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Adaption of Linux SSL servers across cultures

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Abstract

Linux has received significant attention worldwide, but differences in its adoption across countries has gained less interest. This paper aims to fill this gap by investigating the proportion of Linux among SSL servers in the Internet. The findings of this research question earlier findings concerning the influence of culture on adoption of technology. Findings of this research could be useful for both proprietary and open source software companies. Likewise, by understanding the influence of culture on Linux adoption, OSS communities can adjust their activities to gain optimum international operations.

Contents

Introduction

Can national culture influence the adoption of open source software (OSS) in SSL server markets across countries? In this paper Linux is taken as a key representative of OSS since it is the most widely recognized open source product (*Economist*, 2004). In this paper the proportion of Linux SSL servers compared to all SSL servers on the Internet across various countries is examined.

According to Netcraft (2005) in June 2005 there were 393,332 SSL servers (with valid third–party certificates) on the Internet and around 32 percent of them operate Linux. Clearly it is highly competitive market where proprietary software vendors face significant competition introduced by Linux. Open source software are products that often cost nothing to use and are developed by volunteers (*Economist*, 2006). Regardless of openness, OSS has become a big business (Lacy, 2006).

ITC adoption decisions depend highly on individuals in organizations and these decisions are also influenced by a given country's cultural characteristics (Erumban and de Jong, 2006). OSS has been described as a global movement (Krishnamurthy, 2003), but there is little information about differences in adoption rates across countries. Geographic, demographic, socioeconomic and cultural differences between countries are likely to influence how products are adopted (Takada and Jain, 1991). However, cultural settings of societies in ICT adoption has received very little attention in the literature (Erumban and de Jong, 2006). A number of researchers have pointed out the importance of culture in the adoption of technology or in the innovativeness of a country (*e.g.*, Erumban and de Jong, 2006; Lee, 1990; Slowikowski and Jarratt, 1997; Shore and Venkatachalam, 1996). Others see culture as an important factor in innovation and IT adoption (van Everdingen and Waarts, 2003; Straub, 1994). Thus, the activity of OSS community members — users and developers — is affected by cultural factors such as gender and power distance (Pykäläinen and Fang, 2007).

Hence, it is still important to further study culture's role in the context of OSS and its penetration in demanding computing environments. Previous studies have concerned traditional technology products with a cost, but they have ignored freely available technology products. Gallego, *et al.* (2008) tried to forecast (geographical) diffusion/adoption of OSS, but they failed to include national cultures, even though cultural variables can explain adoption rates of innovations across countries (van Everdingen and Waarts, 2003). Only one variable in Gallego, *et al.* (2008) concerned culture, which, however, was not considered a critical success factor in OSS adoption. Likewise, Pykäläinen and Fang (2007) studied culture's influence on the behavior of individuals which arguably have less strict constraints than individuals in organizational settings. Therefore it is important to conduct additional studies concerning OSS and culture.

OSS can be downloaded, distributed and shared freely (Krishnamurthy, 2003) while traditional software licenses tend to be restrictive (Barton and Nissanka, 2001). In addition with OSS there is no lock–in (Bruggink, 2003; *Economist*, 2003; Murphy, 2004). OSS is typically developed by programming communities on the Internet (Hars and Ou, 2002) thanks to a network of enthusiasts (Castelluccio, 2000). OSS provides cost–effective solutions (*Economist*, 2003; Brandl, 2004). Clearly, OSS differs significantly from proprietary software. Thus the influence of culture should be tested in the context of OSS to understand the current global competitive environment in the software sector.

ICT, culture and current research settings

In addition to economical, political and technical factors ICT adoption depends also on cultural factors (Mante–Meijer and Ling, 2001). Slowikowski and Jarratt (1997) found that culture has an role in the adoption of high–tech products. According to Lee (1990) besides economic variables a country's culture also has an important role in determining national innovativeness. Erumban and de Jong (2006) found out that national culture and ICT adoption decisions are significantly associated. Even in corporations cultural differences can affect decisions concerning IT infrastructure adoption (Png, *et al.*, 2001).

Erumban and de Jong (2006) pointed out that ICT adoption variation among countries with similar economic conditions calls for research for other variables. Studying culture's effect on ICT adoption in the context of OSS is interesting because in OSS there are no economical (cheap or zero costs) or political (freedom to everyone) barriers or other restrictions stipulated by commercial software licenses [1]. However, Dekimpe, *et al.* (2000) argued that typical innovating countries are rich, culturally homogeneous, concentrated and free–market economies. Wealthier countries are more innovative in adapting new products because they can afford new products and accept the risks inherited in new features (Lee, 1990). It is common that adoption rates of products differ across countries despite the fact that they are launched simultaneously in multiple countries (van Everdingen and Waarts, 2003), although later adopter countries may witness faster diffusion (*e.g.*, see Takada and Jain, 1991; Gruber, 2001). Timing is less critical in the current context because OSS is still a relatively new phenomenon and it is available worldwide largely for free.

Income and education level

OSS appeals to high–end users (Krishnamurthy, 2003) and it has been popular among professional users (Comino and Manenti, 2005; Lerner and Tirole, 2002). If mainly professional users use OSS then the proportion of Linux on SSL servers could relate to the education level of a given country. There is also empirical evidence that education levels influence the adoption of ICT (*e.g.*, Lucchetti and Sterlacchini, 2001; Erumban and de Jong, 2006). However, education level was not found to influence OSS community members' activity (Pykäläinen and Fang, 2007). In a demanding computing environment, regardless of the general education level in the country, it is assumed, that only professionals manage these servers. Thus,

> Hypothesis 1: Education level does not influence on proportion of Linux in SSL servers across countries/cultures.

Experience with Linux, however, can be an influential factor — those who setup Linux SSL servers must be proficient and experienced. Thus it is reasonable to expect that only professionals familiar with Linux manage these servers. Moreover, Mustonen (2003) argued that the OSS programmers do not pay specific attention to use of software within or outside the community. Therefore, a higher number of Linux professionals could translate to a higher Linux adoption rate in a given country. In this paper Linux kernel developers are taken as a representative of all Linux professionals. Thus,

> Hypothesis 2: The presence of Linux professionals has a positive influence on the proportion of Linux on SSL servers across countries/cultures.

Wealthier countries may be faster in adopting new products or more innovative (Dekimpe, *et al.*, 2000; Lee, 1990), yet the effect of income level could be different in OSS adoption, because of its low costs (or free of charge). Thus, everyone can access it regardless of their income level. Gruber (2001) did not find a significant effect of income level on the speed of diffusion of mobile telecommunications in central and eastern European countries. OSS community members' activity, however, was influenced by a given country's economic development (Pykäläinen and Fang, 2007). Naturally, when considering SSL servers, there are still hardware costs, which is likely to influence overall SSL server adoption across countries, but these costs are the same regardless of software licenses. Richer countries may have more SSL servers, but the proportion of Linux SSL servers may not dependent on the wealth of the country. Thus,

> Hypothesis 3: Income level does not influence the proportion of Linux in SSL servers across countries/cultures.

Culture

In this paper, culture's influence on the proportion of Linux on SSL servers was studied by using Hofstede's (1984, 1997) cultural indices. Hofstede's definition of culture is perhaps the most common definition used in cross–cultural management research (Gallivan and Srite, 2005) and his theory is useful in testing hypotheses in cross–cultural comparisons (Fang 2006). In this research, four of the Hofstede's cultural dimensions were employed, namely, individualism–collectivism (IDV), masculinity–femininity (MAS), power distance (PDI) and uncertainty avoidance dimensions (UAI). Hofstede's (1997) data on long–term orientation (LTO) is available only from a limited number of countries and its weaknesses have been pointed out (Fang, 2003). Therefore the exploration of LTO is left for future study.

Culture's effect on ICT adoption can be sometimes explained by the characteristics of a software product (van Everdingen and Waarts, 2003), thus in this section OSS characteristics and their relations to culture were examined. In this research, country level adoption of Linux in SSL servers was studied, which is possible because ICT adoption decisions in organizations depend highly on individuals influenced by a given country's cultural characteristics (Erumban and de Jong, 2006). Likewise, Lee (1990) takes country — not individual or organization — as the unit of adoption for innovation.

Despite criticism of Hofstede's research, Shore and Venkatachalam (1996) suggest that it is useful in studying IT transfer problems. Likewise, Fang (2006) states that clarity and consistency (in identifying cultural dimensions) are strengths of Hofstede's theory; besides they are useful in testing hypotheses. A number of researchers (*e.g.*, Erumban and de Jong, 2006; van Everdingen and Waarts, 2003; Png, *et al.*, 2001; Pykäläinen and Fang, 2007) have used Hofstede's cultural dimensions in studying technology adoption across countries. Thus, Hofstede's cultural dimensions are considered appropriate for this study as well.

Individualism–collectivism

The individualism–collectivism dimension relates to the degree by which individuals are integrated into groups (Hofstede, 1997). Marron and Steel (2000) noted that individualistic cultures embrace individual ownership of intellectual property. Collective cultures, on the other hand, emphasize sharing over individual rights (Marron and Steel, 2000).

Pykäläinen and Fang (2007) analyzed OSS characteristics and their relations to collectivism–individualism dimensions. They noted that OSS presents characteristics of both individualism and collectivism. Some support for positive impact of individualism on ICT adoption has been found (*e.g.*, Erumban and de Jong, 2006; Everdingen and Waarts, 2003), although the individualism–collectivism dimension should not affect organizational IT infrastructure adoption (Png, *et al.*, 2001). Likewise, individualism–collectivism dimension was not found to be influential on the activities of OSS community members (Pykäläinen and Fang, 2007). Thus,

> Hypothesis 4: Individualism of a culture does not influence the proportion of Linux on SSL servers across cultures.

Power distance

The power distance dimension relates to the unequal power distribution between members in organizations or institutions and how it is accepted (Hofstede, 1997). In the development of proprietary software, users and developers are separated and only developers can make changes (Krishnamurthy, 2003). Oppositely, in OSS users can make improvements, fixes and modifications if they wish to do so (Krishnamurthy, 2003).

The power that members of the OSS community possess has been noted by several researchers (*e.g.*, Jesiek, 2003; Dahlander and Magnusson, 2005). Moreover, Murphy (2004) states that the software industry is used to customer lock–in, which is disturbed as Linux threatens to bring a different kind of economics to the markets. Power distance is noted to influence the activity of users in the OSS community (Pykäläinen and Fang, 2007).

Png, *et al.* (2001) found power distance to have only insignificant negative influence on IT infrastructure adoption in companies, whereas Erumban and de Jong (2006) and van Everdingen and Waarts (2003) found that ICT adoption is lower in high–power distance cultures. Pykäläinen and Fang (2007) argued high–power distance countries could be more willing to accept restricting commercial licenses than low–power distance countries. Similarly,

> Hypothesis 5: The power distance dimension has negative influence on the proportion of Linux on SSL servers across cultures.

Femininity–masculinity dimension

Kedia and Bhagat (1988) propose that in organizational context masculine cultures are more effective in adopting imported technologies. In contrast, Png, *et al.* (2001) argue that masculinity should not affect organizational IT infrastructure adoption. Also, Erumban and de Jong (2006) did not find significant influence of the masculinity dimension on ICT adoption. However, Erumban and de Jong (2006) add that if the major purpose of technology is to facilitate communication then the adoption rate could be higher in feminine cultures whereas if the purpose is to compete then adoption could be higher in masculine cultures. Pykäläinen and Fang (2007) found OSS community members' activity to increase in more feminine cultures. In organizational settings, Linux may see higher proportion in more masculine cultures as it may, *e.g.*, due to cost effectiveness, increase competitiveness.

> Hypothesis 6: Masculinity of a culture has a positive influence on proportion of Linux on SSL servers across cultures.

Uncertainty avoidance

Uncertainty avoidance refers to the society's tolerance for uncertainty and ambiguity (Hofstede, 1997). Erumban and de Jong (2006) argue that uncertainty avoidance is one of the most important cultural dimensions that can affect ICT adoption rates across countries. According to Shore and Venkatachalam (1996) in cultures which are characterized with high–uncertainty avoidance, individuals are not willing to abandon familiar systems. As a result, individuals from cultures with low–uncertainty avoidance could be more willing to try new technologies. This is in line with Straub's (1994) observation of differences between American and Japanese respondents' fax and e–mail adoption. Straub explains that uncertainty avoidance was one aspect of Japanese culture that was against e–mail adoption. According to Png, *et al.* (2001) and Erumban and de Jong (2006) ICT adoption is lower in high–uncertainty avoidance countries.

Earlier research seems to provide evidence that the adoption of ICT is lower in high–uncertainty avoidance countries. However, there are characteristics in OSS that may lower perceived uncertainty. For example, Suzor, *et al.* (2004) noted that with the use of open standards [2], users are generally confident that they will be able to access their data even if, in the future, the original software or hardware becomes obsolete. In adoption decisions it is important to know that the software will be produced and developed continuously (Bonaccorsi and Rossi, 2003). Availability of source code guarantees continuity. However, Pykäläinen and Fang (2007) did not find uncertainty avoidance to influence OSS community members' activity. Thus it appears that both uncertainty–avoiding cultures and uncertainty–accepting cultures are willing to accept OSS.

> Hypothesis 7: The uncertainty avoidance dimension does not influence the adoption of Linux on SSL servers across cultures.

Methodology

In this research secondary data from World Bank (2006a), Netcraft (2005), and Tuomi (2004) was used. Cultural indices of each country in this study are from Hofstede (1997). Countries/cultures included in the analysis are listed in Table 1.

Table 1: Countries and cultures included in the research.
Note: *Arab world regional estimates in Hofstede (1997).

Australia	Ireland	Portugal
Austria	Israel	Saudi Arabia*
Belgium	Italy	Singapore
Canada	Japan	South Korea
Denmark	Kuwait*	Spain
Finland	Luxembourg	Sweden
France	Malta	Switzerland
Germany	Netherlands	United Arab Emirates*
Greece	New Zealand	United Kingdom
Hong Kong	Norway	United States

World Bank (2006a) data is from year 2004, Netcraft data is from June 2005, and the Linux kernel credit file data is from 2002. According to Tuomi's (2004) analysis Linux kernel (version 2.5.25) credits file contained 418 contributors (six of them were from unknown geographical location). Gross enrollment ratio for the tertiary level (EDU) is taken as a measurement for general education level in the countries included in this study. Gross National Income per capita (GNI) is used as the indicator of economic development.

The automatically collected data about SSL servers that can be extracted from the certificates and the characteristics of the network connection includes information about the geographical location of the owners of Internet sites and server software among other things (Netcraft, 2005). In the Netcraft (2005) data set there were 19,834, or 5.04 percent, servers from unknown geographical locations.

Linux kernel credits file data includes the developers who have contributed to the Linux kernel development (Tuomi, 2004). The credit file includes only those developers that contributed to the development of Linux kernel, that is their contribution was accepted. Tuomi (2004) looked for geographical data about the contributors and if necessary used other sources to identify geographical locations. In the analysis, Linux kernel developers (NIX) is used as a dummy variable — ‘0’ indicating that there are no Linux kernel developers in a given country and ‘1’ indicating there are Linux kernel developers in a given country.

Only the cultures/countries that had Hofstede’s (1997) four cultural dimensions (IDV, PDI, UAI and MAS), and GNI per capita are included in this analysis. Countries that have higher than US$10,066 (high–income economies in 2004; World Bank, 2006a) GNI per capita are included. This eliminates countries that have less developed IT infrastructure and general development level. However, it does not limit cultural variation between countries even though they are more similar relative to economic factors (Erumban and de Jong, 2006). After all the restrictions were applied, the data set included 30 cultures/countries that had 377 of all 418 (or 90.2 percent) Linux kernel developers, 358,591 (or 91.17 percent) of all SSL servers with valid third–party certificates.

The influence of the cultural dimensions, education level, income level and Linux professionals on the proportion of Linux in SSL server markets was tested by correlation and linear regression models. In addition to Linux SSL servers, the analysis was conducted also for Windows SSL servers and all SSL servers for comparative purposes. In the analysis the percentage of Linux and Windows SSL servers of all SSL servers in each country was used as dependent variables. Overall SSL server adoption was analyzed by using populated weighted adoption of SSL servers across countries.

Results

Table 2 provides the means and standard deviations and number of observations of each variable. Educational data had two missing values, which were replaced with mean values. Replaced values were compared to other educational data available from World Bank (2006b) and found likely not to have affected the analysis. In the correlation and regression analysis missing values in educational data were replaced with mean values.

Table 2: Means and standard deviations (SD) and number of observations (N).

Variable	Mean	SD	N
Linux SSL	31.31	9.93	30
Windows SSL	48.41	10.99	30
SSL adoption (population weighted)	2.485e–4	1.874e–4	30
GNI per capita	28948	11470	30
Education tertiary gross enrollment rate	57.32	21.32	28
Individualism	59.23	21.3	30
Power distance	46.63	20.2	30
Masculinity	49.57	20.67	30
Uncertainty avoidance	63.1	25.48	30
Kernel dummy	n.a.	n.a.	30

In Table 3 there are the correlations between independent and dependent variables. As can be seen in Table 3 there is correlation between a number of variables; some are significant at 0.99 confidence level.

Table 3: Pairwise correlations between variables (N = 30).
Note: Significant values 0.001 ****, 0.01 ***, 0.05 **, 0.1 *.

Variables	1. Linux SSL	2. Windows SSL	3. SSL/Pop	4. GNI	5. EDU	6. IDV	7. PDI	8. MAS	9. UAI

1. Linux SSL									
2. Windows SSL	−0.835****								
3. SSL/pop	0.113	−0.074							
4. GNI (control)	0.152	−0.308	0.575****						
5. EDU (N = 28)	−0.022	−0.0307	0.183	0.101					
6. IDV	0.244	−0.0367	0.668****	0.493***	0.289				
7. PDI	−0.256	0.0628	−0.582****	−0.462**	−0.400**	−0.602****			
8. MAS	0.402**	−0.452	0.066	−0.057	−0.320*	−0.008	0.067		
9. UAI	0.299	−0.183	−0.542***	−0.387**	−0.119	−0.264	0.299	0.196	
10. NIX	0.389*	−0.454	0.526	0.707****	0.286	0.716****	−0.536***	0.076	−0.355

The correlations in Table 3 provide preliminary evidence to support some of the hypotheses. It seems that proportion of Linux SSL servers could depend on the existence of Linux kernel developers in a given country and culture's masculinity index. Naturally, the proportion of Windows SSL servers correlates with the proportion of Linux SSL servers, but there is no perfect correlation as there are several other operating systems as well. The Linux kernel developers dummy variable correlates with several variables and some have rather high correlations. To further study the influence of the cultural dimensions and other variables linear regression models are calculated.

Table 4: Full models, significant values 0.001 **, 0.01 ***, 0.05 **, 0.1 *.**

	Linux SSL			**Windows SSL**			**Overall SSL adoption**		
	Estimate	t–value	Tolerance	Estimate	t–value	Tolerance	Estimate	t–value	Tolerance
Intercept	22.562	1.590		72.45	5.344****		2.888e–5	0.141	
GNI	−1.263e–4	−0.629	0.4333	−1.505e–04	−0.784	0.4333	5.645e–9	1.944*	0.4333
EDU	−6.043e–2	−0.676	0.6806	6.011e–02	–0.704	0.6806	4.839e–7	0.374	0.6806
IDV	−6.286e–2	−0.569	0.415	0.25753	2.607**	0.415	4.761e–6	2.980***	0.415
PDI	−0.1341	−1.303	0.5323	2.344e–2	−0.238	0.5323	−1.590e–6	−1.069	0.5323
MAS	0.1139	1.371	0.7803	−0.1956	−2.465**	0.7803	1.996e–6	1.663	0.7803
UAI	0.1740	2.593**	0.7871	−0.1356	−2.116**	0.7871	−2.791e–6	−2.877***	0.7871
NIX	13.176	2.157**	0.2838	−18.86	−3.230***	0.2838	1.461e–4	−1.655	0.2838
R^2	0.4867			0.6171			0.6987		
Adjusted R^2	0.324			0.4952			0.6028		
F–Statistics	2.98			5.064			7.288		
df	7			7			7		
Model p–value	2.338e–2			1.539e–3			1.444e–4		

From the full regression models presented in Table 4 we can see that the proportion of Linux SSL servers seems to depend on a given culture's uncertainty avoidance index and the presence of Linux kernel developers in a given country. Both of these variables were significant at $\rho < 0.05$. It is worth noticing the differences between Linux and Windows SSL server models (differing signs in IDV, MAS, UAI and NIX), and Linux SSL servers and overall SSL server adoption models (differing signs in GNI, EDU, IDV, UAI and NIX). Using backward selection, we chose a set of variables for each model. Final models are presented in Table 5.

Table 5: The final models summary, significant values 0.001 **, 0.01 ***, 0.05 **, 0.1 *.**

	Linux SSL			Windows SSL			Overall SSL adoption		
	Estimate	t–value	Tolerance	Estimate	t–value	Tolerance	Estimate	t–value	Tolerance
Intercept	6.371	1.094		63.784	9.589****		1.364e–4	1.329	
MAS	0.134	1.845*	0.9375	−0.169	−2.430**	0.93027			0.4333
UAI	0.167	2.658**	0.8244	−0.132	−2.199**	0.8244	–2.887e–6	−3.075***	0.93041
IDV				0.281	3.002***	0.4838	4.967e–6	4.422****	0.93041
NIX	11.071	3.276****	0.8525	−21.886	4.464****	0.4442			
R^2	0.4424			0.6016			0.5902		
Adjusted R^2	0.3781			0.5379			0.5598		
F–Statistics	6.877			9.438			19.44		
df	3			4			2		
Model p–value	1.461e–3			8.594e–5			5.884e–6		

From Table 5 we can see that the proportion of Linux SSL servers depends on a culture's masculinity index (significant at $\rho < 0.1$), uncertainty avoidance index ($\rho < 0.05$) and the presence of Linux kernel developers in a given country ($\rho < 0.001$). All of these had a positive sign in influencing the occurrence of Linux on SSL servers across cultures. These variables have a different effect on Windows SSL and overall SSL server adoption. The proportion of Windows servers was also influenced by a given culture's masculinity, uncertainty avoidance and the presence of Linux kernel developers. However, these have the opposite influence than in the Linux SSL server model. In addition, the proportion of Windows SSL servers is influenced by a given culture's level of individualism. Overall SSL server adoption seems to be influenced by given culture's uncertainty avoidance and individualism. It is worth noticing that the sign of the effect of uncertainty avoidance is the opposite to that found in the Linux SSL server model. Tolerances indicate that multicollinearity does not present problems.

Based on the model for Linux SSL server, hypotheses 2, 6 and 7 were supported as they had a significant effect in estimating the proportion of Linux on SSL servers. Unexpectedly, uncertainty avoidance influenced the model, having a positive influence. The model indicates that when the relative number of Linux kernel developers increases the proportion of Linux SSL servers should increase. Likewise masculinity and uncertainty avoidance indices have similar effects. Hypotheses 1 and 3 were supported as education and income levels seem not to have influence on the proportion of Linux SSL servers across cultures (in the regression model and correlations). Hypotheses 4 and 5 were not supported, suggesting that individualism and power distance indices do not influence Linux SSL server adoption across cultures.

Discussion

The linear regression analysis pointed out relationships between the proportion of Linux adoption on SSL servers and culture's uncertainty avoidance, masculinity–femininity, and the presence of Linux kernel developers in a given country. It is unlikely that a person first installs a Linux SSL server and then becomes a Linux professional. Administering a SSL server is likely to require professional skills, thus the influence of the presence of Linux professionals in a given country is not surprising.

Uncertainty avoidance and masculinity indices demonstrated a positive influence on the proportion of Linux on SSL servers across cultures. The regression model indicates that proportion of Linux SSL server adoption could be higher in more masculine and uncertainty avoiding cultures. One potential reason for the positive influence of masculinity on the proportion of Linux on SSL servers could be improved competitiveness as OSS is more cost–effective than proprietary offerings. This explanation would agree with Erumban and de Jong (2006) on technology adoption, competition and masculinity. Kedia and Bhagat (1988) also noticed that masculine cultures are more effective in adopting imported technologies. The masculinity index of a culture had the opposite influence on the proportion of Windows SSL servers.

The direction of the effect of uncertainty avoidance is interesting. OSS has gained popularity only recently; hence OSS could be less attractive in uncertainty avoiding cultures. On the other hand OSS could decrease uncertainties about a given vendor and openness guarantees that the users can access the data any way they want. Moreover, technological obsolescence is less of a problem with OSS (Bruggink, 2003). Therefore OSS may include less uncertainty, despite its relative novelty. Thus in uncertainty–avoiding cultures, Linux could be a safe option. The effect of uncertainty avoidance on the proportion of Linux adoption on SSL servers is opposite to that of Windows and overall SSL adoption across cultures.

Some characteristics of OSS and earlier research suggested that individualism–collectivism and power distance dimensions could have influenced the proportion of Linux adoption. Interestingly they did not show significant influence in the adoption of Linux. Instead these two dimensions may have a different role in the adoption of OSS at the individual level (Pykäläinen and Fang, 2007).

Education enrollment rate was not considered to be a factor affecting Linux adoption. Generally, administrators of SSL servers are highly educated regardless of the general education level in a given country. This finding supports the notion that OSS is aimed at professional users (*e.g.*, Comino and Manenti, 2005; Krishnamurthy, 2003; Lerner and Tirole, 2002).

The influence of GNI per capita was tested as well and showed no influence on the proportion of Linux on SSL servers across cultures, as expected. However, variables indicating a given country's development (Lee, 1990) and economic wealth (Dekimpe, *et al.*, 2000) were important determinants of innovativeness. Additionally, ICT adoption is influenced by income level (Erumban and de Jong, 2006). Also this study provides evidence for statements about relationship between innovation/ICT adoption and income level, as overall SSL server adoption seemed to be higher in countries with higher income levels.

Culture shows a different influence on the proportion of Linux and Windows adoption, overall SSL adoption and other ICT adoption. In Table 6 the results of culture's influence on the adoption of ICT is summarized. Results indicate that despite earlier studies, researchers should continue to examine culture's influence on technology adoption, because earlier studies have not completely examined the adoption of free technologies across cultures. Obviously, when a product has a price, costs influence adoption decisions.

Table 6: Culture and IT summary of findings.
Note: Study reported no effect '0', positive influence '+', and negative influence '−'. The sign inside brackets indicates only partial or insignificant influence; 'n.a.' if influence was not reported or tested.

Variables/study	**Focal study**			**Pykäläinen and Fang (2007)** (OSS activity)	**Png, *et al.* (2001)** (IT infra)	**van Everdingen and Waarts (2003)** (ERP adoption)	**Erumban and de Jong (2006)** (ICT adoption)
	Linux	Windows	SSL				
GNI	(−)	(−)	(+)	+	n.a.	n.a.	+
EDU	(+)	(−)	(−)	0	n.a.	n.a.	+
IDV	(+)	+	+	0	(−)	(+)	(+)
MAS	+	−	(+)	−	(+)	−	−
PDI	(−)	(−)	(−)	− (for users)	(−)	−	−
UAI	+	−	−	0	−	−	−

As can be seen from Table 6 the influence of uncertainty avoidance on Linux adoption had an opposite influence to that reported in other studies. This disparity warrants further investigation. More importantly, these findings challenge the results concerning culture's influence on ICT and technology adoption in general. Is the influence of income really a strong influence over to adoption of new technologies because of sheer affordability — or favorable attitudes towards new technologies?

Conclusions

In this paper an attempt was made to uncover the influence of culture on the proportion of Linux adoption on SSL servers. The presence of Linux kernel developers — a representative group of Linux professionals — and culture's masculinity and uncertainty avoidance dimensions influence the proportion of Linux SSL servers across cultures and countries. In cultures with characteristics of masculinity and uncertainty avoidance, the softer side of OSS, along with its technical advantages, attract potential users. In other cultures individuals may not be interested in 'buying' into the ideological part of OSS; instead they are looking for more of the rational and technical qualities of the software and other measurable benefits. Therefore, one may conclude that a greater overall adoption of Linux may need more Linux related professionals, *e.g.* through increased education about Linux and a favorable culture as well. Thus, the OSS community should adjust their activities to reflect all of the benefits of OSS.

Finally, there are some limitiations to this study. The model was tested only with data consisting of high–income level countries (GNI per capita higher than US$10,066). Thus, it is questionable whether the model fits to all countries, although the sample used in the analysis included 91.17 percent of all the SSL servers with valid third–party certificates worldwide. Additionally, Hofstede's (1997) cultural dimensions indices may be inappropriate. However, due to its availability and popularity in cross–cultural economics research, Hofstede's theory is considered appropriate for this particular study. Besides, Hofstede's cultural data is useful for testing speciifc hypotheses (Fang, 2006).

About the author

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Notes

1. For example see www.gnu.org.

2. Suzor, *et al.*, 2004, p. 3: "Open standards are file formats and communication protocols which are agreed upon by community consensus and are not controlled by proprietary companies."

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