

## Multi-level framework of open source software adoption

By: Wen Guang Qu, [Zhiyong Yang](#), and Zhongming Wang

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### Abstract:

Numerous studies examine potential facilitators and inhibitors of open source software (OSS) adoption at the firm level. This study represents the first attempt to propose and test a multi-level framework, examining the effects of five country-level variables and two under-explored firm-level factors on firm OSS adoption. The findings suggest that a country's uncertainty avoidance orientation has a positive impact on OSS adoption, whereas power distance orientation and economic development have a negative impact on OSS adoption. In addition, uncertainty avoidance at the country level sets boundaries for the effect of firm-level IT-based networks in a way that the impact of proprietary IT-based networks becomes stronger, but that of open IT-based networks becomes weaker when uncertainty avoidance is high rather than low. The study also develops public policy implications from these findings.

**Keywords:** multi-level | OSS adoption | uncertainty avoidance | power distance | individualism | IT competence | economic development | IT-based networks

### Article:

#### 1. Introduction

Open source software (OSS) continues to gain increasing attention in the business world. Unlike proprietary software (e.g., Windows XP), OSS (e.g., Linux) development occurs in a public, collaborative manner with its source code accessible to the public. This open model permits users to use, change, improve, and redistribute the software. CIO Insight magazine (D'Agostino 2005) reports that 81% of firms deploy or are considering deploying some sort of open source systems or applications, with 60% replacing legacy systems with Linux, or planning to do so in the next two years. Even Microsoft, a giant in proprietary software, is starting to collaborate with such OSS vendors as Red Hat and Novell. Although early OSS users are themselves technologists and the distribution and the use of OSS is initially only among academia, today the development and design of OSS are often for mass consumption (Boulanger, 2005).

Studies that investigate potential facilitators and inhibitors of OSS adoption among firms find that factors such as low cost, high reliability, slack resources, and relevance to business encourage firms to adopt OSS, while the lack of internal skills or external support inhibits firms

from adopting OSS (Dedrick and West, 2004, Goode, 2005, Ven and Verelst, 2008b). These studies provide intriguing findings; however, the focus is primarily at the firm level, whereas they largely neglect the effect of country-level factors. Among the rare exceptions, Mindel, Mui, and Verma (2007) compare OSS adoption levels across a few Southeast Asian countries and find that firms in economically disadvantaged countries are more likely to adopt OSS. Some other scholars (e.g., Tuomi, 2006, Ven et al., 2008) also notice that a country's cultural values, such as power distance orientation, might be influential to a firm's adoption of OSS.

Despite these advocates, no research to date theorizes the effects of country-level factors on OSS adoption and tests these effects using large-scale data from countries with a wide span of cultural orientations and economic development levels. In addition, previous studies in this area largely neglect the nested structure of the OSS adoption data. A common practice in most prior studies that investigates the effects of country-level factors on OSS adoption is to obtain information from multiple firms in each country and then researchers determine a country's OSS adoption level using aggregate measures across all firms. One of the problems with aggregation is that this method loses all firm-level information and the statistical analysis loses power. Assigning an aggregate value obscures the fact that OSS adoption is heterogeneous across firms.

To address the above issues, this paper develops a multi-level framework of firm OSS adoption that specifies the country-level, the firm-level, and the cross-level effects. At the country level, the study describes the impact of a country's cultural, technological, and economic factors on firm OSS adoption. At the firm level, the study examines the effects of proprietary and open IT-based networks on firm OSS adoption. Investigating OSS adoption simultaneously at both country- and firm-levels has important policy and managerial implications. Governments in many countries nowadays are setting up policies to promote the use of OSS. The Brazil government, for instance, proposes a bill to mandate that all software in the federal administration and public entities be OSS (Lewis, 2008). In the U.K., the government enacts a new policy to promote the use of open source software in the public sector (UK CIO Council, 2009). The United Nations also calls on economically disadvantaged countries to adopt OSS to bridge the digital divide with the rich, as the use of OSS can lower costs, increase security, stimulate local economies, and avoid proprietary lock-in (United Nations, 2003). By investigating how a country's characteristics influence firm decisions on OSS adoption, this study provides policy makers with useful guidance to set up relevant policies to promote OSS.

## **2. Research background**

Numerous studies investigate facilitators and inhibitors of firm OSS adoption. Parallel with the structure in innovation adoption research, these factors are classifiable into three groups: organizational, technological, and environmental (DePietro, Wiarda, and Fleischer, 1990). Of these three categories, organizational factors gain the most research attention. Firms are more likely to adopt OSS when they have necessary technical skills (Dedrick and West, 2004, Goode, 2005, Morgan and Finnegan, 2007). By contrast, prior experience with proprietary software may reduce the propensity to adopt OSS due to switching costs (Goode, 2005, Ven and Verelst, 2008b, West and Dedrick, 2006). Managers' stance toward IT innovation (Dedrick and West, 2004, Paré et al., 2009), decision-makers' ideology (Ven and Verelst, 2008a), and the presence of boundary spanners (Ven and Verelst, 2008b) are other key factors affecting OSS adoption. Apart

from the organizational factors, the characteristics of OSS itself also play a role. Low price seems to be the most important thrust of OSS adoption (Dedrick and West, 2004). Compatibility and trialability are the other two technical features that managers seriously take into account when making OSS adoption decisions (Morgan and Finnegan, 2007, Waring and Maddocks, 2005, West and Dedrick, 2006).

Environmental factors influence firm decisions on whether or not to adopt OSS. For example, the availability of third-party technical support facilitates OSS adoption (Paré et al., 2009, West and Dedrick, 2006). More importantly, a number of country-level factors are likely to influence a firm's adoption of OSS. When political pressures on the use of commercial software exist, firms are less likely to adopt OSS, especially for those whose businesses are dependent on the government (Paré et al., 2009). A country's economic development level may also exert a great influence on firm OSS adoption, as Mindel et al. (2007) find that the OSS adoption levels vary across a few Southeast Asian countries, with poorer ones having a higher motivation to pursue technology independence through low-cost technologies such as OSS. The cultural orientation of a country is likely to affect firm OSS adoption as well. Tuomi (2006) advocates that high power distance may be a barrier for OSS adoption.

These observations provide strong evidence to justify the important role of country-level factors in a firm's adoption of OSS. Building upon previous studies, this study develops a multi-level model of firm OSS adoption and specifies five factors at the country level, namely, uncertainty avoidance, power distance, individualism, IT competence, and economic development. The first three are the key Hofstede's cultural dimensions. Although recent publications in the psychology literature further advance the studies of Hofstede, Hofstede's cultural dimensions remain wide acceptance in marketing and are the most popular measures to study cultural effects on innovation adoption across different nations (De Jong et al., 2008, Franke and Nadler, 2008). This study investigates IT competence and economic development because prior research implies that they may influence OSS adoption (Mindel et al., 2007, West and Dedrick, 2006).

The study also examines two variables at the firm level, namely, proprietary IT-based networks and open IT-based networks. IT-based networks are important communication channels for firms. Although communication channels are a key to innovation adoption (Gurbaxani, 1990, Loh and Venkatraman, 1992), little research thus far associates IT-based networks with OSS adoption. This study fills the gap by examining not only the main effects of the two types of IT-based networks on OSS adoption, but also their interactions with uncertainty avoidance to advance the understanding of how the country-level factor sets the boundary for the effects of IT-based networks at the firm level.

### **3. Research framework and hypotheses**

#### **3.1. Country-level hypotheses**

##### *3.1.1. Effect of uncertainty avoidance on OSS adoption*

Uncertainty avoidance refers to the extent to which people feel comfortable in novel, unknown, surprising, and unusual situations (Hofstede, 1991). People in countries with high uncertainty

avoidance feel great stress and anxiety when facing uncertain situations; as a result, they usually try to minimize uncertainty by enacting strict laws and rules, as well as safety and security measures (Hofstede, 1991). In contrast, people in countries with low uncertainty avoidance are more tolerant of opinions that are different from their own.

The uncertainty avoidance of a country likely relates positively to firm OSS adoption. Popular OSS applications such as Linux often have the benefit of high reliability and superior security over proprietary software (Raymond, 1999). A report by Reasoning Inc (2003) shows that the defect rate for the Internet protocol code in Linux is 0.1 defects per 1000 lines of code (KLOC), while that for the proprietary implementation is 0.55 defects per KLOC. Similarly, a study by Bloor Research (1999) pits Windows NT against GNU/Linux in a head-to-head comparison and finds that GNU/Linux is more reliable to Windows NT in seven of nine categories. In the Operating System Availability category, the GNU/Linux system does not experience a single outage due to software during the year of testing, while Windows NT system suffers a total of 68 failures. The high reliability and superior security of OSS is probably due to its unique development approach, that is, in a public, collaborative manner. Just as Raymond (1999, p. 29) points out, “given enough eyeballs, all bugs are shallow.”

Because OSS often has a higher reliability and superior security than the proprietary software, firms in countries with higher uncertainty avoidance should be more likely to adopt OSS than those in countries with lower uncertainty avoidance, *ceteris paribus*.

**H1.** The uncertainty avoidance orientation of a country associates positively with a firm's OSS adoption.

### *3.1.2. Effect of power distance on OSS adoption*

Power distance refers to the extent to which less powerful members expect and accept that the distribution of power is unequal (Hofstede, 1991). In countries with low power distance, people accept consultative or democratic power relations. The less powerful are more comfortable with, and demand the right to contribute to and critique, the decisions made by those in power. On the contrary, in countries with high power distance, people usually accept the power of others according to certain formal positions. The less powerful are usually comfortable with more autocratic and paternalistic power relations (Hofstede, 2001).

A country's power distance orientation may impede a firm's adoption of OSS for three reasons. First, the ideology underlying open source movement does not fit with a culture of high power distance. People usually develop OSS in a public, collaborative manner, which may be in conflict with the values of a culture of high power distance, such as the acceptance of autocratic and paternalistic power relations (Hofstede 2001). Second, a firm's adoption of OSS is a bottom-up initiative; initiators often are technical employees who are adherents to the open source movement (Ven and Verelst, 2008a). In countries with low power distance, technological staff talking to top managers about the advantages of OSS and making recommendation of OSS adoption is culturally acceptable. In countries with high power distance, however, bottom-up communications and recommendations are less likely because the hierarchical distance between technical employees and top managers is wide. Finally, adopting OSS is similar to adopting an

innovation or embracing changes. Firms in countries with high power distance like to maintain the status quo and are reluctant to changes and innovations because new things may threaten the existing power structure (Leung et al., 2005, Moon et al., 2008). Taken together, firms in countries with higher power distance are less likely to adopt OSS than their counterparts in countries with lower power distance, *ceteris paribus*. Formally,

**H2.** The power distance orientation of a country associates negatively with a firm's OSS adoption.

### *3.1.3. Effect of individualism on OSS adoption*

Individualism is the degree of individuals' integration into groups (Hofstede, 1991). People in countries with an individualism orientation prefer a social framework where individuals take care of themselves and their immediate family, contrary to people in collectivistic countries who expect groups to take care of them in exchange for their loyalty (Leidner and Kayworth, 2006). Individuals from individualistic countries tend to make their own choices, while those in collectivistic countries are more readily willing to conform to the norms of the group (Erumban and de Jong, 2006).

Research on the cross-national study of innovation diffusion examines the influence of individualism on individuals' propensity to adopt new products. Yenyurt and Townsend (2003) find that individualism has a positive effect on the diffusion of new products. Similarly, Shane (1993) reports that individualism associates positively with national rates of innovation. More relevant to this study, individualism associates positively with the diffusion of information and communication technologies (Erumban and de Jong 2006). Because OSS is one type of innovation (Dedrick and West, 2004, Ven et al., 2008), the individualism orientation of a country may facilitate its adoption.

**H3.** The individualism orientation of a country associates positively with a firm's OSS adoption.

### *3.1.4. Effect of IT competence on OSS adoption*

A country's IT competence is likely to relate positively to firm OSS adoption. The IT competence of a country is the installed base of IT and IT-related knowledge. Although little research thus far associates a country's technology competence with OSS adoption, past firm-level studies show that internal technological expertise/skills and external technological support are two primary concerns firms usually have when making decisions on OSS adoption. Lack of internal technical expertise on OSS and/or the difficulty in finding staff and developing competence to work with OSS inhibit firms from adopting OSS (Morgan and Finnegan 2007). Yet, the availability of external technology skills and services from IT vendors is an important factor that promotes firms' OSS adoption (Dedrick and West, 2004). Since firms are likely to develop a higher level of IT expertise and skills when they are in a country with stronger IT competence, the IT competence of a country is a facilitator of the firm's OSS adoption. Countries with stronger IT competence can also generate a better external environment to support OSS application, providing more capable IT vendors to supply IT services for OSS. As a result,

**H4.** The IT competence of a country associates positively with a firm's OSS adoption.

### *3.1.5. Effect of economic development on OSS adoption*

A country's economic development level may relate negatively to a firm's OSS adoption. Most OSS applications are downloadable from the Internet free of charge. While the open source movement usually highlights other advantages of OSS, such as better quality, freedom from vendor control, and social benefits, Dedrick and West (2007) find that the most attractive advantage of OSS to user firms is its low cost. Titterton (2003) echoes this finding and suggests that cost savings motivate 70% of all OSS users primarily. The inherent nature of cost saving with OSS is more likely to attract firms in less-developed countries, as these firms often lack financial resources for expensive proprietary software. As a result, firms in countries with high economic development levels tend to have more resources, and therefore are less likely to adopt OSS, *ceteris paribus*.

**H5.** The economic development level of a country associates negatively with a firm's OSS adoption.

### 3.2. Firm-level hypotheses

Many firm-level factors may influence companies' decisions on OSS adoption; however, few studies notice the role of firm networks in the adoption of OSS. Networks are important communication channels for firms, which are the core in the innovation diffusion process (Fichman, 2000). The diffusion of an innovation is a process where the communication of innovation is through certain channels among the members of a social system over time. When taking into account different types of communication channels, adopters tend to use public channels to get information on innovation, but place more emphasis on private channels at the decision stage (Rogers, 1995). Some studies emphasize the role of communication channels in facilitating innovation diffusion (Gurbaxani, 1990, Loh and Venkatraman, 1992).

The existence of IT-based networks is likely a facilitator of OSS adoption for a company. Two types of IT-based networks exist, namely, proprietary and open networks (Zhu, Kraemer, Gurbaxani, and Xu, 2006). The proprietary IT-based networks (parallel with private channels) are for, and available only to, a set of firms with close business relationships (e.g., WalMart and its suppliers), and often require a private communication platform such as customized EDI. Such networks usually involve tightly-coupled, dedicated linkages between network members with high specificity, long-term relationships, and high interdependence (Bakos and Brynjolfsson, 1993). By contrast, open IT-based networks (parallel with public channels) are within an open community, available to the public, and usually use public communication platforms and software (Zhu et al., 2006). Popular open IT-based networks include those using RosettaNet, CIDX and ebXML, which have loosely-coupled linkages between network members with low specificity in assets, short-term relationships, and low interdependence (Gosain, Malhotra, and El Sawy, 2004). Despite the differences between these two types of IT-based networks, the presence of any of them in a company may increase its awareness of OSS and the likelihood of adoption. Consequently,

**H6a.** Firms are more likely to adopt OSS if they have proprietary IT-based networks.

**H6b.** Firms are more likely to adopt OSS if they have open IT-based networks.

### 3.3. Cross-level hypotheses

In addition to the main effects, country-level factors are also likely to moderate the effects of IT-based networks at the firm level. The study here focuses on uncertainty avoidance to examine the cross-level interactions, because uncertainty avoidance is a key contextual factor that may affect the effectiveness of communication channels. In particular, a country's uncertainty avoidance orientation may moderate the effect of IT-based networks on OSS adoption, in a way that the impact of proprietary IT-based networks becomes stronger; however, the impact of open IT-based networks becomes weaker when uncertainty avoidance is high rather than low. People in high uncertainty avoidance countries are likely to rely on information from close and trustful sources, rather than from distant and public sources, to make important decisions (Money and Crofts, 2003). As evident, Japanese firms (in a high uncertainty avoidance country) use more word-of-mouth search in sourcing their corporate travel services than do American firms (in a low uncertainty avoidance country) (Money, 2000). Similarly, using a survey on MBA students in 11 European countries and the U.S., Dawar et al. (1996) find that when making brand choices, consumers in high uncertainty avoidance countries depend more on information from personal sources than from public sources such as consumer magazines. Translating these findings to this study, proprietary IT-based networks should be preferable and trustful in high uncertainty avoidance countries, whereas the information from open IT-based networks is likely to have less value. Therefore,

**H7a.** The positive effect of proprietary IT-based networks on OSS adoption becomes stronger when the uncertainty avoidance orientation of a country is high rather than low.

**H7b.** The positive effect of open IT-based networks on OSS adoption becomes weaker when the uncertainty avoidance orientation of a country is high rather than low.

## 4. Method

### 4.1. Data and variables

The data are from three sources, namely, e-Business Watch ([ebusiness-watch.org](http://ebusiness-watch.org)), Hofstede's scores of national culture ([geert-hofstede.com](http://geert-hofstede.com)), and the World Bank ([worldbank.org](http://worldbank.org)). E-business Watch collected data from decision makers of 14,065 enterprises in 10 sectors across 29 European countries through computer-aided telephone interviews (N = 11,072 at the firm level and N = 22 at the country level in the final sample due to missing data). E-business Watch conducted the survey in March and April 2006 and randomly selected companies to ensure that those in the sample were representative of the respective industry in terms of firm size and age.

#### 4.1.1. Dependent variable

The dependent variable of this study, firm OSS adoption, is from the 2006 e-Business Watch data, using participating firms' responses to the question: "Does the company use open source operating systems like Linux?" (1 = "yes"; 0 = "no"; missing value = "don't know"). Linux is the most important, most popular, and most mature example of OSS (Dedrick and West, 2004, Ven and Verelst, 2008a).

#### *4.1.2. Independent variables at the country level*

Uncertainty avoidance, power distance, individualism, IT competence, and economic development are country-level independent variables. The first three are from Hofstede's website. The IT competence of a country is from the World Bank. Following previous studies (e.g., Oxley and Yeung, 2001, Wong, 2002), this study uses Internet user rate from the year 2006 (i.e., number of Internet users per 100 people) as the indicator of the IT competence of a country. The measurement of economic development of a country is the GDP at purchasing power parity (PPP) per capita in 2006 using data from the World Bank. Prior studies widely use GDP to represent a country's economic development level in the literature (Franke and Nadler, 2008, Spencer and Gomez, 2004).

#### *4.1.3. Independent variables at the firm level*

The two firm-level independent variables of this study, proprietary IT-based networks and open IT-based networks, are from the 2006 e-Business Watch data, using participating firms' responses to the questions: "Do you use proprietary standards agreed upon between you and your business partners for the exchange of electronic data?" and "Do you use XML-based standards such as ebXML, RosettaNet, UBL with buyers/suppliers for the exchange of electronic data?", respectively (1 = "yes"; 0 = "no"; missing value = "don't know").

#### *4.1.4. Control variables*

To provide more rigorous tests of the hypotheses, this study controls the effects of some relevant firm-level factors, including internal IT expertise, innovation orientation, firm age, firm size, and industry. Research suggests that these variables may affect firm OSS adoption (Morgan and Finnegan, 2007, Paré et al., 2009, West and Dedrick, 2006). This study measures internal IT expertise using a dummy variable of whether a firm has its own IT staff and measures innovation orientation of a firm by whether a firm has product innovations in the past year. Nine dummy variables represent 10 industries to which firms belong and three dummy variables represent four types of firm size, that is, micro, small, middle, and large. All of these indicators are from the 2006 e-Business Watch data. Table 1 shows the mean statistics and correlation matrix of the key country-level variables. For illustrative purposes, the table also includes the OSS adoption level of each country, using the proportion of participating firms that adopt OSS in that country. However, readers should note that in the hypotheses testing, the dependent variable is the firm-level, rather than the country-level, OSS adoption score.

**Table 1.** Means and correlation matrix of main variables.

	Mean	1	2	3	4	5	6
OSS adoption level	0.21	1					
Uncertainty avoidance	71	0.20	1				
Power distance	50	0.17	0.48*	1			
Individualism	61	0.05	-0.57**	-0.46*	1		
IT competence	55	-0.19	-0.72**	-0.64**	0.63**	1	
GDP per capita	29,395	-0.47*	-0.36	-0.59**	0.36	0.68**	1

\*  $p < 0.05$ . \*\*  $p < 0.01$ .

## 4.2. Analytical approach

The data of the study have a hierarchical structure, with firms nested within countries. To test the hypotheses, this study uses a multi-level model to simultaneously estimate both firm- and country-level effects. As OSS adoption is a dichotomous variable, the study uses a Bernoulli distribution with a logit function for the analysis. The level-1 (firm level) model for OSS adoption is:

$$\begin{aligned} \text{Log}\left[\frac{P_{ij}}{1 - P_{ij}}\right] \\ = \beta_{0j} + \beta_{1j}PropNet_{ij} + \beta_{2j}OpenNet_{ij} + \beta_{3j}ITemp_{ij} + \beta_{4j}Inno_{ij} + \beta_{5j}Age_{ij} \\ + \beta_{xj}Dummy_{ij}(FirmSize \& Industry) + r_{ij} \end{aligned}$$

where  $P_{ij}$  is the probability that firm  $i$  in country  $j$  adopts OSS.  $\beta_{0j}$  is the intercept.  $\beta_{1j} \dots \beta_{xj}$  are regression coefficients for proprietary IT-based networks (*PropNet*), open IT-based networks (*OpenNet*), and control variables, including internal IT expertise (*ITemp*), innovation orientation (*Inno*), firm age (*Age*), firm size (*FirmSize*), and industry.  $r_{ij}$  is the firm-level error term.

The level-2 (country level) model is as follows:

$$\begin{aligned} \beta_{0j} &= \gamma_{00} + \gamma_{01}UA_j + \gamma_{02}PD_j + \gamma_{03}IDV_j + \gamma_{04}ITcomp_j + \gamma_{05}EconDev_j + u_{0j} \\ \beta_{1j} &= \gamma_{10} + \gamma_{11}UA_j + \gamma_{12}PD_j + \gamma_{13}IDV_j + u_{1j} \\ \beta_{2j} &= \gamma_{20} + \gamma_{21}UA_j + \gamma_{22}PD_j + \gamma_{23}IDV_j + u_{2j} \\ \beta_{3j} &= \gamma_{30} + u_{3j} \\ &\dots \\ \beta_{xj} &= \gamma_{x0} + u_{xj} \end{aligned}$$

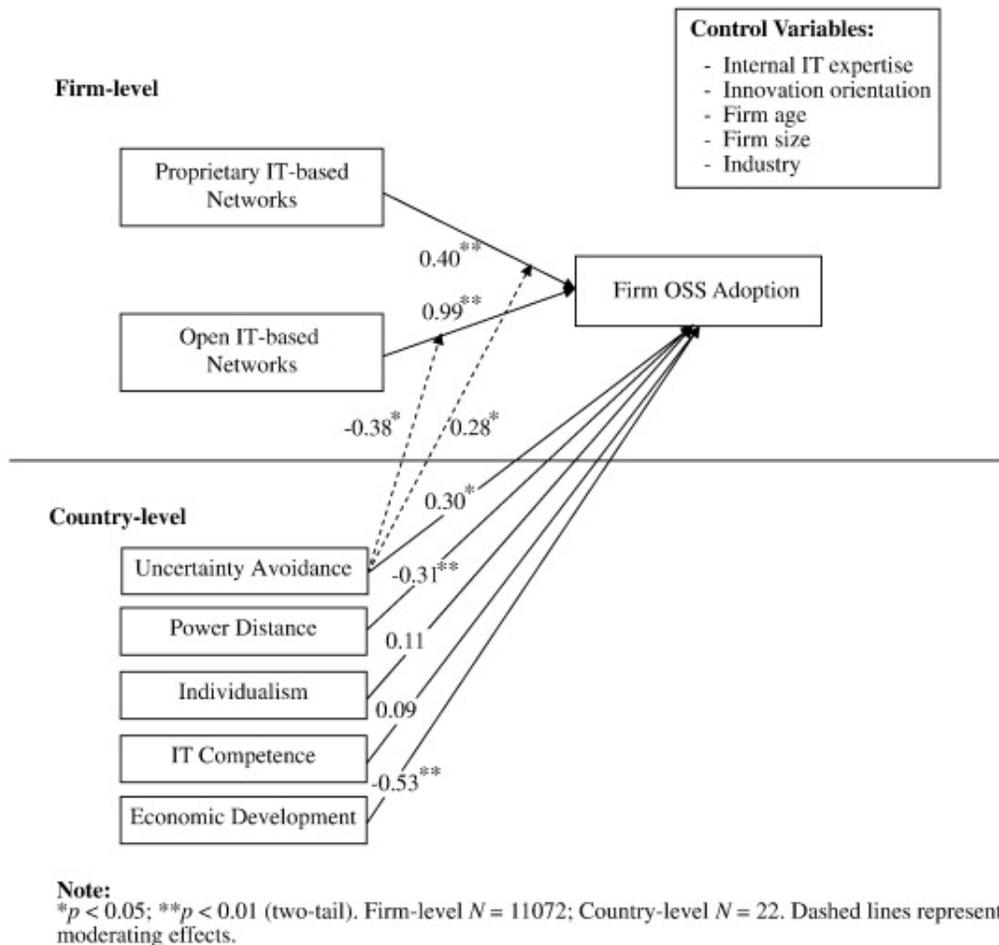
where  $\beta_{0j}$  is the intercept of the level-1 model, which relates to a country's uncertainty avoidance ( $UA_j$ ), power distance ( $PD_j$ ), individualism ( $IDV_j$ ), IT competence ( $ITcomp_j$ ), and economic development ( $EconDev_j$ ).  $\beta_{1j}$  and  $\beta_{2j}$  are the coefficients of proprietary IT-based networks (*PropNet*) and open IT-based networks (*OpenNet*) in the level-1 model, which associate with a country's uncertainty avoidance ( $UA_j$ ), power distance ( $PD_j$ ), and individualism ( $IDV_j$ ).  $u_{0j}$ ,  $u_{1j}$ , and  $u_{2j}$  represent the level-2 error terms.

This study specifies all of the coefficients  $\beta_{0j} \dots \beta_{xj}$  as random effects, with intercepts  $\gamma_{00} \dots \gamma_{x0}$  and error terms  $u_{00} \dots u_{x0}$ . However, this model is underidentified. To solve this problem, the study subsequently constrains the  $\beta$ s of control variables ( $\beta_{3j} \dots \beta_{xj}$ ) to be

constant across countries in further analyses. The HLM final output file does not show any warning message about collinearity/multicollinearity in the random part of the model. Additionally, no off-diagonal element of the Tau matrix is close to 1 or -1, suggesting that the specification of the model is appropriate.

### 4.3. Results

This study uses the statistical package HLM 6 to analyze the multi-level model and standardize all country-level independent variables in order to simplify the interpretation of the results (Raudenbush and Bryk, 2002). Since the focus of this paper is on the country level, this study reports the country-level effects first, then the firm-level effects and the cross-level interactions. At the country level, H<sub>1</sub> predicts that uncertainty avoidance associates positively with firm OSS adoption. Consistent with H<sub>1</sub>, the results show a positive relationship between uncertainty avoidance and firm OSS adoption ( $\beta = 0.30, p < 0.05$ ), indicating that the odds of adoption increase by 35% ( $e^{0.30} = 1.35$ ) with a unit increase in the standardized value of *UA*. H<sub>2</sub> indicates that power distance associates negatively with firm OSS adoption. As Fig. 1 shows, the link from power distance to OSS adoption is negative and significant ( $\beta = -0.31, p < 0.01$ ), thus lending support for H<sub>2</sub>. This finding suggests that the odds of adoption decrease by 27% ( $e^{-0.31} = 0.73$ ) with a unit increase in the standardized value of *PD*.



**Fig. 1.** The multi-level model of OSS adoption and analysis results.

H<sub>3</sub> predicts a positive relationship between individualism orientation and firm OSS adoption. The estimate supports H<sub>3</sub> directionally but is not of statistical significance ( $\beta = 0.11, p > 0.10$ ). Therefore, the findings do not support H<sub>3</sub>. A plausible reason is that OSS is a special type of innovation. While firms often adopt innovations due to their potential in generating additional values or benefits, they adopt OSS usually due to considerations in cost saving and/or risk-avoiding (Ven et al., 2008). According to previous researchers (Aaker and Lee, 2001, Trafimow et al., 1991), the collectivists and the individualists differ in goal orientation or regulatory focus. Individualists usually have a promotion focus and an orientation towards seeking benefits, gains, and self-enhancements, whereas collectivists are with a prevention focus and an orientation towards avoiding uncertainty, mistakes, and losses. Therefore, adopting OSS is unlikely in line with individualists' goal orientation towards seeking for benefits.

H<sub>4</sub> specifies that a country's IT competence associates positively with firm OSS adoption. As Fig. 1 presents, the link between IT competence and OSS adoption is positive, but the estimate is not statistically significant ( $\beta = 0.09, p > 0.10$ ), thereby rejecting H<sub>4</sub>. H<sub>5</sub> predicts a negative relationship between a country's economic development level and firm OSS adoption. Consistent with H<sub>5</sub>, the results show a significant and negative coefficient for this link ( $\beta = -0.53, p < 0.01$ ).

At the firm level, H<sub>6a</sub>, H<sub>6b</sub> specify that firms are more likely to adopt OSS if they have proprietary or open IT-based networks. As Fig. 1 indicates, the link from proprietary IT-based networks to OSS adoption ( $\beta = 0.40, p < 0.01$ ), and that from open IT-based networks to OSS adoption ( $\beta = 0.99, p < 0.01$ ) are both positive and significant. Thus, the results support H<sub>6a</sub>, H<sub>6b</sub>. In terms of the cross-level interactions, H<sub>7a</sub> proposes that uncertainty avoidance moderates the effects of IT-based networks on OSS adoption at the firm level, in a way that the effect of proprietary IT-based networks becomes stronger (H<sub>7a</sub>), but the effect of open IT-based networks becomes weaker (H<sub>7b</sub>), when the uncertainty avoidance orientation of a country is high rather than low. Supporting H<sub>7a</sub> and H<sub>7b</sub> respectively, uncertainty avoidance affects the relationship between proprietary IT-based networks and OSS adoption positively ( $\beta = 0.28, p < 0.05$ ), but negatively affects the relationship between open IT-based networks and OSS adoption ( $\beta = -0.38, p < 0.05$ ).

As for firm-level control variables, consistent with prior studies (e.g., Paré et al., 2009, West and Dedrick, 2006), the results indicate that firms with internal IT expertise and innovation orientation are more likely to adopt OSS. But the effect of firm age on OSS adoption is not significant ( $p > 0.10$ ). The results also show that firm size has a significant effect on OSS adoption, in a way that large firms are more likely to adopt OSS. Industry type significantly affects OSS adoption as well. Firms in the telecommunications industry are the most likely to adopt OSS, while those in the food and beverages industry are among the least likely to adopt OSS. These results are largely consistent with the extant literature.

## 5. Discussion

In a multi-level framework, this study examines the effects of five country-level factors, two firm-level variables, and the cross-level interactions between uncertainty avoidance and IT-based

networks on firm OSS adoption. This study finds evidence consistent with the notion that country characteristics play an important role in OSS adoption at the firm level. Power distance and economic development decrease, but uncertainty avoidance increases OSS adoption. Further, uncertainty avoidance moderates the positive effects of IT-based networks on OSS adoption in a way that the impact of proprietary IT-based networks becomes stronger, but the impact of open IT-based networks becomes weaker when uncertainty avoidance is high rather than low. The present work offers several important contributions.

First, the present research complements the extant literature that examines the antecedents of OSS adoption at the firm level. Focusing firm-level factors alone is inadequate to understand why firms adopt OSS. By investigating both country- and firm-level antecedents of OSS adoption, this study depicts a more comprehensive picture of the factors that matter in OSS adoption. The little past cross-national research on OSS adoption usually uses data from two or few countries, with a focus primarily on how economic development levels may affect firm OSS adoption. However, no research investigates the effects of cultural orientation and technological development in lieu of OSS adoption. In this regard, the present research creates an invitation to researchers for a greater pursuit of understanding the role of country contexts in firm OSS adoption.

Second, although Rogers (1995) notices that different types of communication channels (i.e., public versus private) have differential effects on innovation adopters, no study links this knowledge to the role that IT-based networks may play in OSS adoption. The current study is among the first to demonstrate that proprietary and open IT-based networks facilitate the adoption of OSS. The mechanism is that these two types of IT-based networks are analogous to private and public communications channels. These findings enrich the current literature on firm-level variables and, in doing so, advance the understanding of the differential effects of proprietary versus open IT-based networks on OSS adoption.

Finally, the present research is the pioneer to explore the interplay of uncertainty avoidance at the country level and IT-based networks at the firm level. The results show that the effect of proprietary IT-based networks on OSS adoption becomes stronger, and the effect of open IT-based networks becomes weaker, with the increase of uncertainty avoidance. These findings suggest that with the increase of uncertainty avoidance, firms are likely to rely more on proprietary IT-based networks, rather than on open IT-based networks, to get trustworthy information. These cross-level interactions are novel and important, and point out new research avenues for future researchers to integrate firm- and country-level effects in studying innovation in general and OSS adoption in particular.

### 5.1. Managerial implications

This study suggests that in making OSS adoption decisions, cultural values are important to focus on, among other firm-level variables. One finding is that a country's uncertainty avoidance positively affects a firm's tendency to adopt OSS. With this information, countries like Greece and Portugal (high uncertainty avoidance) may highlight the benefits of reliability and security when promoting the use of OSS. Another finding of this study is that firms in a country with high power distance are less likely to adopt OSS. For policy makers in high power distance

countries (e.g., Slovakia and Romania), setting up a bonus to encourage conversations between IT employees and top managers may be a useful approach to remove the barriers of OSS adoption. Furthermore, the results suggest that firms in less-developed countries are more likely to adopt OSS. For governments of less-developed countries, an important message they need to send to their business managers is the cost saving benefit of using OSS. A relevant message governments may send is the reliability and security of OSS. Due to this feature of OSS, firms should be less likely to experience failures with OSS, which means less maintenance costs and less total cost of ownership.

Finally, the uncertainty avoidance of a country also moderates the effects of IT-based networks on OSS adoption. This study distinguishes two types of IT-based networks, proprietary and open IT-based networks. The results show that both networks, by working as communication channels, can increase a firm's adoption of OSS; however, the effect of proprietary IT-based networks on OSS adoption is extremely important for countries with a high level of uncertainty avoidance. This finding suggests that policy makers consider promoting and rewarding firms' investment of proprietary IT-based networks through such means as tax cuts in order to facilitate the advance of the OSS movement in these countries.

## 5.2. Limitations and future research

This study has three limitations which future research may address. First, this study only focuses on one type of OSS—operating systems. Although operating systems such as Linux are the most important and the most popular example of OSS (Dedrick and West, 2004, Ven and Verelst, 2008a), future research needs to expand this study by investigating other types of OSS. Second, this study identifies five country characteristics that can be relevant to a firm's adoption of OSS. Other country-level factors may also matter in the adoption of OSS. Future research may identify such country characteristics and study their effects on firm OSS adoption. Finally, the sample of this study may contain foreign subsidiaries of multinational firms on which the cultures of both host and home countries have influence. This study only takes the culture of host countries into account due to the lack of necessary information. Future research may purge the sample by removing such firms.

## 5.3. Conclusion

This study finds that a country's cultural, technological, and economic characteristics significantly influence a firm's adoption of OSS. In particular, the uncertainty avoidance of a country positively affects a firm's tendency to adopt OSS, but the power distance and economic development level of a country have a negative effect. In addition, country-level factors also play moderating roles in the adoption of OSS. These findings expand existing research that mainly focus on firm-level factors and augment the understanding of the role of country contexts in OSS adoption. The findings suggest that policy makers of a country cannot simply copy other countries' successful policies regarding OSS promotion and apply to their own country. In order to effectively promote the use of OSS among firms, they need to set up policies that fit the specific situations of their own country. In addition, policy makers also need to communicate the right advantages from the many that OSS possesses to the business managers in their country.

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