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# EMPIRICAL ANALYSIS OF ANTECEDENTS OF PERCEIVED CUSTOMER SATISFACTION WITH LINUX

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## Abstract

*Open Source Software (“OSS”) has attracted significant research interest but research has focused on the development process (“supply side”) of OSS leaving the “demand-side” of OSS relatively unexplored. Further, extant OSS research is lacking in empirical studies. In this study we fill the gap with an empirical analysis of antecedents of perceived customer satisfaction with Linux, the most popular OSS product. We used Ordered Logit technique to analyze a dataset collected through a survey of business-technology professionals. Our results suggest that perceived customer satisfaction with Linux is positively influenced by duration of use and the quality of third party support. We also found a strong relationship between perceived satisfaction with Linux and prevalence of other OSS products in the organization. Further, we found that perceived customer satisfaction with Linux is lower for large firms and higher when the largest distribution of Linux is used. Interestingly, internal IT support capability was found to have no significant effect on perceived customer satisfaction with Linux. Our results contribute to research by verifying traditional customer satisfaction models in an OSS context and also by extending these models to include unique aspects of OSS. On practice side, this research provides directions to the OSS community for achieving higher customer satisfaction.*

**Keywords:** Open Source Software, Linux, Customer Satisfaction, Ordered Logit

## Introduction

Open Source Software (“OSS”) has become an important economic and cultural phenomenon. Sourceforge.net, a leading infrastructure provider and repository for OSS projects, lists more than 100,000 such projects and more than 1,000,000 registered users. Linux computer operating system is the most well-known OSS and almost representative of the entire OSS movement.

Open Source has emerged as a viable alternative to commercial software. Use of OSS products in firms has reached significant levels for many products and is rapidly growing. For example: revenue from Linux operating system is expected to grow to \$35 billion by 2008 (InformationWeek 2005) while Apache web server is estimated to run on 69% of all web servers in Mar 2006 compared to 21% for the nearest competitor Microsoft (Netcraft 2006).

OSS products are different from their commercial counterparts not only in the way they are developed but also in the way they are sold and supported. OSS products can be downloaded and used without any constraints. Third-party aggregators and support providers like RedHat fill the role of a traditional software vendor for distribution and support. As the OSS products and their unique distribution and support mechanisms gain volumes, debate on business value of OSS is gaining prominence (Forrester 2004, Metagroup 2002). However, many important aspects of OSS adoption and usage have not been rigorously studied as yet. In this research we contribute to the debate by providing insights relevant to both user firms and the OSS community by empirically analyzing antecedents of perceived customer satisfaction with the representative OSS product: the Linux operating system.

Information systems researchers have studied customer satisfaction with software systems for a long time and a credible body of research exists for the same. However, all previous research in the field pertains to commercial or

custom made software. In view of radically different nature of development, distribution and adoption of OSS, and the significant amount of investment being put in OSS (New York Times 2004), there is a need to rigorously investigate adoption and usage aspects of OSS and extend the extant IS literature into OSS domain.

Research on OSS, like the object of the research, is in its early stages of maturity. The open source phenomenon has stimulated the curiosity of scholars in a variety of fields, including economics, law, psychology, anthropology and computer science, resulting in a large number of research contributions on the subject. However, the focus has primarily been on the “supply side” of OSS: What motivates developers to contribute to OSS projects without monetary compensation (Ye and Kishida 2003); how do developers organize, communicate and keep control of the projects (von Hippel and von Krogh 2003) etc. Although the research on supply side of OSS has improved our understanding of the OSS development process and helped integrate it with conventional economic frameworks (Lerner and Tirole 2002), the relative lack of attention on the “demand side” of the OSS process is likely to skew our understanding of the OSS life cycle. Development of OSS products is motivated not for its own sake but is mandated because of user needs. The objective of the OSS process is not just to create software but to meet the needs of its target end users. Further, since OSS is driven by user-developers, the demand side is fundamentally linked to the supply side in a virtuous cycle as satisfied users join in as productive developers. Hence, there is a need to rigorously explore the demand side of the OSS life cycle and its linkages to the supply side. Our research fills this gap and contributes to our understanding of the demand side of OSS life cycle. Further, extant research on OSS, as befitting a novel and new stream of research, mainly consists of qualitative works and this research extends the current OSS research on the empirical dimension.

The rest of the paper is arranged as follows: the next section details the background theory and presents our hypotheses. Section 3 details the data used for the study and the methodology used to analyze the dataset. Section 4 presents the results and the paper concludes with a discussion of the results, limitations and future research directions in Section 5.

## Theory and hypotheses

The current research on demand side of OSS has focused mainly on competition between OSS and closed source software. Dalle and Jullien (2000) modeled the diffusion of the Linux operating system and showed that as long as individual adoption thresholds, dependent on idiosyncratic preferences for the dominant standard, is sufficiently low, a threshold effect may be set forth and OSS programs may overcome the existing proprietary standard. Using similar concepts of network effects and externalities, Bonaccorsi and Rossi (2003) modeled the rivalry between OSS and proprietary software and found that even under limiting conditions OSS and closed course software are likely to coexist. Recently Kumar and Krishnan (2005) looked beyond the competition with closed source and looked at impact of OSS adoption on IT expenditure levels in firms. However, they focused only on the monetary impact of OSS adoption.

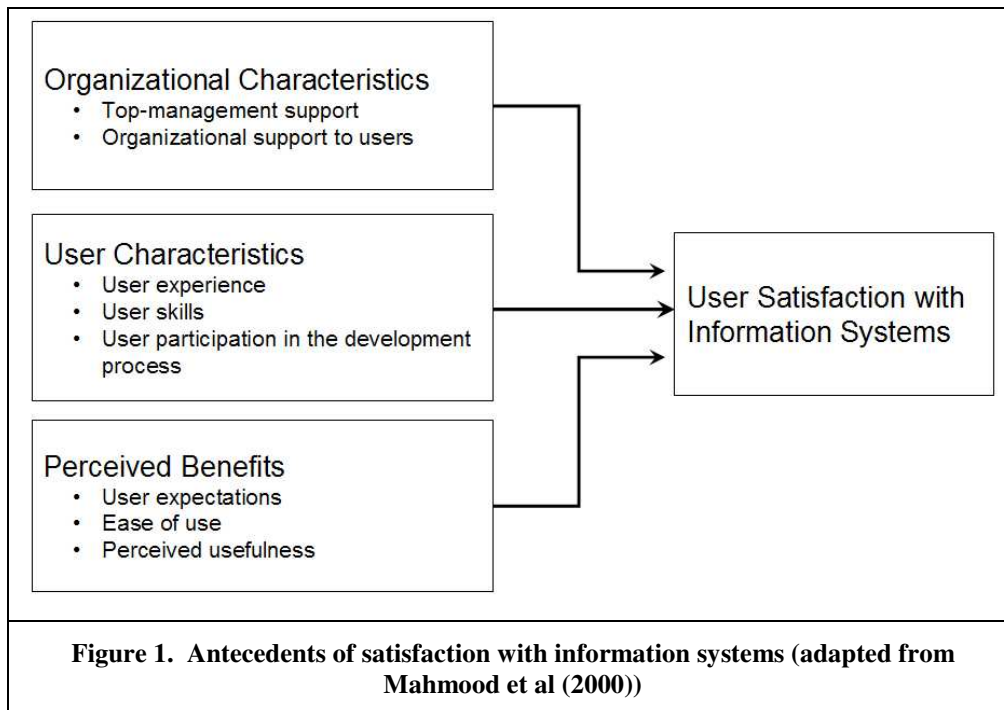
The extant literature on the demand side of OSS has not taken the user experience into account, which is important even for studying competition between OSS and commercial software. This competition would eventually be influenced by the end-user through their satisfaction. Further, study of the nominal spread of OSS (*quantity*) has to be combined with a measure of the *quality* of OSS expansion, such as customer satisfaction with OSS products. Our research extends the current literature to include the *quality* aspects of OSS diffusion in the form of perceived customer satisfaction with the most popular OSS products: Linux.

Seddon (1997) defined satisfaction in IS context as a subjective evaluation of the various outcomes of IS use evaluated on a pleasant-unpleasant continuum<sup>1</sup>. The “satisfaction” construct has been a part of many well accepted theoretical models including Technology Acceptance Model and the DeLone and McLean model of IS success. Previous research has found three broad determinants of satisfaction with information systems: user characteristics, organizational characteristics and perceived benefits (Mahmood et al 2000). User characteristics include user IS experience, user skills and user participation in the development process. Organizational characteristics include such

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<sup>1</sup> User satisfaction has been considered a good proxy for IS Success (DeLone and McLean1992) and hence have attracted significant research interest. Due to space limitations, we are only discussing strictly relevant aspects of previous literature on user satisfaction.

factors as top-management support and organizational support to users. Lastly, perceived benefits consist of user expectations, ease of use and perceived usefulness. This conventional model of antecedents of satisfaction with information systems is illustrated in Figure 1.



User IS experience enables the acquisition of IS skills (DeLone 1988) and the formation of habits related to using systems. Prior literature (Ives and Olson 1984, Barki and Hartwik1994) have shown that user participation affects all aspects of IS success including user satisfaction.

Top-management support refers to the senior executives' favorable attitude towards, and explicit support for the IS (Doll 1985). There is considerable evidence of the importance of top management support for effective IS in prior literature (Doll 1985, Jarvenpaa and Ives 1991). Top management support promotes system quality by facilitating the allocation of needed resources during the course of the project (Thong et al 1996).

IS facilitating conditions reflect the processes and resources that facilitate an individual's ability to utilize information systems (Thompson et al 1991). Better IS facilitating conditions imply circumstances that enhance the pleasure associated with using IS, and allay users anxiety regarding IS thereby improving satisfaction (Venkatesh et al 2003).

Finally, quality of development and support team indicates the technical expertise and communication skills of the development and support team (Wixom and Watson 2001). A competent development and support team would interact better with users thereby promoting favorable attitudes towards the system and eliciting greater user participation resulting in higher satisfaction.

Customer satisfaction with Linux would depend not only on general principles of satisfaction with information systems as mentioned above but also on unique characteristics of OSS. Further, since OSS involves a very different form of development, distribution and support, effect of many factors may be different in magnitude as well as in direction in case of Linux.

Increased user experience has been shown to positively affect satisfaction with information systems (DeLone 1988). Learning to effectively use OSS products involves significant learning and higher duration of use will contribute to acquiring necessary skills and forming usage habits necessary for efficient use of the system. Higher duration of use will allow users to have higher participation and hence derive higher satisfaction. Thus, we can posit the following hypothesis:

**Hypothesis 1:** *Perceived customer satisfaction with Linux is positively associated with duration of use.*

A higher level of OSS prevalence can affect customer satisfaction with Linux in two ways. First, as software is considered a classic example of a network effect good, existence of a bigger OSS user community will lead to higher value (through better cooperation, learning and compatibility) for Linux users resulting in higher customer satisfaction. Bonaccorsi and Rossi (2003) argued for the existence of a positive network externality effect proportional to the number of adopters of OSS. Further, higher OSS prevalence in the firm indicates higher levels of top management support for OSS in the firm. Higher management support has been shown to be critical in successful IS implementation (Doll 1985, Jarvenpaa and Ives 1991), and hence perceptions of higher management support is likely to lead to successful OSS implementations and as a result, higher customer satisfaction. Thus, we can argue that higher levels of OSS prevalence will be associated with higher user satisfaction, leading to the following hypothesis:

**Hypothesis 2:** *Perceived customer satisfaction with Linux is positively associated with higher prevalence of OSS in the firm.*

Satisfaction of end users from information systems has been shown to depend on the level of support available to them (Bergeron and Berube 1988, Thompson et al 1991). When users are well supported then they are likely to encounter fewer problems and hence experience increased satisfaction. Thus, we can argue that customer satisfaction with Linux will be higher when support provided to users is better. However, in case of Linux, users are supported both by the internal IT support function of the firm as well as by the specialized third party OSS support providers. Hence we can posit the following hypotheses regarding impact of level of support on customer satisfaction with OSS:

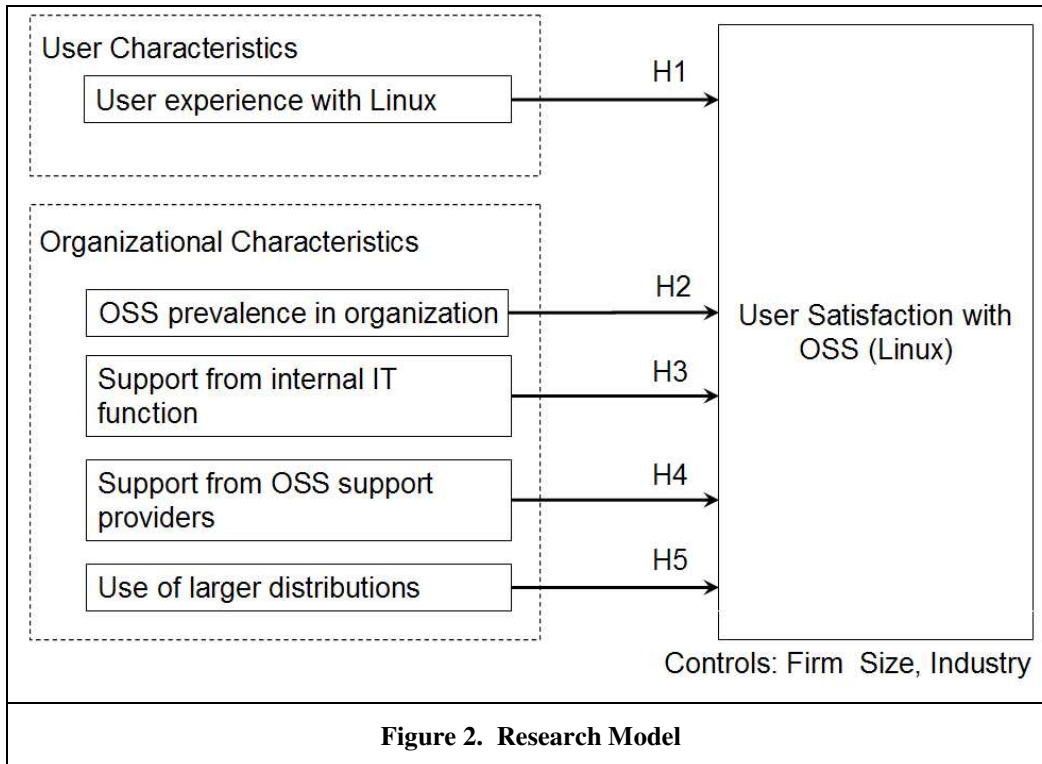
**Hypothesis 3:** *Perceived customer satisfaction with Linux is positively associated with higher level of support received from internal IT support function of the firm.*

**Hypothesis 4:** *Perceived customer satisfaction with Linux is positively associated with higher level of support received from third party OSS support providers.*

One of the unique features of OSS projects is “forking” in which separate groups of developers maintain different versions of the same software. For example: OpenBSD, NetBSD and DragonflyBSD are forked versions of the same underlying BSD system. Further, even in absence of forking, many different “flavors” or “distributions” of the same OSS product may co-exist in the market. For example: there are more than 200 different distributions available for Linux operating system. All the distributions do not provide the same level of support to the users and hence selection of the appropriate distribution can have an impact on the customer satisfaction with the OSS product. The larger distributions can be expected to be able to deploy large resources needed to provide requisite support to users. Further, the large OSS community associated with larger distributions would enable sustainable future development of the distribution, leading to higher customer satisfaction. Hence, we can posit the following:

**Hypothesis 5:** *Perceived customer satisfaction with Linux is positively associated with use of the larger distributions of OSS.*

With increase in firm size, the coordination and communications requirements for providing effective support to users increases. Further, for organizations that switch to OSS (e.g. from Windows to Linux in our case) from closed source software products, the complexity of the change process increases with firm size. Considering the significant impact of firm size on IT spending, we are controlling for firm size in the study. Similarly, industry is controlled for at a broad sector level (services or manufacturing). The research model including the hypotheses detailed above and the control variables is shown in Figure 2. As our research focus is on customer satisfaction with Linux, and not comparing it with other software, we have not included software specific factors (like ease of use) in our research model. Our research model includes many elements of the conventional model of customer satisfaction (Figure 1) but also incorporates elements unique to OSS domain.



## Data and methodology

The data for the study was collected through a survey of IT professionals by the reputed IT industry magazine InformationWeek. The survey was targeted at business-technology professionals with the objective of exploring how companies use open-source applications and Linux. The survey was conducted during April-May 2004 and a preliminary, practice-oriented analysis of the survey data was published in August (InformationWeekv2004). The survey was answered by 392 business-technology professionals. Of these responses, 125 responses were rejected due to missing values and the study consisted of the remaining 267 observations.

The constructs corresponding to the hypotheses presented above were operationalized using data gathered through the survey, as explained below:

**Perceived customer satisfaction with Linux (LINSAT):** Perceived customer satisfaction with Linux is the dependent measure in the study. Respondents were asked to rate their organization's satisfaction with Linux on a scale of 1-10 with 1 meaning not at all satisfied and 10 meaning extremely satisfied.

**Duration of Linux use (LINDUR):** Respondents were asked to indicate the duration of Linux use in their organization on a four point scale. In this scale 1 means less than 6 months, 2 means more than 6 months but less than 1 year, 3 means more than 1 year but less than 2 years and 4 means more than 2 years. Although this coding scheme is not on an interval scale, results were found to be robust against changes in coding scheme (for example: to a dummy variable with value 1 for more than 1 year duration and value 0 for less than 1 year duration).

**Firm's Internal IT support capability (ITCAPB):** The respondents were asked to rate Linux development and support expertise available inside the firm. The responses were then coded on a scale of 1 to 4 with 1 denoting low levels of internal capability to support Linux and 4 representing high levels of internal capability to support Linux.

**Level of support provided by third party support provider (SUPSAT):** The quality of support provided by third party Linux support vendors was measured by asking respondents to rate their organization's satisfaction with available fee-based support for Linux on a scale of 1-10 where 10 meant extremely satisfied and 1 meant not at all satisfied.

**Prevalence of OSS in the firm (PREVOSS):** Prevalence of OSS in the firm was measured by asking the respondents to assess their firm's software architecture on the dimension of openness. Respondents could indicate whether their firm's software architecture is predominantly closed source, predominantly OSS or a mix of the two. The responses were then coded on a scale of 1 to 4 with 1 meaning low levels of OSS prevalence and 4 meaning high levels of OSS prevalence in the firm.

**Use of the largest distribution of Linux (REDHAT):** RedHat is the most popular Linux distribution and is estimated to have more than 60% market share in some categories of the Linux market (ITFacts 2004). Consequently, use of the largest distribution of Linux was measured using a binary scale where 0 indicates that the firm does not use RedHat Linux while 1 indicates that the firm does use RedHat Linux.

**Firm size (REVENUE):** Respondents were asked to classify their organization into one of the six different revenue ranges specified and based on the classification, firm size was coded on a scale of 1 to 6, in increasing order of firm revenue.

**Industry (INDUSTRY):** Industry choices by the respondents were coded as either Manufacturing or Services. A dummy variable was introduced to capture the information.

The Logit family of analysis models is a natural choice for analysis of our dataset since the dependent variable is discrete. Ordered Logit model further assumes that there is a natural order in the possible values of the dependent variable (Dobson 2002), which is clearly applicable in our case as our dependent variable is a rating of customer satisfaction with Linux on a scale of 1 to 10. Ordered Logit analysis have been widely accepted and used as an appropriate analysis technique when the dependent variable is discrete but possesses a natural order (Cummings 2004), as is the case in our study. Consequently, we have used the Ordered Logit Model to analyze our dataset in this study.

## Results and analysis

The Ordered Logit model was estimated using Maximum Likelihood Estimation technique. The results of the Ordered Logit model are shown in Figure: 3 below. The results include significance probabilities for both the asymptotic Wald test and also the Likelihood-Ratio tests, both of which are used for significance testing of Ordered Logit models (Hamilton 2004). We get the same coefficient values and significance levels for both test so in our case there is no conflict between the two tests.

	Coefficient	Wald Test	Maximum Likelihood Ratio Test	Significance
LINDUR	0.312	0.022	0.022	* *
PREVOSS	0.426	0.002	0.002	* * *
ITCAPB	0.009	0.950	0.950	Not Sig.
SUPSAT	0.349	0.000	0.000	* * *
REDHAT	0.655	0.050	0.050	* *
REVENUE	-0.257	0.000	0.000	* * *
INDUSTRY	-0.222	0.402	0.401	Not Sig.

Prob > F = 0.00, Pseudo R-Square = 0.09

\* Significant at 10%, \* \* Significant at 5%, \* \* \* Significant at 1%

**Figure 3. Result of the Ordered Logit analysis**

The coefficients in the result of the Ordered Logit analysis shown in Figure 3 above can be interpreted in a manner similar to standard Logit models of binary choice. The exponentiated coefficients in Logit can be interpreted as the odds ratios for a unit change in the corresponding variable. The Ordered Logit model is a proportional odds model where the odds ratio is assumed to be same for all the categories of the dependent variable. Thus, the exponentiated coefficients in Ordered Logit represent the odds ratio of being in a higher category for a unit change in the corresponding variable. On a basic level, we can consider positive coefficients to mean that higher values of the corresponding variable would increase the probability of the dependent variable being in a higher category while a negative coefficient would mean that higher values of the corresponding variable would decrease the probability of the dependent variable being in a higher category.

The results support the hypotheses that customer satisfaction with Linux increases with higher duration of use. This indicates that like closed source systems, longer experience and increased participation allow the users to climb the learning curve and derive higher satisfaction. Significant positive impact of greater OSS prevalence on customer satisfaction with Linux supports the existence of positive network externality for OSS products. Higher OSS prevalence assists the users in gaining experience and improves their participation, thereby improving satisfaction. It also signals higher top management support for OSS products which again has a positive effect on customer satisfaction.

Higher level of support from OSS support providers was found to have a significant positive impact on customer satisfaction while firm's internal capability to support OSS was found to have no significant impact on customer satisfaction with Linux. This result is remarkable as it indicates toward maturity of OSS distribution and support channels. The results indicate that OSS support providers have been successful in effectively replacing in-house support functions in firms.

User of the largest distribution of OSS (RedHat in case of Linux) was found to have a significant and positive impact on customer satisfaction with Linux. This is in line with expectations that the larger distributions have the resources to sufficiently fulfill support requirements and also have large community support for sustaining future development.

Further, we can see from the results that customer satisfaction with Linux is lower for larger organizations. This underscores the complexity of large scale system implementation and shows that smaller organizations may be better positioned to efficiently handle the transfer from closed source to an OSS environment. Industry control was statistically insignificant pointing towards no significant difference in Linux customer satisfaction between manufacturing and services sector.

## **Discussion and conclusion**

Although we have focused on customer satisfaction with Linux, since Linux is the most popular OSS product and is often considered representative of entire OSS category. Raymond (1999) argued that Linux is a demonstration case for OSS as “*Linux started with the best name recognition, the broadest software base, and the largest developer community*”. Hence, this research and its insights can be considered applicable to a broad range of OSS products.

The results have highlighted the conventional aspects of OSS, areas in which OSS is similar to commercial software and also uncovered unique aspects of OSS. Positive effect of duration of use and support quality is in line with similar relationships for commercial software as discovered in previous research (Figure 1). It is heartening to see that as in OSS development (Lerner and Tirole 2002); accepted wisdom explains a major part of the puzzle in the case of OSS use also. However, the study also uncovers unique aspects of OSS like the impact of OSS prevalence, firm size and internal support capability.

The study has important implications for OSS community and OSS user organizations as customer satisfaction is important to both. OSS community would want to ensure highest levels of customer satisfaction with OSS so as to ensure continued success of OSS products in the marketplace. The OSS user organizations would want to optimize their investment in OSS and get maximum performance or satisfaction with their OSS investments.

The results point towards a “learning-curve” effect in realizing value from OSS investments. We show that duration of use has significant positive impact on satisfaction with OSS and hence firms need to be patient about their OSS



investments. However, as we do not compare satisfaction from an OSS product and a comparable commercial product, we cannot say whether the learning curve for OSS products is significantly different than that for commercial products. We show that satisfaction is positively affected by adoption of popular and stable distributions of OSS, which indicates that it is advantageous to be a smart follower and adopt stable and popular distributions of OSS products. This way firms can ensure that they will not be tied down to unsustainable distributions. The results point towards maturity of OSS distribution system as well. The fact that firm's internal support capability does not significantly affect customer satisfaction with OSS while performance of OSS support providers have a significantly positive impact, indicate that OSS distribution channels have reach the stage where firm's can outsource support to OSS support providers without any adverse effect on customer satisfaction.

The study also points towards optimum size and method of OSS adoption. Results show that smaller organizations are better suited to successfully employ OSS than larger firms. Further, as satisfaction with OSS is higher with higher prevalence of OSS in the organization, the risk for organization decreases as OSS adoption level in the organization increases as the positive network externality of OSS products make every additional piece of OSS adoption more valuable.

The study provides direction to the OSS community regarding what kind of OSS product can provide higher levels of customer satisfaction and hence have a better chance of succeeding in a competitive market. The study points towards factors that the community needs to take into consideration for ensuring continued success of OSS movement. The results provide evidence against forking of projects and having too many competing distributions of identical OSS products, as customer satisfaction is higher for the largest distributions. Hence, success in a competitive market will be better ensured by having few large distributions which can provide the needed support and help increase user satisfaction with the product. The significant positive impact of performance of independent OSS support providers highlights the success of OSS distribution mechanism. The study provides evidence that support structures are shifting to independent support providers rather than internal IT support functions. The OSS community can highlight this maturity of the distribution and support structure to get better traction in the market. Since satisfaction with OSS reduces with firm size, OSS community would find it beneficial to concentrate its efforts on small and medium enterprises rather than large organizations.

The study focuses on customer satisfaction with OSS in firms and does not attempt to compare it with the same from commercial software. Hence, although the study points toward factors which can help OSS products succeed in firms, it does not say whether OSS would be better suited than commercial software for a given set of conditions. Our lack of adequate understanding of relative suitability of OSS vs. commercial software for a particular requirement situation remains one of the major gaps in OSS research.

Empirical research is constrained by the availability of relevant data and this study is no exception. The study would have benefited from more granular data on industry and Linux version. Since the InformationWeek survey was confidential and reported without individual or organizational identification information, we could not extend the available data to include other relevant variables. The survey was conducted with a practitioner audience in mind and we did not have significant control over the survey administration. This has resulted in methodological weaknesses like single measures for constructs and discrete measurement of variables. Further, since the research is based on a single survey, it suffers from possible single response bias. In spite of these weaknesses, we believe that this research is an important first step towards empirical understanding of the demand side of the OSS phenomenon.

Open Source movement has attracted significant research interest recently. However, focus of OSS research has been on the development process ("supply side"), while the use of OSS ("demand side") has not been studied thoroughly. This is an important lacuna in current research as the whole reason of existence of OSS is to meet the needs of current and potential users. Understanding of how OSS is used by individual and organizations and what drives satisfaction from OSS use important for understanding the continued success of the OSS movement. How successful OSS is in meeting the needs of its users will decide whether OSS will continue to grow and continue to challenge the commercial software or whether it will decay and die. Through this research we have put the focus on the use of OSS and the user experience with OSS. Our results show there are both similarities with commercial software and also unique aspects of customer satisfaction with OSS products.

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