What Motivates Software Practitioners to Contribute to Inner Source?

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ABSTRACT

Software development organizations have adopted open source development practices to support or augment their software development processes, a phenomenon referred to as *inner source*. Given the rapid adoption of inner source, we wonder what motivates software practitioners to contribute to inner source projects. We followed a mixed-methods approach–a qualitative phase of interviews with 20 interviewees, followed by a quantitative phase of an exploratory survey with 124 respondents from 13 countries across four continents. Our study uncovers practitioners' motivation to contribute to inner source projects, as well as how the motivation differs from what motivates practitioners to participate in open source projects. We also investigate how software practitioners' motivation impacts their contribution level and continuance intention in inner source projects. Based on our findings, we outline directions for future research and provide recommendations for organizations and software practitioners.

CCS CONCEPTS

• **Software and its engineering → Collaboration in software development**; • **Human-centered computing → Empirical studies in collaborative and social computing**.

KEYWORDS

Inner source, motivation, software development, open collaboration, internal open source

1 INTRODUCTION

Open source software (OSS) has been making an enormous impact on the software industry. OSS is recognized to be capable of delivering high-quality software products with a fast development cycle [12]. Software development organizations have widely adopted OSS in a variety of ways, e.g., integrating OSS components into proprietary software products [20] and leveraging OSS tools as part of software development processes [17]. In addition to the adoption of OSS, numerous software development organizations have shown a significant interest in adopting OSS development practices to exploit the benefits of OSS [61]. The use of OSS development practices within organizations is called *inner source*. Inner source allows universal access to the development artifacts inside an organization [39, 48]. Thus, everyone within the organization can potentially become contributors to inner source projects. Unlike traditional software development within an organization, contributors of an inner source project do not belong to a single team or organizational unit.

The growth of inner source adoption led to the emergence of a number of studies on inner source. Prior studies investigate the challenges of inner source adoption, e.g., cultural transition [2, 27] and competing tensions among stakeholders within organizations [25, 62, 63, 70]. Researchers also propose frameworks [14, 27, 55, 61, 65], tools [8, 38] and models [16, 68, 70] to support practices of inner source software development. Nevertheless, there has been little focus on investigating what motivates software practitioners to contribute to inner source development. An understanding of software practitioners' motivation is of essential importance to attract the participation of more practitioners and sustain inner source development.

To address this gap, we followed a mixed-methods approach to investigate software practitioners' motivation to contribute to inner source development. We started with semi-structured interviews with 20 software practitioners with experience in inner source development, who have an average of 8.1 years of professional experience in software development. Through the interviews, we qualitatively investigated the motivation that drives software practitioners to participate in inner source development, as well as their experience in inner source development. We further performed an exploratory survey with 124 software practitioners from 13 countries to quantitatively validate the motivation and practices that are uncovered in our interviews. We investigated the following research questions:

RQ1. What motivates software practitioners to participate in inner source projects?

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Software practitioners are motivated by both internal motivation[1], e.g., *helping others*, and external motivation[2], e.g., *job responsibility*, to contribute to inner source development. The survey respondents report stronger agreement on internal motivation than on external motivation. The survey respondents who contribute to *utility-oriented* projects show stronger motivation for *sharing* than those who contribute to *service-oriented* projects[3].

RQ2: How does the motivation of software practitioners differ when they contribute to inner source development compared with open source development?

In comparison with open source development, software practitioners tend to have higher motivation for *software improvement* and *job responsibility* when they contribute to inner source development. Meanwhile, they show lower motivation for *fun* when they participate in inner source development.

RQ3: How does motivation influence the contribution level and continuance intention of software practitioners in inner source development?

The level of *job responsibility* motivation is positively correlated with the contribution level of software practitioners in inner source development. The levels of all measured motivators are positively correlated with the intention of software practitioners to be involved in inner source development in the future, where the correlations vary from moderate to weak.

Based on our findings, we discuss implications and provide practical lessons for attracting and retaining software practitioners for inner source development. In summary, we make the following contributions: (1) We identify 14 motivators of software practitioners to contribute to inner source development based on a mixed-methods approach; (2) We highlight the differences between inner source and OSS motivations; (3) We provide practical implications for sustaining inner source development, and outlined future avenues of research; (4) We provide the interview guide, questionnaire, and survey responses publicly accessible for future investigation by others[4].

2 RELATED WORK

2.1 Research on Inner Source

Prior research presents a steady stream of case studies with organizations and companies that have adopted inner source programs, including Alcatel-Lucent [26, 27], DLR [54], DTE Energy [58], Ericsson [65], Google [71], Hewlett-Packard [14, 42], IBM [5, 68], Kitware [40], Microsoft [3, 45], Nokia [39], Philips Healthcare [70], and SAP [48]. These studies report specific inner source programs of various organizations and companies. The specific inner source programs could be further classified into two models, *infrastructure-based* inner source and *project-specific* inner source, according to the classification framework of inner source introduced by Gurbani et al. [27]. For instance, IBM and Microsoft adopted *infrastructure-based* inner source programs, where a central group provides suitable inner source infrastructure and individuals and teams within an organization/company can run their own inner source projects. Philips Healthcare and Alcatel-Lucent adopted *project-based* inner source programs, in which an organizational unit (a core team) takes responsibility for a specific inner source project. Organizations and companies implement different inner source development practices in terms of participatory reuse, collaborative development, self-selection of tasks, and volunteering [7]. In addition, some studies propose metrics to quantify inner source development practices, e.g., size of an inner source program [14, 39, 48, 65] and inner source collaboration [6, 26].

Inner source allows universal access to development artifacts throughout an organization/company [39, 48]. Thus, everyone within the organization/company can potentially become contributors to inner source projects. Gurbani et al. [26] suggest that multiple roles are involved in the community of an inner source project. The initiator of an inner source project assumes the role of a *benevolent dictator*. Some contributors become experts in the course of development, who are further promoted to be *trusted lieutenants*. The benevolent dictator and trusted lieutenants form a core team of an inner source project. Additional roles of contributors may emerge to tail the implementation of inner source to a particular context [27].

The motivation of contributors to participate is of essential importance to the success of software development projects [74]. Nonetheless, there is no existing study that systematically explores the motivation of software practitioners to contribute to inner source development. In this work, we quantitatively analyze software practitioners' motivation to contribute to inner source development, and further investigate the relationship between motivation and contribution level and continuance intention of software practitioners.

2.2 Research on Motivations in Software Engineering

Motivation has been the object of studies in a variety of areas for a long time [59], including software engineering. In software engineering, the motivation of software practitioners has been intensively studied since the 1980s. Proper management of motivation could help organizations achieve higher levels of productivity, as well as avoid human resource turnover, budget overflow, and delivery delays [4, 18]. Sharp et al. [56] provide an overview of the motivation models in software engineering, based on which, they propose a new model. More recently, Sach et al. suggest a trend towards more socially oriented motivation in software engineering via interviews with 13 professional software engineers [52]. França et al. [19] present a variety of factors that influence work motivation and job performance in software engineering.

Due to the high degree of autonomy, intrinsic motivation, and self-determination of OSS contributors, motivations in software engineering may not apply to OSS development [49]. Thus, motivation to contribute to OSS has been extensively studied since the 2000s. Some researchers conducted broad surveys to collect

[1]Internal motivation: people stand behind a behavior out of their interests and values [51].
[2]External motivation: people do a behavior for reasons external to the self [51].
[3]Utility-oriented projects fill an immediate need in functionalities; service-oriented projects provide stable and robust services to end-users of the inner source software; exploration-oriented projects make innovation accessible to the inner source community. [7].
[4]https://doi.org/10.5281/zenodo.6367434

OSS contributions [23, 30]. Other researchers conducted surveys focused on motivations of specific OSS communities, e.g., Linux [31] and Apache [28, 49]. In addition, prior studies investigate the motivation of specific groups of OSS contributors, e.g., newcomers [29], one-time code contributors [37], quasi-contributors [60], and students [57].

In 2012, Von Krogh et al. [69] provided a literature review of studies on the motivation for participation in OSS development. They identified ten categories of motivations, grouped as intrinsic, internalized-extrinsic, and extrinsic motivations. Intrinsic motivation moves the person to act for the fun or challenge entailed rather than in response to external pressures or rewards [51]. In contrast, extrinsic motivations are based on outside incentives when people change their actions due to an external intervention [21]. Developers can also internalize extrinsic motivations in a way that they are perceived as self-regulating behavior rather than external impositions [13, 49]. These internalized extrinsic motivations include reputation, reciprocity, learning, and own-use. Researchers also investigated the relation between motivation and other factors, e.g., retention [72], task effort [32], intention to contribute [73], and contribution level [41]. Most recently, Gerosa et al. [22] replicate, and extend previous research on motivation to contribute to OSS, and investigate the shift of motivation.

Considering inner source is the use of open source development practices within organizations, in this work, we investigate the difference in motivations when software practitioners contribute to inner source compared with open source development.

3 METHODOLOGY

Our research methodology followed a mixed-methods approach, as depicted in Figure 1. We collected data from two different sources[5]: (1) We interviewed 20 software practitioners with experience in inner source development, and derived a list of statements and potential answers for survey questions from the results of interviews; (2) We surveyed 124 respondents with experience in inner source development. To preserve the anonymity of participants, we anonymized all items that constitute Personally Identifiable Information (PII) before analyzing the data, and further considered aliases as PII throughout our study (e.g., we refer to the interviewees as P1 - P20).

3.1 Interviews

The left part of Figure 1 describes the process of interviews.

3.1.1 Participant Selection. We recruited full-time software practitioners with experience in inner source development from tech companies (e.g., Alibaba, Huawei, and Tencent). Interviewees were recruited by emailing our contact in each company, who disseminated the news of our study to their colleagues. Volunteers would inform us if they were willing to participate in our study with no compensation. 20 volunteers contacted us and participated in the interviews. In the remainder of this paper, we denote these 20 interviewees as P1 to P20. The 20 interviewees have an average of 8.1 years of professional experience in software development (min: 4, max: 20, median: 6.5, std: 4.2), and an average of 2.6 years of experience in inner source development (min: 0.5, max: 8, median: 2.0, std: 2.0). Table 1 summarizes the interviewees who perceived themselves as having "extensive" experience (in comparison to "none" and "some" experience) in a particular job role.

Table 1: Interviewees with "extensive" experience in a particular job role.

Role	Number of Interviewees
Programming	16 out of 20
Design	8 out of 20
Management	2 out of 20
Testing	2 out of 20

3.1.2 Protocol. The first author conducted a series of face-to-face interviews with the 20 software practitioners. Each interview took 30-45 minutes. The interviews were semi-structured and made use of an *interview guide*[6].

The interview comprised three parts. In the first part, we asked some demographic questions about the experience of the interviewees in software development. The questions covered various aspects of experience, including years of experience, tenure[7], programming languages, job roles, and experience in open source development. In the second part, we asked the interviewees about their specific experience in *inner source* development. Specifically, we asked: (1) how many projects they have participated in; (2) what roles they have played in the projects; (3) how much time per week they spend contributing to their primary project. In the third part, we asked open-ended questions about the motivations to contribute to inner source. This part aims to allow the interviewees to speak freely about their opinions without the interviewer biasing their responses. At the end of each interview, we thanked the interviewee and briefly informed her of our next plans.

3.1.3 Data Analysis. We conducted a thematic analysis to process the recorded interviews by following the steps below:

Transcribing and Coding. We transcribed the recordings of the interviews as the interviews proceeded, and developed a thorough understanding by reviewing the transcripts. The first author read the transcripts and coded the interviews using NVivo qualitative analysis software [1]. To ensure the quality of codes, another author verified initial codes created by the first author and provided suggestions for improvement. After incorporating these suggestions, we generated a total of 468 cards for codes - 21 to 35 cards for each coded interview. After merging the codes with the same words or meanings, we have a total of 127 unique codes. We noticed that when our interviews were drawing to a close, the collected codes from interview transcripts reached saturation. New codes did not appear anymore; the set of codes was considered stable.

Open Card Sorting. Two of the authors then separately analyzed the codes and sorted the generated cards into potential themes for thematic similarity (as illustrated in LaToza et al.'s study [35]). The themes that emerged during the sorting were not chosen beforehand. We then use the Cohen's Kappa measure [9] to examine the agreement between the two labelers. The overall Kappa value

[5]The interviews and survey were approved by the relevant institutional review board (IRB). Participants were instructed that we wanted their opinions; privacy and sensitive information would not be intentionally mentioned.

[6]Interview guide online: https://doi.org/10.5281/zenodo.6367434

[7]the length of time a software practitioner has been with her current organization/company.

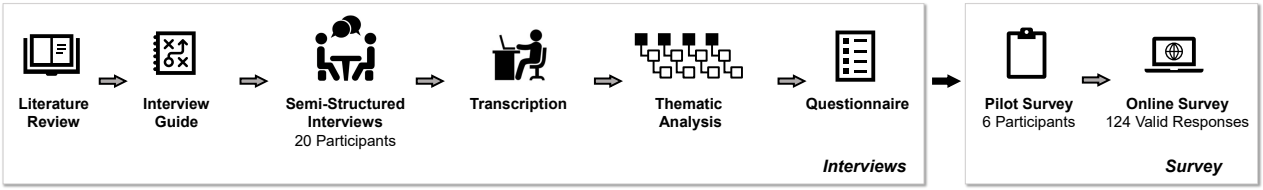


Figure 1: Research methodology.

between the two labelers is 0.81, indicating substantial agreement between the labelers. After completing the labeling process, the two labelers discussed their disagreements to reach a common decision. To reduce bias from the two authors sorting the cards to form initial themes, they both reviewed and agreed on the final set of themes. Eventually, we derived 14 statements that describe the motivation of software practitioners to contribute to inner source development, and options for survey questions regarding inner source practices.

3.2 Survey

The right part of Figure 1 describes the process of our online survey.

3.2.1 Recruitment of Respondents. We spread the survey to a broad range of companies from various locations worldwide. No identifying information was required or gathered from our respondents. To get a sufficient number of respondents from diverse backgrounds, we followed a multi-pronged strategy to recruit respondents:

- We contacted professionals from various companies around the world and asked their help to disseminate our survey within their organizations. Specifically, we sent emails to our contacts in Alibaba, ByteDance, Google, Hengtian, Huawei, Tencent and other companies, encouraging them to disseminate our survey to their colleagues. By following this strategy, we aimed to recruit respondents in the industry from diverse organizations.
- We sent an email with a link to the survey to 2,562 practitioners who contributed to 25 open source repositories initiated by tech companies and hosted on GitHub (e.g., `tensorflow` and `angular`) and solicited their participation. We aimed to recruit OSS contributors who have inner source experience in addition to professionals working in the industry. Out of these emails, five emails received automatic replies notifying us of the absence of the receiver; two emails indicated the receivers left their organizations.

3.2.2 Protocol. We conducted an IRB-approved anonymous online survey to validate and quantify the observations from the interviews and literature. We followed Kitchenham and Pfleeger's guidelines for personal opinion surveys [33] and used an anonymous survey to increase response rates [67]. Respondents have the option to specify that they prefer not to answer or do not understand the description of a particular question. We include this option to reduce the possibility of respondents providing arbitrary answers.

We piloted the preliminary survey with six practitioners with inner source experience, who were different from our interviewees and survey takers. We obtained feedback on (1) the length of the survey, and (2) the clarity and understandability of the terms. We made minor modifications to the preliminary survey based on the received feedback and produced a final version. The collected responses from the pilot survey are excluded from the presented results in this paper.

To support respondents from China, we translated our survey to Chinese before publishing the survey. We chose to make our survey available both in English and Chinese because English is an international lingua franca, and Chinese is the most spoken language. We expected that a large number of our survey recipients are fluent in one of these two languages. We carefully translated our survey to make sure there exists no ambiguity between English and Chinese terms in our survey. Also, we polished the translation by improving clarity and understandability according to the feedback from our pilot survey.

3.2.3 Survey Design. The survey includes different types of questions, e.g., multiple-choice and free-text answer questions. The potential answers and statements of multiple-choice questions were derived from the results of our interviews. We include an "*I don't understand*" option in case some questions are not applicable to the experience of respondents, or respondents had a poor understanding.

The survey consists of three sections, grouping questions by topic to minimize the cognitive load on participants and allow them to consider the topic more deeply [36]. Specifically, the following sections have been captured in the survey (the complete questionnaire is available online as supplemental material[8]):

Demographics. We collected demographic information about the respondents to allow us to (1) filter respondents who may not understand our survey, i.e., respondents without any experience in inner source development, (2) break down the results into groups. Based on the selections of respondents, we could exclude invalid responses and divide the survey respondents into various groups. To focus the respondents' attention on a particular inner source project, the survey asked respondents to answer following questions according to the experience with their *primary* inner source project.

We received a total of 327 responses, and first excluded two responses made by non-software practitioners who described their job roles as sales and legal affairs. We then excluded 191 responses made by respondents who claimed that they do not have experience in inner source development. We further excluded 10 incomplete responses from 10 respondents who have experience in inner source development but selected the "I don't understand" option for one to two questions out of seven questions. The seven questions receive

[8] Questionnaire Online: https://doi.org/10.5281/zenodo.6367434

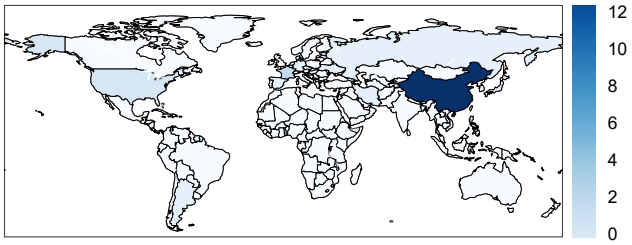


Figure 2: Countries of residence survey respondents reported. The darker the color is, the more respondents reside in that country. The legend indicates the number of respondents.

Table 2: Demographics of survey respondents.

Demographics	Statistics	%
Age		
Mean	31.6	-
Min	20	-
Max	53	-
Median	30	-
Std	6.4	-
Gender		
Female	10	8.1%
Male	113	91.1%
Prefer not to say	1	0.8%
Tenure		
0-1 years	6	4.8%
1-3 years	46	37.1%
3-5 years	28	22.6%
5-10 years	26	21.0%
10-20 years	17	13.7%
>= 20 years	1	0.8%
Job Role		
Development	102	82.3%
Testing	7	5.6%
Project Management	15	12.1%
Professional Experience		
0-1 years	1	0.8%
1-3 years	17	13.7%
3-5 years	29	23.4%
5-10 years	48	38.7%
10-20 years	25	20.2%
>= 20 years	4	3.2%
Experience in OSS Development		
Yes	65	52.4%
No	59	47.6%

one to three "I don't understand" responses in total. In the end, we had a set of 124 valid responses.

Our survey respondents reside in 13 countries across 4 continents as shown in Figure 2. Note that only 28 out of the 124 respondents reported their current country of residence because it is optional to answer the relevant question. The top four counties in which respondents reside are China (12), France (3), United States (2), and Netherlands (2). As presented in Table 2, our survey respondents are diverse in terms of age, gender, tenure, job role, professional experience, and experience in OSS development.

Experience with Inner Source. This section investigates the specific inner source experience of software practitioners, specifically, project objective, governance model, role(s), contribution level, and continuance intention in inner source development. The questions include:

- *What best describes the objective of the primary inner source project you contribute to? (Exploration-oriented / Utility-oriented / Service-oriented)*
- *How is your primary inner source project governed? (By a single organizational unit / By multiple organizational units / By all organizational units)*
- *What best describes the role(s) you play in your primary inner source project?*
- *How much time per week do you spend contributing to your primary inner source project?* (0-5 hours per week / 5-10 hours per week / 10-20 hours per week / >= 20 hours per week)

In terms of the third question, we provided two dimensions of options for roles, project-centric roles and community-centric roles, as suggested in [66]. In terms of the project-centric roles, an inner source contributor can be *Coder*, *Project Manager*, and *System Administrator*. As for the community-centric roles, an inner source contributor can be *Founder*, *Advocate*, *Mentor*, *Strategist*, *Treasurer* and *Writer*. The fourth question is commonly used in OSS studies as a proxy for participant contribution [44].

To understand the continuance intention of software practitioners, we further asked respondents to state how strongly they agree or disagree with the statement "*I look forward to being involved in inner source development in the future*" on a 5 level Likert-scale (*strongly disagree*, *disagree*, *neutral*, *agree*, *strongly agree*). The construct is used in a previous study [34] to measure continuance intention of software practitioners in OSS development.

Motivation to Contribute to Inner Source. This section focused on motivation to contribute to inner source projects. The motivation items were extracted from our interviews and presented as statements to which respondents were asked to state how strongly they agree or disagree on a 5 level Likert scale (*strongly disagree*, *disagree*, *neutral*, *agree*, *strongly agree*). In addition, we asked respondents to specify any other motivations that were not included in our questionnaire. More details about the questions and format are available in Section 4, along with the corresponding results.

3.2.4 Data Analysis. We analyzed the survey results based on the question types. For multiple-choice questions, we reported the percentage of each option is selected. In terms of free-text answer questions, we followed an inductive approach in which two authors separately performed open card sorting and regularly discussed emerging themes until an agreement was reached. For Likert-scale questions, we conducted multiple analyses as below:

Factor Analysis. To identify meaningful clusters of closely related motivation items, we conducted an exploratory factor analysis to analyze the Likert-scale ratings of the survey questions with respect to motivation. Specifically, we first used the `fa.parallel` function in the `psych` R library to select the optimal number of factors for factor analysis. We then used principal axis factor analysis in the `psych` R library [47] to group related motivators with a cut-off point of |0.4| for factor loadings. As a result, we reduced a large set of

motivators into a small set (*factors*) while retaining the majority of original information [64].

Comparison. To compare with OSS motivations (RQ2), we used the survey data in a recent study on OSS motivations by Gerosa et al. [22]. The study conducted a survey of 242 OSS contributors to measure OSS motivations using 21 Likert-scale questions. The 21 Likert-scale questions capture ten categories of OSS motivations, namely, *Ideology*, *Altruism*, *Kinship*, *Fun*, *Reputation*, *Reciprocity*, *Learning*, *Own-Use*, *Career*, and *Pay*, as proposed by Von Krogh et al. [69]. In terms of the comparisons across subgroups of our survey respondents, we classified our respondents into different subgroups based on their characteristics.

We used the Wilcoxon rank-sum test for Likert-scale answers to perform comparisons. All statistical tests assumed a p-value < 0.05 as a significant level. Benjamini-Hochberg correction was applied to adjust p-values in multiple comparisons. In addition, we used Cliff's delta to measure the magnitude of the differences because Cliff's delta is reported to be more robust and reliable than Cohen's delta [50]. The magnitudes are assessed with the thresholds as specified in [50]: if $|\delta| < 0.147$, the effect size is negligible; if $0.147 \leq |\delta| < 0.33$, the effect size is small; if $0.330 \leq |\delta| < 0.474$, the effect size is medium; and otherwise the effect size is large.

Correlation Analysis. We conducted correlational analyses to explore the associations between Likert-scale ratings of motivation and other variables in our survey results. Given ordinal variables were involved, we used Spearman correlational analysis to evaluate the associations.

3.2.5 Evaluation of Data Quality and Measurement Model. We evaluated the quality of collected survey data, followed by an evaluation of the measurement model of motivations.

Sampling Adequacy. Before applying exploratory factor analysis [10] on our survey data, we checked the suitability of the data for factor analysis. Specifically, we calculated two statistical measures for our constructs related to motivations, i.e., Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity [15]. The result of KMO (0.9) is well above the recommended threshold 0.6 [15], which indicates that sampling is adequate and factor analysis is appropriate for our survey data. The Bartlett's test of sphericity is highly significant at $p < 0.001$, which indicates that factor analysis could be worthwhile.

Internal Consistency Reliability. Internal consistency reliability refers to the extent to which the items are consistent with one another. We use Cronbach's α [11] as a measure of internal consistency. The Cronbach's α values for our motivation items score well above the recommended threshold 0.7 [24], with all 14 items scoring between 0.92 and 0.94.

4 RESULTS

We explained the results of three research questions that investigate the motivation of software practitioners to contribute to inner source development.

4.1 Motivation to Contribute to Inner Source Projects (RQ1)

We identified 14 motivators from our interviews as shown in Table 3. In our interviews, the 20 interviewees mentioned an average

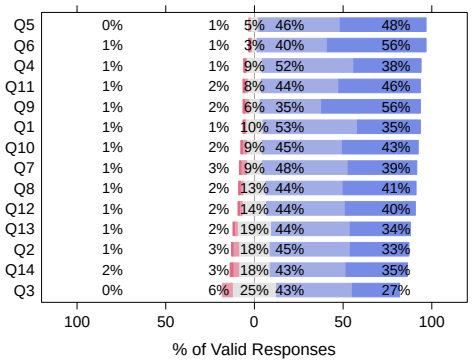


Figure 3: Survey responses to the 5-point Likert-scale items for motivators to contributing to inner source projects. Left hand (red) indicates levels of disagreement, middle (grey) indicates neutral, and right hand (blue) indicates levels of agreement.

of 4.6 motivators (min: 2, max: 7, median: 4.5, std: 1.6). *Job responsibility* (Q3) is the most frequent theme to emerge as a motivator to contribute to inner source projects, discussed by 13 of the 20 interviewees. 12 out of the 20 interviewees mentioned *learning new things* (Q9) as their motivators to participate in inner source projects, which is the second most frequent theme for motivation in our interviews.

In the questionnaire, we asked the respondents "I contribute to the (primary) inner source project because ..." and presented the 14 motivators derived from our interviews. As shown in Figure 3, the top three motivators are *helping others* (Q5), *sharing* (Q6), and *belief in effectiveness of inner source* (Q4). Specifically, 94%, 96% and 90% of our respondents agree (or strongly agree) with the three motivators, respectively. It is worth noting that the top three motivators are respondents' internal motivations. Meanwhile, external motivations, i.e., *job responsibility* (Q3) and *support from managers/leaders* (Q2), are reported less important than internal motivations.

We further used exploratory factor analysis to investigate underlying structure of the 14 identified motivators. The exploratory factor analysis suggests that 13 of the 14 motivators load on two factors; one motivator (Q12) did not conform to any particular factor. The factor loadings for each motivator are presented in the last two columns of Table 3; loadings less than 0.40 are not shown in the table for ease of presentation. Factor loadings indicate how strongly each item correlates with its underlying factor. We labeled the two factors as *internal motivation* (Factor 1) that reflects the belief and desire of a software practitioner, e.g., *helping others* (Q5) and *sharing* (Q6), and *external motivation* (Factor 2) that comes from outside an individual, e.g., *support from managers/leaders* (Q2) and *job responsibility* (Q3).

Difference in Motivation across Roles in Inner Source Projects. Our survey respondents take a broad variety of project-centric roles [66] in inner source projects. Specifically, 121 out of 124 respondents reported that they take an average of 1.3 project-centric roles in their primary inner source projects (min: 1, max: 3, median: 1, std: 0.6). 106, 31 and 26 respondents participate in inner source projects as *Coder*, *System Administrator* and *Project Manager*, respectively. Note that 34 respondents (27.4%) take 2 and more project-centric roles in inner source projects. We further explored

Table 3: Motivators to contribute to inner source projects.

	Survey questions	# Interviewees	What the interviewees say	Factor 1	Factor 2
Q1	Inner source enhances my expertise for my career development.	10	*The experience helps me build up my expertise* (P7); *It is good for my career* (P9)	0.74	
Q2	My manager/leader supports my contribution to inner source.	3	*My manager believes inner source helps to promote best practices in software development, thus supporting me to involve in inner source projects* (P6); *My manager encourages me to develop our modules commonly required across business units* (P12)		0.55
Q3	Contributing to inner source is my job responsibility.	13	*It is determined by my job role* (P2); *It is business-driven ...* (P3)		0.77
Q4	Adoption of inner source can benefit my company/organization.	4	*I believe that adoption of inner source facilitates innovation and communication between business units with my company/organization* (P2); *I think [inner source projects] can help people collaborate across business units* (P3)	0.66	
Q5	I enjoy helping others if I can.	5	*I publish the software, hoping others could benefit from it* (P4); *Our inner source software can help people improve their productivity* (P3)	0.57	
Q6	Inner source helps (me/my team) share software and knowledge.	9	*People with similar ideas gather together to share knowledge* (P6); *People could share good stuff* (P9)	0.74	
Q7	I feel good when I belong to a certain group of people.	2	*It is great to collaborate with people for inner source projects ... not feeling alone* (P6)	0.64	
Q8	I enjoy the fun when I contribute to inner source projects.	6	*It is fun to discuss and solve problems* (P8); *Because it is interesting* (P12)	0.64	
Q9	Inner source gives me an opportunity to learn new things.	12	*Inner source helps to broaden my horizon* (P2); *I could learn new stuff from my experience in inner source* (P16)	0.95	
Q10	Inner source community provides feedback to improve my software.	10	*The users could provide valuable feedback to improve my product* (P1); *We could get useful feedback for our software from a broader range of users* (P10)	0.83	
Q11	Inner source provides me with a means of learning from others.	4	*I can ask questions and exchange experiences with a wide range of people* (P8)	0.93	
Q12	I would like to create required but unavailable features/software.	4	*I wanted to solve the problems that I was facing in my daily work* (P4)		
Q13	Inner source helps me build up my reputation as an expert.	8	*Inner source helps to make capable people become visible and builds influence within the organization* (P1); *... technical impact* (P4)	0.62	
Q14	Inner source helps me expand my professional network with colleagues.	2	*I can build connections with people from other product lines by creating values for them* (P7)	0.64	

the differences in distributions of Likert responses for motivations between coders and non-coders of inner source projects. Although non-coders reported slightly higher ratings across the 14 motivators than coders did (1.07x), no statistically significant differences exist between these two subgroups.

Meanwhile, our survey respondents participate in inner source projects with a broad variety of community-centric roles [66]. 103 out of 124 respondents reported that they take an average of 2.5 community-centric roles in their primary inner source projects (min: 1, max: 6, median: 2, std: 1.4). Particularly, 63, 53, 49, 45, 38 and 4 respondents participate in inner source projects as *Mentor*, *Advocate*, *Writer*, *Founder*, *Strategist*, and *Treasurer*, respectively. 70 respondents take 2 and more community-centric roles in inner source projects. The top 2 community-centric roles 18 non-coder respondents take are *Strategist* (9) and *Mentor* (8). We further explored the differences in distributions of Likert responses for motivations between respondents with and without community-centric roles. Although respondents with community-centric roles reported higher ratings (1.10x) than those without community-centric roles, no statistically significant differences exist between these two subgroups.

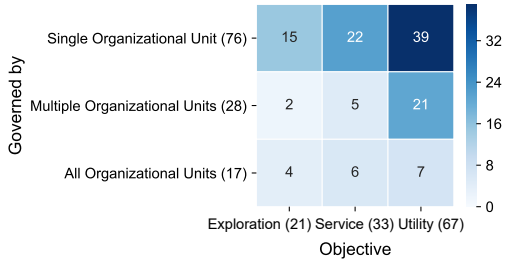


Figure 4: Objectives and governance models of inner source projects in which survey respondents participate.

Difference in Motivation across Types of Inner Source Projects. Our respondents contribute to diverse types of inner source projects, in terms of objectives and governance models as shown in Figure 4. The majority of our respondents (54%) have contributed to *utility-oriented* projects. In the meantime, most of our respondents (61%) reported that their primary inner source projects are governed by

a single organizational unit. Note that 3 respondents selected *Other* and explained that their projects are governed by individuals.

We further examined if statistically significant differences exist in motivations across contributors of various types of inner source projects. The results indicate that statistically significant difference exists in the *sharing* motivator (Q6) between contributors of *utility-oriented* projects and those of *service-oriented* projects ($p = 0.03$), with a small effect size ($\delta = 0.33$).

4.2 Comparison of Motivation: Inner Source vs. Open Source (RQ2)

In RQ2, we compared what motivates practitioners to contribute to inner source projects with what drives them to participate in open source projects. Previous studies have extensively investigated the motivation of practitioners to contribute to open source projects. Thus, we use the survey data from a most recent study, Gerosa et al.'s work [22], for the comparison. Gerosa et al. conducted a survey of 242 OSS contributors to measure OSS motivations using 21 Likert-scale motivation items.

We started by qualitatively studying the relationship between our motivation items identified in RQ1 (as shown in Table 3) and those in Gerosa et al.'s work. For each motivation item, we coded the corresponding survey question by removing words related to inner source. With the codes of survey questions, we identified the related OSS motivators as described in Gerosa et al.'s work. Finally, we identified 9 common motivators of software practitioners as listed in the first two columns in Table 4. The 9 common motivators were distributed across 7 out of 10 OSS motivation categories proposed by Von Krogh et al. [69]. The uncovered three categories include *Ideology*, *Reciprocity* and *Learning*. Note that we identified *learning new things* (Q9) as a motivator to contribute inner source projects. Given that we did not find a match for Q9 in Gerosa et al.'s work, we did not conduct further comparison for the *learning* motivation.

We then investigated the differences in Likert ratings for the 9 common motivators as shown in Table 4. The two *Likert Distribution* subcolumns present the distributions of ratings for motivators to inner source and open source development. For the Likert distributions, the leftmost bar indicates strong disagreement, the middle bar indicates neutrality, and the rightmost bar indicates strong agreement. For example, most software practitioners strongly agreed that they contribute to inner source projects because of their *job responsibility* (Q3), but strongly disagreed that they are "paid to contribute" to open source projects.

The *P-value* column indicates whether the difference in the agreement for each motivator is statistically significant. The table is sorted by the p-values with Benjamini-Hochberg correction. Statistical significant differences at a 95% confidence level are highlighted in green (Benjamini-Hochberg corrected p-values < 0.05).

The *Effect Size* column indicates the magnitude of difference in the agreement for each motivation. We used Cliff's delta to measure effect sizes. Effect sizes are additionally colored on a gradient from blue to orange based on the magnitudes of difference as referring to the interpretation of Cliff's delta: blue color means the former group is more likely to agree with the statement, and orange color means the latter group is more likely to agree with the statement.

Based on the observed statistically significant differences in motivations, we can say with some certainty that:

- **Software Improvement and Job Responsibility**: Software practitioners tend to have significantly higher levels of *software improvement* (Q10) and *job responsibility* (Q3) motivations to contribute to inner source projects than to open source projects, with large effect sizes ($\delta = 0.613$ and $\delta = 0.574$).
- **Fun**: Software practitioners tend to have a slightly lower level of motivation for *fun* (Q8) to dedicate time to inner source projects than to open source projects, with a small effect size ($\delta = -0.218$).
- **Unavailability of Software and Sense of Belonging**: Software practitioners tend to have slightly higher levels of *unavailability of software* (Q12) and *sense of belonging* (Q7) motivations to contribute to inner source projects than to open source projects, with small effect sizes ($\delta = 0.214$ and $\delta = 0.205$).

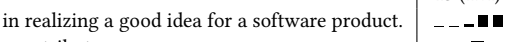
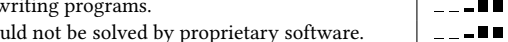
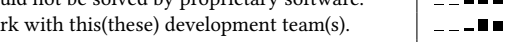
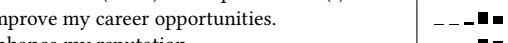
4.3 Effect of Motivation on Contribution Level and Continuance Intention (RQ3)

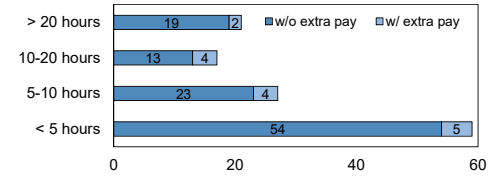
RQ3 explores whether motivation is predictive for the contribution level and continuance intention of software practitioners in inner source development. Specifically, we conducted correlation analyses to estimate the impact of the motivators identified in RQ1 on contribution level and continuance intention of software practitioners. We measured the contribution level as hours per week software practitioners spent on their primary inner source projects; and the continuance intention as the agreement level to a statement in our survey describing their intention to contribute to future inner source development.

Contribution Level. As shown in Figure 5(a), the distribution of hours spent on their primary inner source projects is skewed, as our respondents reported. 59 out of 124 respondents (47.6%) spend less than 5 hours per week on their primary inner source projects. On the contrary, 16.9% of our respondents spend more than 20 hours per week. We further investigated the relationship between financial rewards and contribution levels of practitioners in inner source projects. 12.1% of our respondents reported that they have received *extra* pay beyond their salaries to work on inner source projects. Software practitioners with extra pay tend to dedicate more time per week to inner source projects than those without extra pay. However, the difference is not statically significant according to the Wilcoxon rank-sum test.

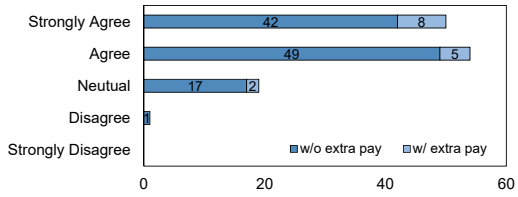
Continuance Intention. Most of our respondents (83.9%) strongly agree or agree that they are willing to involve in future inner source development as shown in Figure 5(b). We noticed that 20 out of 124 respondents (16.1%) were neutral or disagreed when asked if they plan to make future contributions to inner source projects. The 20 respondents with no/low continuance intention contribute to various types of inner source projects as shown in Figure 6. Among the 20 respondents with no/low continuance intention, 5 participate in *exploration-oriented* projects governed by a single organizational unit. We notice that two contributors out of five in *service-oriented* projects governed by multiple organizational units show no/low continuance intention.

Table 4: Comparison of motivation to contribute to inner source (IS) and open source projects (OSS).

Motivation to Contribute to IS	Motivation to Contribute to OSS (Gerosa et al.)	Likert Distribution IS (124)	Likert Distribution OSS (242)	Cliff's Delta IS vs. OSS	P-value IS vs. OSS
Q10 Software improvement	I need help in realizing a good idea for a software product.			0.613	0.000
Q3 Job responsibility	I am paid to contribute.			0.574	0.000
Q8 Fun	I have fun writing programs.			-0.218	0.001
Q12 Unavailability of software	Problem could not be solved by proprietary software.			0.214	0.003
Q7 Sense of belonging	I like to work with this(these) development team(s).			0.205	0.004
Q1 Career development	I want to improve my career opportunities.			0.140	0.082
Q13 Reputation	I want to enhance my reputation.			0.126	0.111
Q6 Sharing	I want to share knowledge and skills.			-0.036	0.966
Q5 Helping others	I deeply enjoy helping others.			0.002	0.966



(a) Hours/week spent on inner source development.



(b) Ratings to the statement "I look forward to being involved in inner source development in the future".

Figure 5: Contribution level (a) and continuance intention (b) of software practitioners in inner source development.

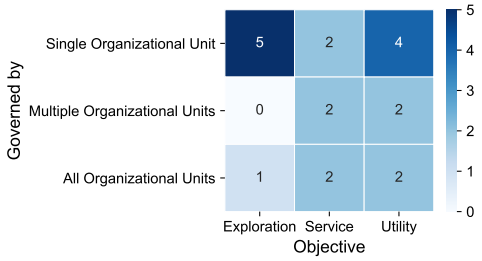


Figure 6: Inner source projects in which survey respondents with no (low) continuance intention participate.

We further assessed the relationship between financial rewards and the intention of software practitioners to contribute to future inner source development. Although the practitioners with extra pay show stronger intention to continue making contributions to inner source projects in the future than those without extra pay, the difference is not statistically significant according to the Wilcoxon rank-sum test.

Effect of Motivation. We present the correlation coefficients of a series of correlation analyses in Table 5. Correlation coefficients measure the strength of association between two variables, ranging from -1 to 1. Zero indicates that no monotonic association exists between the two variables. The relationship gets stronger as the coefficient approaches the extreme value, i.e., ±1. The strength of association can be assessed with the thresholds as specified in [53]: for absolute values of ρ, 0.00-0.10 is regarded as negligible, 0.10-0.39 as weak, 0.40-0.69 as moderate, 0.70-0.89 as strong, and 0.90-1.00 as very strong correlation.

Table 5: Correlation coefficients between motivation and contribution level (CL) and between motivation and continuance intention (CI).

		CL		CI	
Motivation					
Q1	Career Development	0.09		0.58	***
Q2	Support from Managers/Leaders	0.17		0.56	***
Q3	Job Responsibility	0.23	**	0.31	***
Q4	Belief in Effectiveness of Inner Source	0.11		0.61	***
Q5	Helping Others	0.01		0.49	***
Q6	Sharing	0.09		0.55	***
Q7	Sense of Belonging	0.07		0.56	***
Q8	Fun	0.09		0.55	***
Q9	Learning New Things	0.07		0.57	***
Q10	Software Improvement	0.10		0.45	***
Q11	Learning from Others	0.05		0.50	***
Q12	Unavailability of Software	-0.02		0.36	***
Q13	Reputation	-0.05		0.38	***
Q14	Networking	0.03		0.43	***

*Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$*

We observed that statistically significant correlations exist between motivation and contribution level, as well as between motivation and continuance intention:

- **Effect on Contribution Level.** The levels of the *job responsibility* motivation (Q3) are positively correlated with the weekly contribution of software practitioners to the inner source projects. However, somewhat unexpectedly, the levels of other measured motivators are not significantly correlated with the levels of practitioners' weekly contribution.
- **Effect on Continuance Intention.** The levels of all 14 measured motivators are positively correlated with the intention of software practitioners to contribute to future inner source development. The *belief in effectiveness of inner source* motivation (Q4) shows the greatest correlation ($\rho = 0.61$) with continuance intention among the 14 motivators. In addition to the motivator Q4, the levels of other 10 motivators

(e.g., *career development*) are moderately correlated with continuance intention. A statistically significant but weak correlation exists between three motivators (e.g., *Reputation*) and continuance intention. Note that the *job responsibility* has the smallest correlation ($\rho = 0.31$) with continuance intention among the 14 motivators.

5 DISCUSSION

We reflect our findings from the research questions, delving into factors that can help in attracting and retaining software practitioners for inner source development. We also highlight the avenues of future research.

Internal Motivation. Software practitioners are motivated by their *belief in effectiveness of inner source* to contribute to inner source projects (RQ1). Specifically, 90% of the survey respondents strongly agree or agree that they contribute to inner source projects because "adoption of inner source can benefit my company / organization" (Q4). On the other hand, this motivator is positively correlated with the continuance intention of software practitioners in inner source projects, with the greatest correlation coefficient across the motivators (RQ3). The results implies that the cultural shift for adopting inner source development may directly impact the success and sustainability of inner source projects. In order to achieve "effectiveness" and "buy-in" of practitioners, it is essential to demonstrate the benefits of inner source first. A previous study [6] claimed that organizations usually lack measurement capabilities for evaluating inner source initiatives to communicate the benefits. Future studies could put more effort into providing metrics to evaluate the improvements due to the adoption of inner source.

Compared to open source development, software practitioners tend to have a significantly higher level of *software improvement* motivation to contribute to inner source development (RQ2). The improvement of software requires a community of users and developers within an organization so that the software project can benefit from organization-wide input and continuously evolve. However, the organizational units within an organization may aim for different goals and have different priorities. Thus, the organization could perform a certain level of coordination to guide the improvement of inner source software.

External Motivation. The *job responsibility* motivation was bottom ranked in our survey results (RQ2). Specifically, 70% of our survey respondents strongly agree or agree that they contribute to inner source projects because "contributing to inner source is my job responsibility" (Q3). The low rank of external motivations are observed in previous OSS studies (e.g., [22] and [28]). At the same time, the *job responsibility* motivation was the only variable among the identified motivators positively correlated with the contribution level of software practitioners, but with the weakest correlation with the continuance intention of practitioners (RQ3). Job responsibility could enable software practitioners to dedicate time to inner source development, but has a weak impact on their continuance intention. Organizations may provide more flexibility to their employees, e.g., flexibility for task selection [65], to retain contributors and enable inner source communities to flourish.

As another external motivation, *support from managers/leaders* shows a moderate positive correlation with the continuance intention of practitioners (RQ3). The support from managers or leaders is more likely to lead to software practitioners' sustainable contribution in inner source development.

Financial Incentives. We expected extra pay beyond the salary to affect the contribution level and continuance intention of software practitioners, but no statistically significant difference is introduced by extra pay (RQ3). This may be because we only have a limited number of respondents (15 out of 124) who contribute to inner source projects with extra pay. Future studies could explore the effect of financial incentives on contribution level and continuance intention in inner source development.

Variety in Roles. 85.5% of our respondents (106 out of 124) take *Coder* as their project-centric roles (RQ1). Only 14.5% of the respondents joined their primary inner source projects by taking non-coder roles. The percentage of non-coder contributors in inner source projects is lower than the percentage (18.9%) in OSS projects as reported in Gerosa et al.'s work [22]. We observed that most of the non-coder contributors take core community-centric roles, e.g., *Strategist* and *Mentor*. Future work could investigate whether various roles in inner source development play different from those in open source development.

The prevalent existence of community-centric roles in inner source development (RQ1) is in line with the findings from OSS studies [66]. Thus, organizations may define an entry path in terms of community-centric roles for newcomers.

6 THREATS TO VALIDITY

Internal Validity. The interviewees were selected by a contact at each tech company. The procedure partially alleviates the threat of selection bias beacause the interviewer has no contact with interviewees before the interviews. The threat of selection bias would always be present when the interviewees were not fully randomly sampled. However, given that our interviews include practitioners with various job roles and from different companies, the threat has limited effect. Some of our respondents may have a poor understanding of the questions. To reduce the impact of this issue, we included an "I don't understand" option in the survey and ignored responses marked as such. We also dropped responses that were submitted by people whose job roles are none of these: software development, testing, and project management. Two of the authors translated our survey to Chinese to ensure that respondents from China could understand our survey well. To reduce the bias of presenting the survey bilingually, we carefully translated our survey to ensure there is no ambiguity between English and Chinese terms. We polished the translation by improving clarity and understandability according to the feedback from our pilot survey.

Construct Validity. In our interviews, the evaluation apprehension was ameliorated by the anonymity of the interviewees, as well as the guarantee that all the information obtained during the interviews would be used only by the researchers. The interviewer might have influenced the interviewees by asking specific questions. To mitigate this risk, we used open-ended questions to elicit as much information as possible. The interviewees may have a different understanding of the questions than what we had intended.

To minimize this aspect, we encouraged the interviewees to ask questions at all times. Our survey results are based on respondents' self-reported responses, which may be subject to bias and not exactly represent reality. We followed recommendations to reduce social-desirability bias by ensuring respondents' anonymity [43].

Our study made a direct comparison of the responses to matched survey questions regarding motivators between two surveys, ours and Gerosa et al.'s [22] from their replication package[9]. To match survey questions between the two surveys, two authors removed context related words, e.g., inner source and open source, and coded the survey questions. They discussed the codes and agreed on the matched questions between the two surveys. The matched survey questions between the two surveys tend to capture a common motivation. Nonetheless, the differences in the wording of matched survey questions may influence the responses respondents would give in unintended ways, and further introduce bias to the comparison of survey data. To minimize the unintended effects from wording, we followed a guideline for defining survey items provided by the BRUSO model [46], making sure that the survey items are brief, relevant, unambiguous, specific and objective. We also conducted a pilot survey to collect feedback and further improve the clarity and understandability of survey items.

Conclusion Validity. The interviews were conducted at different locations and each interview was done in one session. Thus, answers were not influenced by internal discussions. To ensure that the interview instrument is of high quality to obtain reliable measures, we conducted several pilots to improve the questions and layout of the interview guide prior to conducting the interviews. We did our best to randomly select survey respondents from both tech companies and open-source projects. Our survey respondents come from 13 countries across 4 continents who are working in various job roles with a wide range of experience.

External Validity. To improve the generalizability of our findings, we interviewed 20 interviewees from various companies. We further surveyed 124 respondents from 13 countries across four continents who are working for various companies or contributing to open-source projects that are hosted on GitHub, in various job roles.

7 CONCLUSION AND FUTURE WORK

This work followed a mixed-methods approach to explore software practitioners' motivation to contribute to inner source projects. We identified 14 motivators that drive practitioners to participate in inner source development, as well as several statistically significant differences between the identified motivators and OSS motivators that motivate practitioners to participate in open source projects. Besides, we observed several statistically significant correlations between the identified motivators and software practitioners' contribution level and continuance intention in inner source development. Future work could put efforts into investigating other factors that impact practitioners' contribution and continuance intention in inner source projects, and leveraging the factors to design strategies to sustain and grow inner source development.

[9] https://doi.org/10.5281/zenodo.4453904

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