

OPEN-INNOVATION AND OPEN-SOURCE SOFTWARE PROJECTS: CHALLENGES AND ROLE OF FINANCIAL CONSTRAINT

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ARTICLE INFO	ABSTRACT
Article History: Received: 10 Sep 2019 Revised: 22 Mar 2020 Accepted: 25 Jul 2020 Available Online: 10 Sep 2020 Keywords: Open-Innovation, Open-Source Software, motivating spillovers, External Knowledge, intellectual property Management, internal innovation. JEL Classification: F34, O57	In the recent decade, open innovation (OI) has attracted much attention within the field of innovation management research. Now, most of the firms are adopting OI practices to expedite the performance. However, open-source software projects are facing crucial challenges such as motivating spillovers (MS), incorporation of external knowledge (EK), intellectual property (IP) management, and maximization of internal innovation (II). Additionally, open-source software projects are facing the major issue of financial constraint (FC) to develop and maintain the OI system. To address this issue, the prime objective of the current study is to inspect the role of FC during the management of OI challenges in Pakistan. To accomplish this objective, this study adopted a quantitative research approach and a cross-sectional research design. Survey questionnaires were distributed among the managerial employees of open-source software projects via a mail survey. SMART-PLS 3 (SEM) was utilized to conduct the analysis. The study revealed that FC is a moderating variable between the maximization of II and OI performance. FC is one of the limiting factors towards the maximization of II which automatically decreases the OI performance. Hence, the current study contributed by investigating the role of FC in OI practices. Therefore, this study is beneficial for open-source software developers to enhance OI.

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1. INTRODUCTION

Innovation is the application of “an idea, invention, technology or process to product, services or process which fulfils the certain need and replicated at a reduced cost” (Hameed, Basheer, Iqbal, Anwarv & Ahmad, 2018; Hameed & Naveed, 2019; Hameed, Altaf & Ahmed, 2019). Majorly, innovation has two types, closed innovation and open innovation (OI). Traditionally, in an organization, scientists bring new ideas; develop new products according to the demand of customers remaining within the boundaries of the firm but they never look outside the boundaries of the firm for new idea generation (Conboy & Morgan, 2011) which is the example of close innovation. Therefore, close innovation is one of the isolated processes in which a small group of people and certain individuals are involved in an idea generation and value creation process which only depends on the internal ability of this group or individuals and they do not look outside the firm. Chesbrough (2012) while challenging the close innovation model explains that all the project of research depends on the internal knowledge of the firm. However, now the innovation trend has been changed, organizations are working in a different way on conceptualization as well as commercialization which makes the boundaries of firms become permeable (Trott & Hartmann, 2009). In contrast to the closed model of innovation, knowledge, as well as ideas, cannot flow (inter or exit) through a single way but it flows through different ways like external players, partnership, internal research investigation, etc. (Lameras et. al., 2012). Hence, “OI is the use of purposive inflows and outflows of knowledge to accelerate internal innovation (II), and expand the markets for external use of innovation, respectively” (Chesbrough, 2006). According to Lichtenthaler (2008), OI is both outside-in and inside-out transfer of technologies and ideas.

This notion of “OI” was first introduced by the Chesbrough (2003a, 2003b) and has rapidly grown the attention of various researchers as well as practitioners, demonstrated by many publications as well as dedicated conferences and quickly growing the literature. OI is a key trend in innovation practices as well as in research (Fu, 2012). Different studies have been conducted which explain the OI as well as explain the effect of OI on different firm’s innovative performance (Chesbrough, 2003b; 2006; Dahlander & Gann, 2010; Enkel, Gassmann, & Chesbrough, 2009; Hitchen, Nylund & Viardot, 2017). Generally, the OI phenomenon is connected with open source software projects (West &

O'Mahony, 2008) that are generally carried out within large international communities (Harison & Koski, 2010). These open-source software are developed by different software developers in various software projects. Therefore, these open source software projects require a huge investment to boost up OI activities. To expedite this process, the research and development (R & D) department is an indispensable element that requires a huge amount of finance. Hence, open-source software projects are lacking in finance, due to which it is not possible to develop open-source software. Therefore, the FC is one of the crucial factors which limits the OI system in open source software projects.

A few numbers of studies describe that OIs in software houses like open-source software (Henkel, 2006; west & Gallagher, 2006). Van de Vrande (2009) discusses the different challenges like administration, commitment, idea management and lack of finance is also the challenge to OI. According to Rahman and Ramos (2013), OI faces different constraints like policy constraints, human-related constraints, competition constraints, and some type of general constraints. Other different challenges are also studied like, motivating spillovers (MS), maximization of internal innovation (II), incorporation of external knowledge (EK) (west and Gallagher, 2006), coordination problem, and incentive problem (Rodríguez, & Lorenzo, 2011). Intellectual property (IP) has also been discussed many times and it is highlighted that IP plays a vital role in the OI process (see, for example, Lichtenthaler, 2007). However, the current study highlights a major limiting factor, an FC which is generated while mitigating the other challenges. As to motivate different factors that contribute to OI such as employees, suppliers, and other stakeholders, requires rewards and other benefits which is a costly process. EK incorporation requires coordination with a supplier which increases the overall cost (Hitchen, Nylund & Viardot, 2017). Furthermore, to enhance II, R & D department is mandatory which is a costly process. On the other hand, patents and copyrights also increase the overall cost. Thus, the smaller firms are lacking with essential resources (West & Gallagher, 2006) such as small open-source software houses.

As the important challenges in eyes of researchers are maximizing II, MS (West & Gallagher, 2006), incorporation EK (Rodríguez, & Lorenzo, 2011, West & Gallagher, 2006), and IP management (Hagedoorn & Ridder, 2012). However, in rear cases, the researcher considered the effect of FC on managing the OI challenges (Van de Vrande 2009, Rahman & Ramos, 2013). In rare cases, any study properly documented the issue of FC. Consequently, a gap exists in the management of OI challenges. Moreover, the combined effect of these challenges has also not been checked. That is the reason the current study examined the combined effect of various challenges such as MS, maximizing II, incorporation EK, and IP management along with the moderating impact of FC in OI. Moreover, it is suggested by Greco, Grimaldi & Cricelli (2015), it is needed to conduct a study on the cost aspect of the OI. Therefore, the objective of the current study is to inspect the role of FC during the management of OI challenges. However, the study has two sub-objectives: (1) To explore the major challenges and their impact on OI system adoption and (2) To explain the moderating role of FC. Open-source software highlights many ways form different firms to improve their competitive advantage with the help of using different ideas of OI (West & Gallagher, 2006). The software is a basic need to promote firms and to advance a competitive advantage in the current competitive environment. Additionally, the literature is missing with comprehensive studies on open source software projects. Therefore, the focus of this research is Pakistani based open-source software projects. Thus, this study aims at giving an overview of the evolving research field of OI in a phase that is still very fluid in open-source software projects. The purpose of this study is to portray the main challenges in the area of OI. It also purposes at debating potentially significant fields of examination that are still left rather unexplored within the sector of open-source software projects. Hence, the current study contributes to the knowledge by identifying a new problematic area related to FC. In rare cases, any study properly documented the problem of FC in open source software projects in Pakistan.

2. REVIEW OF LITERATURE AND HYPOTHESIS DEVELOPMENT

“OI is a paradigm which assumes that firms can and should use external ideas as well as internal ideas, and internal as well as external paths to market, and look to advance their technology” (Chesbrough, 2003). According to Gassmann and Enkel (2006), OI follows three different paths. The first path is the outside-in process which targets the EK and knowledge bearers. The second path is inside out process gearing to the exploitation of technology externally and the third path is coupled processes that describe the cooperative innovation with competitors in strategic alliances. Innovation management research has increased in the current years (Popa, Soto-Acosta & Martinez-Conesa, 2017). OI offers different opportunities but faces different challenges (Vanhaverbeke et al. 2008). According to the West and Gallagher (2006), the management of OI faces various challenges in open source software projects. These challenges include: to find a way to exploit the innovation within the organization, to incorporate external innovation for the development of innovation inside the organization, IP management, and to motivate various contributing factors which promote OI.

2.1 Resource-Based View (RBV)

According to the resource-based view (RBV), a company's success is largely depending upon the resources and these resources consist of assets as well as various capabilities (Umrani, 2016). These assets comprises of tangible as and intangible (Collis, 1994). On the other hand, capabilities consist of intangible such as the skills and the knowledge of company employees (Teece, Pisano & Shuen, 1997). Additionally, knowledge, skills of employees, and other capital equipment key resources of any firm (Barney, 1991). In this study, the incorporation of EK facilitates OI. As knowledge is one of the resources (Barney, 1991) of open-source software projects. Knowledge from customers, stakeholders, and supplies through a good relationship is a competitive edge for any open-source software house. A good relationship with customers and supplies is one of the tangible assets of open source software which is a valuable resource to achieve success. In line with RBV, in the current study employee's skills and capabilities are based on the maximization of II. Better skills of employees determine the OI success by generating valuable internal ideas. RBV, resources consist of capabilities as well as assets ((Iqbal & Hameed, 2020; Umrani, 2016). The talent of employees and information provides good quality outcomes and increase the performance of the business (Amit & Schoemaker, 1993). On the other hand, IP management such as patents or copyrights is the assets of open-source software projects. Therefore, in line with an RBV, IP is one of the valuable intangible assets of open-source software projects. Moreover, the motivating factors such as employees of a company, suppliers of the company, customers of the company, and other stakeholders are also the assets or strength of open-source software projects which are considered as resources. Hence, the current study is in line with RBV, as the success of OI through MS, motivated employees and other factors, EK incorporation through a good relationship with supplies, maximization of II through capabilities of employees, and protection of IP through patents and copyrights are the resources of open-source software projects. Makadok, (2001) described that the spirit of the RBV process is to consider the use of various resources at the complete capability to gain exclusive core competencies to attain a competitive advantage. Therefore, OI success in open sources software projects requires full use of all these resources

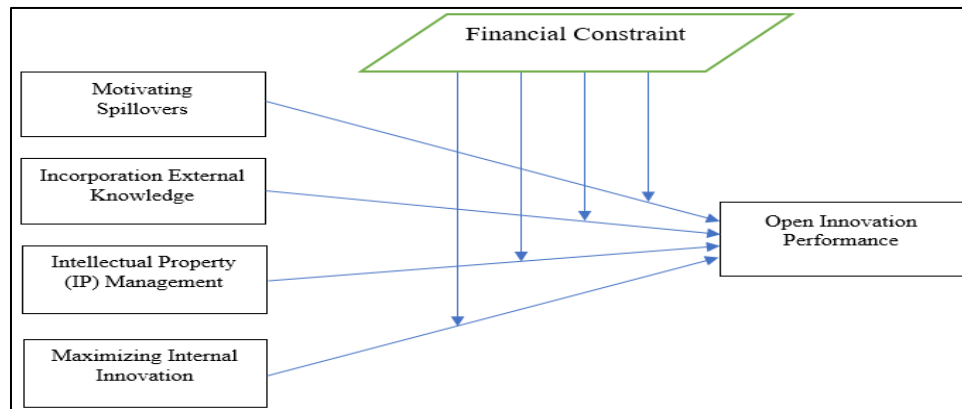


Fig. 1. Theoretical Framework

2.2 Motivating Spillovers

Motivation is the state of being incited to action (Kirstein, 2010). It is one of the psychological processes resulting from reciprocal action among two things, one is individual, other is the environment, this relationship affects an individual's choices, efforts of individual and persistence of individual (Latham & Ernst, 2006). It is necessary to motivate diverse factors that improve OI to increase OI practices (West & Gallagher, 2006). From the statement of West and Gallagher (2006), it is clear that an increase in motivation will increase OI. Hence, a question arises that how to motivate them for better innovation? It is one of the challenges of OI. Different theories are presented on motivation. According to Taylor's theory rewards motivate people and increase their performance. According to Armstrong (2007), Vroom's expectancy theory describes that motivation is only achieved when there will be a relationship between performance and outcome. The outcome means the expectations of the employees like promotion, rewards, benefits, increments but it increases the overall cost. Therefore, different rewards can increase performance and motivation will automatically increase OI, however, it generates FC which limits OI activities. Incentive problem is related to the creation and value capturing of ideas and knowledge of inventors (Rodríguez, & Lorenzo, 2011). However, coordination costs for OI are increased when the collaborating firm's incentives are not aligned (Almirall & Casadesus-Masanell, 2010).

Finally, to promote OI; it is needed to motivate the factors which maximize OI. Therefore, there is a direct relationship between motivation and OI, but FC lies between these two. Thus, from the above discussion, it is concluded that:

H₁: *MS significantly improves OI performance.*

H₂: *FC moderates the relationship between MS and OI performance.*

2.3 Incorporation of EK

Companies are facing an increasing need to incorporate EK for innovation. However, coordination costs are produced in the innovation procedure (Hitchen, Nylund & Viardot, 2017). In inter-firm collaboration, expanse increases from the organizational complexity of disintegrating work tasks among various firms as well as coordination of diverse practices to be accomplished across organizational boundaries, and associated communication as well as various decisions (Gulati and Singh, 1998). The unwillingness of employees to utilize extra-organizational knowledge is one of the important challenges of OI (Chesbrough & Crowther, 2006; Huston & Sakkab, 2006; Lucas & Goh, 2009). Employees of an organization have not a positive attitude towards the use of knowledge which is outside the boundaries of an organization like not invented here syndrome (NIH) and employees have also a negative attitude towards the commercialization of ideas (Lichtenthaler, & Lichtenthaler, 2010). According to the definition of OI, it is the process in which both internal and EK combine to bring something new. Therefore, it is clear that EK incorporation is positively correlated with OI. On the other hand, it increases the overall OI cost.

Coordination costs of OI are more increased due to extremely competitive markets and various factors related to the industry (Wu, 2012), learning races among different partners related to the business (Hamel, 1991), various possible knowledge leakage (Kale et al., 2000), and moreover, expenses rising from the structural severity of cooperative arrangements (Doz, 1996). The involvement of suppliers in OI could be valuable to mitigate the time-to-market of new products, and improving their quality (Greco, Grimaldi & Cricelli, 2015), however, it increases the overall cost. Coordination with external partners like suppliers brings a new idea from outside the boundaries of the firm (Rodríguez, & Lorenzo, 2011) but coordination with the supplier is a costly process (Almirall & Casadesus-Masanell, 2010). Therefore, EK incorporation is vital for the OI system. According to the Zabala Martinez (2009), technological knowledge is not sufficient to gain competitive advantage, coordination/EK incorporation is needed, however, on the other hand, Chesbrough (2012) mentioned that collaboration with partners is one of the expensive processes. Therefore, it can be described that during OI launching, EK incorporation is one of the important challenges and need to be overcome for better OI practices, however, it is one of the costly processes. Thus, from the above discussion it is hypothesized that;

H₃: *EK incorporation significantly improves OI performance.*

H₄: *FC moderates the relationship between the incorporation of EK and OI performance.*

2.4 Intellectual Property (IP) Management

The possession of knowledge, experience, technology, associations with the customer as well as professional services that provide a competitive edge in the market is known as IP (Chesbrough, 2006). IP is one of the assets which secures the commercial achievement of an innovation (Von Zedtwitz, et. al., 2004). Therefore, it is one of the vital parts to promote OI. However, the management of IP is the problem of OI which faces companies (Chesbrough, 2006). Chesbrough (2006) also said that imitation and devaluation of the idea are the challenges that arise due to the OI. IP has a vital role in the OI process due to which inflows and outflows of knowledge (Lichtenthaler, 2007) but IP management is one of the expensive as well as complex processes (Savitskaya, 2011). According to Benkler (2002) increase in IP management, increase the overall cost. According to Brem, Nylund, and Hitchen (2017), IP has a positive influence on firm performance by increasing OI success. IP is one of the important elements of OI (Freel & Robson, 2017). However, the protection of IP is most important in OI, but it increases the cost of the OI system. The costs of collaboration also comprise those of shielding the knowledge from other companies (Liebeskind, 1996; Winter, 1987). OI experiences cost due to complications connected with value appropriation (West, 2003).

Formal and informal IP protection is used by different firms (Amara et al., 2008). Formal mechanisms include legal basis such as patents, design registration as well as trademarks. On the other hand, informal mechanisms include extra-legal such as secrecy, complexity as well as speed-to-market. It is found that informal ways to be more broadly used as compared to formal mechanisms. United Kingdom (UK) based study by Hall et al. (2014) shows that only 22% of companies prefer to utilize formal IP protection. However, approximately 34% of companies prefer to utilize an informal mechanism. This is because the formal IP protection requires more cost. Small scale companies hardly have the necessary resources (west, 2006) such as open-source software projects that could not afford sufficient

finance to protect their IP. Therefore, it can be described as IP management significantly improves OI but FC disturbs this relationship.

H₅: *IP management significantly improves the OI system.*

H₆: *FC moderates the relationship between IP(IP) management and OI performance.*

2.5 Maximizing II

OI holds that businesses should progressively utilize both internal as well as external sources to generate innovation rather than only relying on one of them (Freel & Robson, 2017). Therefore, with the incorporation of EK, internal knowledge/innovation is also equally important. However, the maximization of II requires the R & D department which one of the costly processes and various open-source software projects are unable to invest in the R & D department. How to best use internal research and development capabilities to gain a maximum advantage is the central concern to OI in open source software houses (West and Gallagher, 2006). Communication is one of the key factors to increase employee innovation, both outside as well as inside communication is crucial for employee innovation (de Jong & Den Hartog, 2007). Furthermore, ideas only generate when employee's communication with each other and share their ideas with each other, that's why communication among employees of the firm is much beneficial for innovation. According to Kengchon (2012), communication needs meetings as well as seminars in which all employees participate and discuss their ideas, but this process of meetings and seminars required more finance which increases the overall cost of the OI system. Additionally, OI has widespread application, companies face a tough time in implementation due to the FCs (Van de Vrande et al., 2009; Saguy, 2011). Lack of finance is one of the constraints of OI (Rahman and Ramos, 2013).

Finally, the maximization of II is directly related to the OI system, but FC disturbs this relationship. Thus, from the above discussion it is hypothesized that;

H₇: *Maximization of II significantly improves the OI performance.*

H₈: *FC moderates the relationship between maximization of II and OI performance*

3. RESEARCH METHOD

The use of a suitable method is one of the most critical steps in research. While considering the objectives, nature of the population, and the design of sampling, it is investigated that the quantitative method is an appropriate technique used to measure the objectives (Burns & Grove, 1993) with a cross-sectional research design. Probability sampling is used, and questionnaires were distributed by using stratified sampling among those managerial employees who are directly involved in open-source software projects within open-source software houses by targeting the three main cities (Lahore, Multan, Bahawalpur) of Punjab state Pakistan. All open-source software houses were contacted and found the number of employees of software houses in each city. With the help of mail 256 questionnaires were distributed in Lahore, 30 in Multan, and 14 in Bahawalpur. Table 1 shows the stratified sampling and sample size of each city.

Table 1. Stratified Sampling

S. No	City	No. of software Houses	No. of Employees	Sample/city
1	Lahore	350	3150	3150/3684*300=256
2	Multan	54	358	358/ 3684*300 =30
3	Bahawalpur	10	176	176/3684*300 =14
	Total	414	3684	300

According to Comrey and Lee (1992), "a sample which is less than 50 members will have noticed to be a weaker sample; a sample size of 100 participants will be weak; 200 will be adequate; 300 will be considered as good; 500 very good and 1000 will be outstanding." Therefore, the 300 sample size was selected. The data weres collected via mail and the response rate was 39% of 300 which is equal to 117 responses. According to Sekaran (2003), if the data is collected via mail then a 30% response is enough.

All the measures are adapted from previous studies by de Rochemont (2010), Meulenbroeks (2011), Mahrous (2011), and Kirstein (2010). MS is measured through 03 items, maximization of II is measured by using 04 scale items, incorporation of EK is measured by using 04 scale items, IP management is measured by using 04 scale items, the FC is measured by using 06 scale items, and OI is measured by using 06 scale items.

4. ANALYSIS AND RESULTS

4.1 Measurement Model Assessment

SmartPLS 3 Algorithm was used to measure the measurement model. Henseler et al., (2009), Hair et al., (2014), and Hair et al., (2010) described that assessment of the outer model requires 1) individual item reliability, 2) internal consistency, convergent validity, and discriminant validity. By following these guidelines each of these steps was performed and the details are provided below in Figure 2 and Table 2.

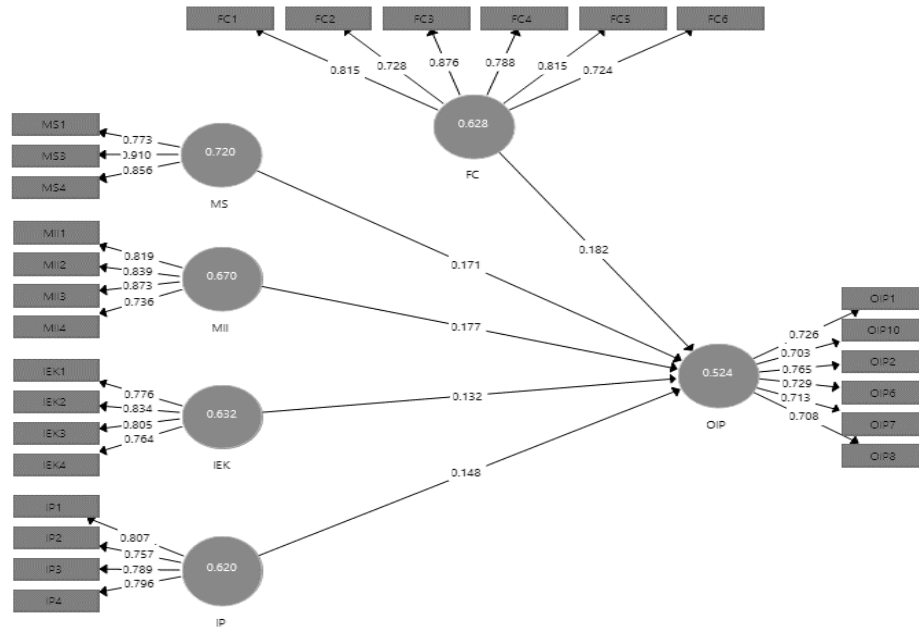


Fig. 2. Assessment of Measurement Model

While the basement of the model, initially the number of items was 32, 5 items were deleted having factor loading below than 0.7. Finally, 27 items were retained with a factor loading of more than 0.7 (Hameed; 2019; Ul-Hameed, Mohammad & Shahr, 2018; Ul-Hameed, Mohammad, Shahr, Aljumah & Azizan, 2019). Figure 2 shows that all the factor loading is greater than the accepted range of 0.7. Therefore, internal consistency or convergent validity is attained. Fornell and Larcker (1981) propose that the average variance extracted (AVE) should be above 0.5. Figure 2 along with Table 2 depicts that the average variance extracted (AVE) is higher than 0.5. Moreover, composite reliability (CR) should be more than 0.7 (Jauhar, Ghani & Islam, 2016). It is shown in Table 2 that CR is more than an acceptable range (0.7).

Table 2. Internal Consistency, Convergent Validity, and Average Variance Extracted (AVE)

Construct	Indicators	Loadings	CR	AVE
Motivating Spillovers	1. The incentive is the most important factor which motivates people to enhance OI.	.773	.830	.720
	2. Incentive system influence the innovation performance.	.910		
	3. I feel a sense of personal satisfaction when I innovate new ideas.	.856		
Maximization Internal Innovation (MII)	1. "Internal ideas are always welcomed in our organization.	.819	.890	.670
	2. Communication between partners occurs without problems.	.839		
	3. Sufficient non-financial resources are available in our organization to achieve the desired innovation.	.873		
	4. Carrying out OI activities requires an internal R & D department.	.836		

Incorporation External knowledge (IEK)	1.	Bringing of EK to the internal system enhance the OI system.	.776	.873	.632
	2.	Our organization encourages employees to initiate new external collaboration practices.	.834		
	3.	Collaboration with external partners adds value to our innovation resources.	.805		
	4.	Collaboration with external partners/suppliers or customers adds value to our innovation activities.”	.764		
Intellectual Property (IP) Management	1.	IP rights protection is more important for open source software projects companies.	.807	.867	.620
	2.	Poor IP management holds back innovation practices.	.757		
	3.	I learn IP rights in our organization.	.789		
	4.	Benefit from process improvement protected by using IP rights (e.g., patents, model, trademark).	.796		
Financial Constraint (FC)	1.	Enough financial resources are available in our organization to achieve the desired innovation.	.815	.910	.628
	2.	Before you took the decision to engage in an OI, your greatest concern was cost.	.728		
	3.	Incentive systems increase the financial cost of the overall OI process.	.876 .788		
	4.	During the undertaking of an OI project, my level of satisfaction was low about the financial cost of IP management.	.815 .724		
	5.	Collaboration with external partners adds financial cost.			
	6.	R & D department and patents/copyrights increase the cost.			
Open Innovation Performance (OIP)	1.	“You choose to engage in the OI model, believed that it is a way to commercialize the idea.	.726	.869	.524
	2.	Collaboration efforts with a number of individuals outside the organization to work on a project for mutual gain are the best description of OI.	.765		
	3.	You choose to engage in the OI model believe that outsourcing of expertise would benefit.	.729		
	4.	New ideas are always welcomed for OI in our organization.	.713		
	5.	In my opinion, the out-or-in licensing of IP is the best description of OI.	.708		
	6.	In my opinion sharing of internal and EK enhances the OI.”	.703		

Table 2 displays that factor loading, composite reliability, and AVE is greater than accepted value 0.7, 0.7, and 0.5, respectively. To inspect the discriminant validity, correlation and cross-loading are required. In this direction, the correlations among latent constructs were compared with AVE square roots (Fornell & Larcker, 1981) as shown in Table 3 which fulfills the requirement. In addition to this, the discriminant validity was also determined using a criterion provided by Chin (1998). Chin (1998) explained that the indicator loadings are compared with other reflective indicators, as shown in Table 4.

Table 3. Latent Variable Correlations and Square roots of Average Variance Extracted

	1	2	3	4	5	6
FC	0.793					
IEK	0.385	0.795				
IP	0.335	0.517	0.787			
MII	0.383	0.532	0.481	0.818		
MS	0.388	0.494	0.339	0.484	0.848	
OIP	0.416	0.458	0.421	0.471	0.443	0.724

Table 4. Cross Loading

	FC	IEK	IP	MII	MS	OIP
FC1	0.815	0.292	0.259	0.429	0.376	0.389
FC2	0.728	0.302	0.321	0.197	0.098	0.165
FC3	0.876	0.440	0.337	0.413	0.378	0.450
FC4	0.788	0.257	0.264	0.259	0.316	0.260
FC5	0.815	0.299	0.285	0.275	0.286	0.326
FC6	0.724	0.180	0.120	0.104	0.269	0.248
IEK1	0.336	0.776	0.352	0.411	0.464	0.440
IEK2	0.325	0.834	0.421	0.444	0.334	0.309
IEK3	0.340	0.805	0.454	0.489	0.381	0.333
IEK4	0.214	0.764	0.430	0.350	0.362	0.341
IP1	0.313	0.465	0.807	0.474	0.276	0.337
IP2	0.375	0.437	0.757	0.386	0.358	0.294
IP3	0.167	0.363	0.789	0.353	0.235	0.340
IP4	0.219	0.371	0.796	0.307	0.214	0.349
MII1	0.358	0.453	0.382	0.819	0.474	0.354
MII2	0.324	0.430	0.383	0.839	0.355	0.414
MII3	0.289	0.431	0.452	0.873	0.412	0.435
MII4	0.292	0.439	0.351	0.736	0.352	0.325
MS1	0.391	0.297	0.217	0.342	0.773	0.338
MS3	0.361	0.505	0.327	0.479	0.910	0.423
MS4	0.236	0.438	0.311	0.399	0.856	0.359
OIP1	0.362	0.433	0.409	0.424	0.382	0.726
OIP10	0.167	0.298	0.313	0.334	0.188	0.703
OIP2	0.301	0.409	0.395	0.332	0.386	0.765
OIP6	0.423	0.311	0.226	0.379	0.304	0.729
OIP7	0.238	0.197	0.173	0.268	0.289	0.713
OIP8	0.254	0.258	0.240	0.261	0.324	0.708

4.2 Structural Model Assessment

The current study employed standard bootstrapping with 5000 bootstraps samples. This was performed by following the instructions provided by the various scholars in their studies (see, for example, Hair et al., 2014; Hair, Ringle, & Sarstedt, 2011). SmartPLS 3 was used to examine the relationship between variables. The direct relationship between four variables, namely, MS, maximization II, incorporation EK and IP management was examined with OI performance. As shown in Table 5. Table 5 depicts the direct relationship among all independent variables with the dependent variable. To examine the direct relationship beta value (β) and p-value ($p < 0.05$) were observed. It is found that MS (MS) has a significant positive relationship with OI performance (OIP) with $\beta = 0.206$ and $p = 0.003$ ($p < 0.05$). Thus, H1 is accepted. In the case of incorporation EK (IEK), $\beta = 0.159$, and $p = 0.028$ ($p < 0.05$) which shows a significant positive relationship with OI performance (OIP). Hence, H3 is accepted. Moreover, in case of IP and maximizing II (MII), $\beta = 0.175$ and $\beta = 0.202$, $p = 0.029$ ($p < 0.05$) and $p = 0.007$ ($p < 0.05$), respectively. These values show that IP and maximizing II (MII) both have a significant positive relationship with OI performance (OIP). Therefore, H5 and H7 are accepted.

Table 5. Hypothesis Testing Results

Hypothesis	Relationship	β	SD	T Statistics	P-Value	Decision
H ₁	MS $\rightarrow$ OIP	0.206	0.068	3.016	0.003	Supported
H ₃	IEK $\rightarrow$ OIP	0.159	0.072	2.198	0.028	Supported
H ₅	IP $\rightarrow$ OIP	0.175	0.080	2.185	0.029	Supported
H ₇	MII $\rightarrow$ OIP	0.202	0.075	2.685	0.007	Supported

4.3 Moderation Effect

SmartPLS 3 Bootstrapping techniques were used to analyze the moderating effect. Table 6 shows the result of the moderating effect. It is found that the moderating effect between MS (MS) and OI performance (OIP) is insignificant, as the $t = 0.302$ and $p = 0.773$ ($p > 0.05$). Thus, H2 is rejected. Furthermore, it is found that the moderating effect between incorporation of EK (IEK) and OI performance (OIP) is insignificant with $t = 0.169$ and $p = 0.866$ ($p > 0.05$). Hence, H4 is rejected. Moreover, the moderating effect between IP and OI performance (OIP) is also insignificant with $t = 0.008$ and $p = 0.993$ ($p > 0.05$). Thus, H6 is rejected. On the other hand, H8 is accepted. As the moderating effect of maximizing II (MII) and OI performance (OIP) is significant with $t = 3.476$ and $p = 0.001$ ($p < 0.05$).

Table 6. Structural Model Assessment (Moderator Effect Results)

Hypothesis	Relationship	β	SD	T Statistics	P-Value	Decision
H ₂	MS*					Not Supported
	FC  OIP	-0.017	0.057	0.302	0.773	
H ₄	IEK*					Not Supported
	FC  OIP	0.015	0.086	0.169	0.866	
H ₆	IP*					Not Supported
	FC  OIP	-0.001	0.071	0.008	0.993	
H ₈	MII*					
	FC  OIP	-0.226	0.065	3.476	0.001	Supported

4.4 Assessment of Variance Explained (R²)

PLS-SEM inner model acclaims another imperative standard which is R-Squared value assessment. Chin (1998) described that the R-squared value of 0.60 is substantial and 0.19 is weak. However, 0.33 is considered as moderate. Below Table 7 highlighted the R-Square.

Table 7. R-Square (R²)

Latent Variable	Variance Explained (R ²)
OI Performance	33%

Table 7 shows a 33% R-Square value which indicates that five sets of variables including MS, maximization II, incorporation of EK, IP management, and FC collectively explained 33% of the variance in OI performance. According to Chin (1998), 33% is a moderate R-square value.

4.5 Assessment of Effect Size (f²)

Chin (1998) demonstrated that f² is the changes in the r-squared values through a specific latent variable. Generally, it is calculated based on a formula provided in various studies (see, for example, Callaghan et al., 2007; Cohen, 1988; Selya et al., 2012). However, SmartPLS 3 has the ability to calculate effect size (f²) directly.

$$\text{Effect Size (f}^2\text{)} = \frac{\text{R}^2 \text{ Included} - \text{R}^2 \text{ Excluded}}{1 - \text{R}^2 \text{ Included}}$$

Table 8. Effect Size (f²)

R-Squared	f-squared	Effect Size (f ²)
MS	0.044	Small
Maximization II	0.037	Small
Incorporation EK	0.022	Small
IP Management	0.031	Small

According to Cohen (1988), “the f-squared values 0.02, 0.15, and 0.35 is considered as weak, moderate and strong effects, respectively.” In this study, all values are small, as shown in Table 8.

4.6 Assessment of Predictive Relevance (Q²)

Using the blindfolding process, this study used the Stone-Geisser test for predictive relevance (Q²) of the model (Geisser, 1974). The cross-validated redundancy examines the capacity of a research model to predict the relevance of dependent variables as well as also clarifies the quality of the overall model.

Table 9. Predictive Relevance (Q²)

Total	SSO	SSE	Q ² = (1-SSE/SSO)
OI Performance (OIP)	1434	1214.052	0.153

The cross-validated redundancy value (Q²) should be greater than zero (Chin, 1998; Henseler et al., 2009). Table 9 shows that Q² is 0.153 which is greater than acceptable value. Hence, it clarifies the quality of the overall model.

5. RESEARCH FINDINGS AND DISCUSSION

The results of the current study found that MS enhances OI. The motivation of various factors particularly employees increases the OI performance in open-sources software projects. West and Gallagher (2006) found a strong association between MS and OI with a positive relationship in open-source software. Thus, the current study is in line with West and Gallagher (2006). Moreover, the results of the study found a positive association between EK incorporation and OI performance. It is found that the maximization of EK incorporation enhances the OI practices in open-source software projects. According to Teirlinck and Spithoven (2008), EK relations expedite internal research

and development which increases innovations. Additionally, West and Gallagher (2006) also found a positive linkage between EK incorporation and OI. Thus, findings of the current study are consistent with Teirlinck and Spithoven (2008), and West and Gallagher (2006).

Furthermore, it is also found that II and IP management increases OI performance in open-source software projects. Lichtenthaler (2010) found that IP management enables the firm to open-up their innovation activity. Opening-up the innovation strategy through patents/copyrights increases OI performance. Moreover, Chesbrough (2012) describes that II has a significant role to enhance OI. Hence, the current study is consistent with Lichtenthaler (2010) and Chesbrough (2012). Majorly, the current study examined the moderating role of FC. The results of the study demonstrate that the maximization of II requires intensive financing. That is the reason FCs limit the positive contribution of II maximization and OI performance. As it is shown in Table 6 moderating effect is significant with a p-value 0.001. However, $\beta = -0.226$, the negative sign indicates that FCs reducing the positive relationship between maximizing II and OI performance. It means that open-source software projects facing the issue of financing for internal R & D. As it is mentioned by prior studies (see, for instance, Van de Vrande et al., 2009; Saguy, 2011) OI has widespread application, companies face a tough time in implementation due to the FCs. Moreover, II requires seminars and various events, one of the platforms for employees to discuss different innovative ideas (Kengchon, 2012) which is one of the costly processes. Majorly, the maximization of II requires heavy investment in the R & D department which is not possible for small-scale software developers.

Nevertheless, the moderating effect is insignificant between MS and OI performance. It is also insignificant between EK incorporation and OI. Moreover, it is insignificant between IP management and OI performance. It reveals that FC has no effect on the positive contribution of MS, EK incorporation, and IP management towards OI performance. After the completion of this study, results were discussed with selected respondents and open-source software developers regarding the insignificant moderating effect in the above three cases. A question was raised to selected respondents, why the finance does not affect in the case of MS, EK incorporation, and IP management? Most of the respondents revealed that no doubt, incentive provision is an expansive process, however, these incentives are not given especially to boost up the OI. Moreover, incentives are only provided in that case when a stakeholder contributes to enhancing the returns which do not affect the overall cost. It means that incentives are only provided from additional returns. In the case of IP management, it was revealed that most of the open-source software developers do not patents/copyright their idea, they just try to become first in the market. As it is discussed in the literature, only 22% of firms prefer to utilize formal IP protection. However, approximately 34% of companies prefer to utilize an informal mechanism (Hall et al., 2014). Further, it is also described by various other studies, although patents are one of the primary focus of attention in innovation, these tend to be the least emphasized appropriability mechanisms, as most companies emphasizing more deeply secrecy development as well as lead-time advantages (Cohen et al., 2000; Leiponen and Byman, 2009) rather than formal IP management. Finally, the incorporation of EK requires a connection with suppliers, partners, and customers. Most of the open-source software developers build good relations with supplier, partners, and customers by facilitating better and timely services which do not require more cost.

6. CONCLUSION

The current study examined the role of MS, maximization II, incorporation of EK, and IP management on OI performance. Majorly, the moderating role of FC was also analyzed in the management of OI challenges. This study is conducted on open-source software projects. As open-source software projects are facing various issues regarding OI practices. Due to a different issue, the performance of open-source software projects is not up to the mark. Data were collected from managerial employees of open-source software projects. Only those employees are selected who have direct involvement in open-sources software projects. After the completion of this study, results were discussed with selected respondents and open-source software developers for more clarity. The study revealed that MS, maximization II, incorporation of EK, and IP management are the major challenges of OI in open-source software projects. These four elements have an extensive contribution to OI performance. Open-source software projects require special focus to these challenges to enhance OI performance. Moreover, sufficient finance is required to maximize II. OI requires the internal R & D department to expedite II, which is a costly process. However, to resolve the other challenges such as MS, incorporation of EK and IP management does not require extensive finance in open-source software projects. It is recommended for the open-source software developers to maximize II through the R & D department. As II is the most crucial part of OI. Researchers are invited to investigate the role of venture capital to mitigate the issue of FC. Hence, future research is required to investigate the solution of FC through venture capital among various open-source software houses.

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