A Brief Review of Studies on Open Source Software in Developing Countries in Peer-Reviewed Journals

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There has been much attention given to the promising benefits of open source software (OSS) for the development of the domestic software industries of developing countries. This study attempts to build a base for scholarly research on the subject of OSS in developing countries by reviewing the work that has been published in peer-reviewed academic journals. Major sub-streams of research include applications of OSS in developing countries, and the analysis and recommendations of government policies. This review also details the geographical regions covered by the scholarly research, extensions of the open source model to applications of open content, and theoretical approaches that have been adopted in the scholarly literature.

Keywords: Open source software, developing countries, Linux, digital libraries, geographical information systems, GIS, open content

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There has been much attention given to the promising benefits of open source software (OSS) for the development of the domestic software industries of developing countries. This study attempts to build a base for scholarly research on the subject of OSS in developing countries by reviewing the work that has been published in peer-reviewed academic journals. Major sub-streams of research include applications of OSS in developing countries, and the analysis and recommendations of government policies. This review also details the geographical regions covered by the scholarly research, extensions of the open source model to applications of open content, and theoretical approaches that have been adopted in the scholarly literature.

1. Introduction

The emergence of open source software (OSS) has radically changed the technological landscape of the computing industry, affecting the strategic dynamics involved in various commercial enterprises, including proprietary software developers, hardware manufacturers, and makers of network products alike. OSS can be defined as "software that is made freely available to all" [1], and that is developed and maintained by numerous contributors who are scattered around the world, but who interact through a virtual community on the Internet. The majority of these public-good producers contribute freely to the provision of the project in return for only intangible rewards. However, it is important to note that "freedom" has a particular meaning in open source contexts: "Free [open source] software is a matter of the users' freedom to run, copy, distribute, study, change and improve the software" [2]. This is quite distinct from *freeware*, which is software provided at no price. In contrast, open source software licenses often permit sale of the products at any price, with the caveat that the buyer be informed of their right to full access to the source code at no charge.

It has normally been believed that high management control is necessary to ensure the quality of a software or information product project [3]. However, through flagship products such as the Linux operating system, the Apache Web server, and the Firefox Web browser, the open source model has demonstrated convincingly that the apparently anarchistic process of open source development can yield products of high quality [4]. This is partially explained by the famous quote attributed to Linus Torvalds (of Linux fame), "Given enough eyeballs, all bugs are shallow". That is, with thousands of contributors, any buggy or inefficient code is fixed, and only the best quality code is left, and is continuously improved upon.

Although OSS has arisen in developed nations, as have virtually all information technologies, there has been much attention given to its promising benefits for the development of the domestic software industries of developing countries. A number of reports have been commissioned by governmental and non-governmental agencies on the general subject of information and communication technology (ICT) for development; many of these mention the role of open source software. By far the most comprehensive of these has been Weerawarana and Weeratunga's [5] report for the Swedish International Development Cooperation Agency (Sida). Another important report was conducted by Bannerman [6] for the International Development Research Centre, which broadly presented how intellectual property issues relate to the use of OSS for development in developing countries. Key advantages of OSS that she highlighted are that it facilitates the localization of software; builds domestic knowledge and skills; assures governments of security concerns with foreign software, and independence from foreign control; and can lead to considerable cost savings. However, she detailed various issues and problems, including lack of user-friendliness in most OSS; the insufficient incentives for innovation; and the hazards of international software patents. Specifically focusing on Brazil, Stefunato and Salles-Filho's [7] thorough survey and review on the OSS industry in

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Brazil is an invaluable source that reported on the state, as of 2005, of OSS usage and local development.

Most of these reports and recommendations have been mostly descriptive, and lack thoroughly researched theoretical bases. However, more recently, the use and development of OSS in developing countries has begun to attract the attention of scholars who have attempted to more rigorously study this phenomenon from many different angles. This study attempts to build a base for scholarly research on the subject of OSS in developing countries by reviewing most of the important scholarly work that has been done thus far. Because the focus here is on high-quality scholarly work, the studies reviewed here are mainly limited to those that have been published in peer-reviewed journals. Thus, work that has been published in conference proceedings is not included, nor has other work that has not passed through scholarly peer review, with a few notable exceptions.

This review begins with studies on applications of OSS in developing countries, involving Linux, digital libraries and education, and geographical information systems. Next, it covers the bulk of work in this area, involving the analysis and recommendations of government policies concerning OSS in developing countries and regions. It follows by listing the geographical regions that have been covered in the current scholarly journal literature. Next, it discusses extensions of the open source model in developing country to applications of open content. Finally, before the conclusion, it highlights the few theoretical approaches that have been adopted in the scholarly study of OSS in developing countries.

2. Applications of OSS in developing countries

With the existing studies in peer-reviewed journals, the application of OSS in developing countries has been applied to Linux (the most popular open source operating system), digital libraries and education, and geographical information systems (GISs).

2.1. Linux

By far the most common application cited in the literature is the use of Linux. In fact, most papers that studied Linux examined it in its competition for market share with Microsoft Windows, the world's leading desktop operating system. Chae and McHaney [8] mentioned the announcement of collaboration among the governments of China, Japan and South Korea to build a common Linux distribution to face the international Windows competition. Kshetri [9] studied

the micro- and macroeconomic considerations of Linux adoption in developing countries. Shen [10,11] analyzed the government's role in the competition between Linux and Windows in China. Szulik [12] discussed the role of Linux as an enabling platform for realization of the vision of the One Laptop Per Child project.

2.2. Digital libraries and education

A second common application area is in the domains of digital libraries and education. Three peer-reviewed journal articles on open source software in India involved the implementation of digital repositories and libraries in the ICFAI Business School, Ahmedabad by Gayatri Doctor. She documented the implementation of the Greenstone [13] and DSpace [14,15] open source digital repositories for documenting the progress of student internships, and storing digital archives of scholarly and teaching material, respectively. She found that the process was complex, but it enabled the recording and development of intellectual capital within the business school.

Witten [16] described the great potential of digital libraries to provide critical access to humanitarian information in the areas of healthcare, agriculture, and education, without the interference of commercial enterprises with their private interests. He particularly advocated open source digital library software because of its potential for accessible customization and extension. However, he highlighted the practical limitations of much OSS, at least in the digital library domain, due to the difficulty in training people to use and develop it.

Matthew Szulik, the CEO of Red Hat, the leading provider of commercial Linux, presented the great potential of the One Laptop Per Child project in advancing education to children in the developing world [12]. One Laptop Per Child is a humanitarian project to provide each child in participating developing countries with a specially designed laptop tailored for children in the developing world (for instance, the rugged laptop is powered by crankshaft). These laptops run a customized version of Fedora, the open source version of Red Hat Linux. Szulik laid out the goals of the project, being mainly to provide these children with a tool for self-directed, collaborative learning that would include them in today's information society.

2.3. Geographical information systems

Ramli et al [17] described the implementation of the open source Geographic Resources Analysis Support

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System (GRASS) GIS in studying landslide hazards in Malaysia. Although their study emphasized the open source nature of the product, there was little in their analysis that highlighted features of the software particular to the open source model, other than the fact that a cost-free product was affordable in a developing country context, despite the complexity involved in using it.

Câmara and Fonseca [18] briefly presented the case of TerraLib, an open source GIS developed by academic research centres in Brazil with government funding. This is notable as the only case we found (in peer-reviewed journals) of OSS actually developed within a developing country. Câmara and Fonseca described how the project managers strategically attempted to shift the product placement of TerraLib from an academic project to an open source product attractive to commercial vendors who could help support continued development of the project.

3. Government policies on OSS in developing countries

So far, the most abundant body of scholarly work conducted on OSS in developing countries has been the analysis, recommendation, and criticism of government policies that support or direct OSS development in their countries. These studies focused geographically on OSS in Asia, particularly China, and in Brazil. Cross-national studies analyzed economic and piracy issues.

3.1. Asia

Chae and McHaney [8] reported the 2003 agreement among the governments of China, Japan and South Korea to collaborate on various technologies, including in building a common Linux distribution among the three countries. Eventually, three computer enterprises from each of these countries (later joined by one from Vietnam) collaborated to produce the Asianux Linux distribution. While not a major Linux distribution today (although it is still actively used and marketed by its enterprise sponsors), it represents an attempt by the participant governments to found their natural infrastructure on locally-developed OSS, rather than on the foreign Microsoft's Windows platform.

Kshetri and Schiopu [19] similarly examined the development of the OSS industry in these three countries, in light of their governments' strong support for the development of domestically-grown software. They discussed how the governments' roles in these countries have significantly shaped the natures of their entire software industries.

Cook and Horobin [20] discussed the value of Southeast Asian countries implementing e-government by means of OSS. Whereas they could employ proprietary software to meet e-government goals, they argued that OSS usage by the government is particularly valuable in that it reduces dependence on software industries from developed countries, and at the same time builds intellectual property within the implementing country.

Goth [21] reported on China's recent national regulations that have been put in place to favour the development of the local software industry. These measures include tax incentives for domestic software developers, mandates for government agencies to acquire software from local developers, and support of OSS. Goth reported on criticisms and cautions of these measures, mainly from China's trading partners.

Studying the case of competition between Linux and Microsoft in China, Shen [10,11] discussed the conflicting perspectives of the government's role in supporting the development of the local software industry. Shen advocated strong enforcement of intellectual property rights in order to combat piracy, which ironically put Microsoft at an advantage vis-à-vis local software developers, since piracy floods the market with high-quality Microsoft products to the development of local products. She also advocated government support of the local software industry by adopting OSS in government controlled- or influenced-projects.

3.2. Brazil

In a massive treatment of over 300 pages, Kogan [22] argued that the Brazil's recent promotion of what they call an "open source" or "universal access" intellectual property regime is ill-founded. He strongly argued the need for intellectual property rights to maintain and nurture an economy based on innovation, contrary to what he called the socialist views of those campaigning to nullify or greatly reduce intellectual property rights in Brazil or other countries. He argued that such moves would greatly hamper the development of Brazil's local and international competitiveness. In fact, the open source philosophy is firmly based on a regime of strong intellectual property rights—the legal basis for all open source licenses is standard copyright, without which such licenses would have no legal force; this is particularly the case with licenses such as the GNU General Public License that have a "copyleft" provision that requires those who modify open source code to share their modifications with others. Without strong copyright laws, any company could take incorporate open source code into

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Using a GIS developed in Brazil as a case, Câmara and Fonseca [18] applied the taxonomy they developed to recommend that how government-sponsored open source projects should be strategically shifted to being supported by larger OSS communities. They particularly recommend that governments work toward sponsorship by commercial and scientific interests that might find the project beneficial, after adopting their recommended focuses for projects.

3.3. Cross-national studies: Economics

Kshetri [9] examined the economic factors at the microeconomic and macroeconomic levels that affect the adoption of Linux rather than Microsoft Windows in developing countries, particularly drawing examples from the Indian software climate. While generally advocating the benefits of this open source technology, Kshetri advices against mandatory government policies on adopting either open source or proprietary technologies, arguing that such policies might not work in the best national interest for the long run.

Haaland [23] presented three arguments for the promotion of OSS in developing countries. First, OSS has the potential of developing the skills of the domestic software industry, in contrast to the unidirectional technology transfer of proprietary software from developed nations. Second, even taking total cost of ownership into consideration, OSS is far cheaper, in light of low labour costs in developing countries. Third, because of ready access to the source code, OSS is much easier to tailor to local needs than is proprietary software developed in and for other cultures.

Countering arguments by some that developing countries ought to be lax in their enforcement of intellectual property rights in order to permit their citizens benefit from intellectual property from developed nations, Saint-Paul [24] argued that such behaviour would cause these countries more harm than good. Not only would such a policy lower innovation domestically and internationally, but the nations whose intellectual property is being disregarded would be bound to retaliate with unfavourable trade treaties that would damage the negligent country.

3.4. Cross-national studies: Piracy

Saint-Paul's [24] study was in fact one which studied software piracy, albeit in the context of economics. In another study whose primary focus was software piracy, Eschenfelder et al [25] compared the extent of Internet posting on websites from various countries of the DeCSS software for descrambling DVD digital rights management codes, which was illegal in many countries. They compared postings on European Union countries and China (including Hong Kong and Macau). While DeCSS is not OSS (in fact, its illegal status means that it is not subject to any legal license), among other factors, Eschenfelder et al considered whether DeCSS posting coincided with rhetoric taken from the free software movement; indeed they found a high correlation between DeCSS posting and free software rhetoric.

4. Geographic regions covered

Several articles reviewed here studied OSS issues in developing countries in general. However, many focused on the issues within particular countries. While it is true that developing countries share many common issues, especially when compared to more developed nations, it cannot be expected that the software industries of most developing countries would be very similar to those of the population giants of China, India, and Brazil, the countries that have received the most research focus. Thus, this section lists the studies reviewed that focus on particular countries by geographical region.

Asia has received the greatest attention in OSS studies involving issues common to developing countries, mainly because of the tremendous population of the countries involved. Cook and Horobin [20] studied Southeast Asia in general. Chae and McHaney [8], Goth [21], Eschenfelder et al [25], Kshetri and Schiopu [19], Shen [10] and Shen [11] studied China. Doctor [13], Doctor [14], Doctor and Ramachandran [15], and Kshetri [9] studied India. Ramli et al [17] studied Malaysia.

Only two peer-reviewed journal articles have thus far been published concerning OSS in Latin America, both focusing on Brazil, though there have been several very thorough reports on this country's thriving OSS industry, and on its government's strong support for OSS: Câmara and Fonseca [18] and Kogan [22].

Although South Africa has quite a healthy open source software industry, there has not of yet been scholarly research in peer-reviewed journals that studies OSS in any part of Africa. Nor have there been peer-reviewed scholarly journal articles on any other

region of developing countries, such as the Middle East or Eastern Europe.

5. Open content

The same open source philosophy that has been traditionally applied to software development can be applied to the collaborative creation of non-software information products, such as encyclopedias, books, and dictionaries. Most notably, the seven-year-old Wikipedia is a comprehensive general encyclopedia, comprising over nine million articles in over 200 languages, built using the "open source" model. This extension of the open source model to apply to non-software information products is generally called "open content." The United Nations Conference on Trade and Development (UNCTAD) [26], in their annual report on science and technology for development, described the value of OSS in building the native capacity for innovation within countries that foster this model of software development. However, they mainly focused on the open content extrapolation of the open source model to various applications of open innovation, where various enterprises in an industry collaborate with each other and with consumers to collectively develop business and engineering solutions to common problems and challenges. Thus, there is significant potential for the development of non-software open content to be beneficial for developing countries. This section reviews the nascent scholarly work in this area.

Marsden [27] reported on hacking of bicycles that he observed in Zambia and Malawi, modifying their factory-built functionality. Although he referred to this as "open source bicycles," it is better considered as an application of the open content phenomenon to the development of bicycles. However, it is unclear from his report what the legal status of such hacking might be. Informal, unauthorized hacking of purchased equipment is universally common (often called "modding"), such as in modifying video games and video game consoles to run new games or other software that was not originally intended [28].

Doctor's [13-15] studies on open source platforms for building digital repositories and digital libraries in India merged open source software with open content, since the software platform naturally used the same development philosophy as the information product that was developed upon it. While there is no technical necessity for the platform for open content development to be open source, it is natural that those who are accustomed to working within the flexible parameters of open content would want a software platform for development that is equally flexible. This

is the case with Wikipedia, the free (that is, open content) encyclopedia (http://www.wikipedia.org), where an open source wiki software platform (MediaWiki) was custom-built to serve the needs of Wikipedia.

Wikipedia is noteworthy as the world's largest non-software open content project. Similar issues that face the use and development of OSS in developing countries face the use and development of Wikipedia by citizens of developing countries, particularly in the non-European language versions of Wikipedia. However, there has not yet been any scholarly journal article that has treated Wikipedia in developing countries. Devouard [29] presented the Wikimedia Foundation's (http://www.wikimedia.org) goal of helping to build "a world in which every single person is given free access to the sum of all human knowledge." The Foundation's primary thrust in this area is in sponsoring and fostering the development of Wikipedia. However, she pointed out that due to low access of the Internet, low literacy, and low capability in European languages, a majority of world citizens, particularly in Africa, are practically excluded from this access. She laid out the Foundation's plans for achieving access to this open content participation for Africans by various means "such as DVDs (free or for a small fee), USB key, OLPC (One Laptop per child) computers, books, etc." [30]. Other initiatives supported by interested third-parties include the production and distribution of offline versions of Wikipedia on CDs, particularly in non-English African languages [31]. The Wikimedia Foundation is presently engaged in an active campaign to raise international awareness of the benefits of promoting participation and access of its open content projects to citizens of developing countries [32]. Hopefully, as Wikipedia becomes more diffused in developing countries, it will attract scholarly attention to understand how open content in general can benefit developing countries.

6. Theoretical approaches to studying OSS in developing countries

Perhaps due to the recency of this research sub-stream, there is a paucity of formal theoretical methods in the study of OSS in developing countries, even in the body of peer-reviewed journal articles in this study. Most of the studies were descriptive of current practices or policies, or prescriptive in suggesting recommended policies and practices; few, however, were directed by strong theory. There are, nonetheless, two cases of articles that did attempt to build their studies based on existing or emergent theory.

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Câmara and Fonseca [18] proposed a taxonomy for classifying open source projects to determine their potential suitability for support by policy makers that might want to host or sponsor the project for the purpose of developing domestic software capabilities. Their taxonomy is based on two dimensions. The shared conceptualization refers to how readily the concept of the software can be communicated to other potential software contributors, facilitating their interest and meaningful contribution. The modularity of a project refers to the ease of dividing the project into distinct modules that can be worked on separately, based on the interest, resources and capabilities of different software contributors, thus facilitating the distributed, non-centralized development of the project. Câmara and Fonseca argued that while it is very difficult to develop a project with both high conceptualization and high modularity (despite the famed exceptions like Linux and Perl), governments that sponsor valuable projects that are low on both dimensions should strategically work towards shifting the nature of the project to one of either high modularity or high shared conceptualization, if the project is to meaningfully survive and thrive as an open source project.

In their study on Internet postings of frequently illegal DeCSS software for descrambling DVD codes, Eschenfelder et al [25] drew from institutional theory and collective action theory to explain the national variations in frequency of postings. Their attempts to apply institutional theory, which explains individuals' or groups' actions by the societal institutions in which they are located, failed to give them compelling explanations for the distribution of DeCSS postings. Their analysis based on collective action theory was complex and led to many speculations to explain their findings. However, their interpretation is severely limited by the fact that they did not apply the theories in order to generate hypotheses for specific testing; rather, they brought in the theories to try (uncompellingly) to explain their findings.

There is a strong need to study OSS in developing countries from a solid theoretical perspective. While there is an emerging body of theory for the study of OSS [33], based on its background in software engineering and the economics of IT adoption, the broad and multidisciplinary field of ICT for development still struggles to find a comprehensive, uniting theory [34].

7. Conclusion

This paper has presented some important works in the rapidly growing body of research that has focused on OSS in developing countries. While there has been high quality work in this area, there needs to be a broader range of topics and directions. In particular, there needs to be studies focusing on open source applications for consumers and businesses, beyond Linux. The promising new applications in open content also deserve research attention. Geographically, there needs to be scholarly work in Africa, in Latin America outside of Brazil, and in the Middle East. Most lacking, however, are studies based on grounded theory that can present reliable and generalizable new knowledge to the questions that developing countries face in adopting and developing OSS.

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