified as belonging to either the core or the peripheral group of developers (Crowston, Wei, et al. 2006). In Distributed Version Control Systems (DVCS) based development platforms like GitHub, we can delineate the core and peripheral contributors based on their rights of access to the main project code (Rullani and Haefliger 2013). In this classification, the core contributors are those who can directly make changes to the main project code, while the peripheral contributors are those who are not given write access to the project but still contribute to the project. Studies that have looked at the contributor groups from the nature of their participation and type of contribution have established the importance of both the core and peripheral groups as antecedents to the success of the project (Sagers 2004; Setia et al. 2012). However, the interplay between the two groups of contributors and how they facilitate the emergence of informal network governance mechanisms is less understood. Given this gap in our understanding, the second essay studies the mechanisms through which effective organization of teams can overcome the challenges of distributed work. Specifically, the second essay addresses the following broad research question:

*How does informal governance mechanisms that emerge in FLOSS teams influence the survival of FLOSS projects?*

**Community ideologies:** Though, volunteer driven FLOSS development was founded on the ideological beliefs of ‘openness’, ‘co-operation’, and ‘absence of any commercial appropriation’, in recent years the FLOSS movement has witnessed two ideological shifts. First, the emergence of ‘permissive FLOSS licenses’ that allow commercial appropriation of the collaboratively developed code (Daniel et al. 2018), and second, ‘organizational ownership’ of FLOSS projects (Fitzgerald 2006). The fusion of the two vastly different ideologies (open vs. commercial software) has created a new corporate-communal landscape which has altered the value creation mechanisms that were embedded in the founding ideologies of FLOSS (Germonprez et al. 2016). Given this dynamism of community ideologies, understanding ideological shifts that reshapes the phenomenon and their impact on FLOSS project outcomes is important for ensuring the long-term viability of the FLOSS development approach. Theoretically, this dynamism implies that the mechanisms that are shaped by the ideological beliefs are associated with boundary conditions of time, which need to be clearly established (Suddaby 2010). Of the mechanisms shaped by community ideologies, its influence on the motivations of contributors is particularly noteworthy (Daniel et al. 2018). Because ideological beliefs shape the motivational needs of the volunteer contributors (Daniel et al. 2018), and motivational needs of contributors shape the emergent work structures in FLOSS projects (Howison and Crowston 2014), it is expected that ideological shifts could influence the mechanisms through which dominant work structures in FLOSS projects are related to their outcomes. Motivated by the need to understand these ideological shifts considering their influence on the unique work orchestration mechanisms examined in essay 1, essay 3 attempts to answer the following research question:

*How do ideological shifts transform the value creation mechanisms associated with FLOSS work structures?*

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). Given this trade-off when organizations own FLOSS projects, each essay of this dissertation explores the implications of organizational ownership on the value creation mechanism being studied.

## 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 foundations and their implications contribute to different aspects of FLOSS research and practice. To collect data for our analysis, we selected FLOSS projects started in early 2014 by both organizations and individuals on GitHub. We collected detailed task level data and followed the projects for a period of three years. During this period, some projects in our sample grew and become popular, for example, POP[[3]](#footnote-3), a project started by Facebook and the project Slick[[4]](#footnote-4), which was started by an individual. While some other projects in our sample tended to lose popularity and become inactive.

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. Developing 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. 2008a), 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 foundations of the FLOSS community and studies its influence on project success. This essay scrutinizes two ideological shifts seen in the FLOSS community that have altered the beliefs of ‘openness’, ‘co-operation’, and ‘prevention of commercial appropriation’, on which the open source phenomenon was founded. 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

Table1. 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) * Ideological fit in open source communities (Daniel et al. 2018)   **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: Research questions, methods, and main findings

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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?   **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 of the project to number of individual task contributions in the project * Ownership type of the project | **Empirical model:**   * OLS * Negative binomial regression   **Main findings:**  The results from the analysis of over 6500 FLOSS projects hosted on GitHub support a nonlinear relationship between the degree of superposition and the success of the FLOSS project. Moreover, we find that the type of ownership moderates this nonlinear relationship such that (1) organizational ownership mitigates the influence of the degree of superposition on the success of the project, and (2) under organizational ownership, the optimal degree of superposition (the point at which the success of the project is at a maximum) is lower than for individual-owned projects. |
| **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?   **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 contributor   **Independent variables:**   * Proportion of contributors with write access (core contributors) * Contributor type (core or peripheral contributor) * Ownership type of the project | **Empirical model:**   * Cox-proportional hazard model * Hierarchical linear model   **Main findings:**  Using a Cox proportional hazard model, this essay demonstrates that the relationship between the proportion of core contributors (who are given write access to the source code) and the survival of the project, is moderated by the nature of project ownership — individual versus organization owned projects. Interestingly, the observed moderation is a crossover interaction effect that changes from negative for individual owned projects to positive for organization owned projects. |
| **Essay 3: Community ideologies**  **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?   **Unit of analysis:**   * Project level of analysis   **Dependent variables:**   * Project popularity measured as the number of stars that a project has received * Likelihood of survival of the project   **Independent variables:**   * Choice of license (Permissive or restrictive) * Degree of superposition, operationalized as the ratio of number of versions of the project to number of tasks in the project   **Instrument variable for choice of license:**   * Geert Hofstede dimension – Individualism vs. collectivism * Country’s social protection contribution as a percentage of total expenditure in the year 2014-2015 | **Empirical model:**   * 2 stage least square model with endogenous regressors * Probit model with endogenous regressors   **Main findings:**  Using an instrument variable approach, our analysis of over 4000 FLOSS projects hosted on GitHub confirm the significance of both the ideological shifts with some interesting contextual differences across the two project outcomes. Specifically, we find that the ideological shift pertaining to license type has a significant influence on both the examined project outcomes, whereas organizational ownership has a greater influence on popularity as compared to the survival of FLOSS projects. |

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)
3. <https://github.com/facebook/pop> [↑](#footnote-ref-3)
4. <https://github.com/kenwheeler/slick> [↑](#footnote-ref-4)