THE EFFECT OF ICT INFRASTRUCTURE SOPHISTICATION AND INTERCONNECTION ON THE PROPENSITY FOR CLOUD COMPUTING ADOPTION

Niki Kyriakou, Department of Information and Communication Systems Engineering, University of the Aegean, Greece

nkyr@aegean.gr

Euripidis Loukis, Department of Information and Communication Systems Engineering, University of the Aegean, Greece

eloukis@aegean.gr

Abstract

Cloud computing (CC) is expected to lead to new highly beneficial models of information and communication technologies (ICT) acquisition and management in firms. According to relevant literature CC enables firms having weak ICT support to create sophisticated ICT infrastructures rapidly and at a low cost. However, the adoption of CC has been below expectations. Therefore, it is important to conduct further research on factors affecting CC adoption positively or negatively. In this paper is presented an empirical investigation of the effects of two important firm's ICT infrastructure characteristics, its sophistication and electronic interconnection with suppliers and customers, on firm's propensity to adopt CC. It is based on a large dataset collected from 676 European firms from the glass, ceramics and cement industries through the e-Business Survey of the European Commission. It has been concluded that in these industries both the sophistication and the electronic interconnection of firm's ICT infrastructure have a positive effect on its propensity to adopt CC. This finding is not in agreement with the high expectations from and promises of CC: in this context it is not the firms lacking a highly sophisticated and interconnected ICT infrastructure that have more interest and propensity to use CC services in order to obtain it, but on the contrary the firms having such a strong infrastructure in order to reduce its cost.

Keywords: cloud computing, adoption, ICT sophistication, ICT interconnection.

1 INTRODUCTION

Cloud computing (CC) is one of the most important developments in the area of business exploitation of Information and Communication Technologies (ICT), which is expected to lead to a great revolution and a new paradigm in business computing. According to US National Institute for Standards and Technology (NIST), CC is defined as "[…] a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of computing resources (e.g. networks, servers, storage, applications, services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." (Espadanal and Oliveira, 2012). Marston et al. (2011) attempt a composition of existing definitions, and define CC as a new ICT service model, through which customers can have computing resources (both hardware and software) delivered to them on-demand over a network – usually the Internet – providing location and device flexibility.

Armbrust et al. (2010) provide a more narrow definition of CC, stating that this term 'refers to both the applications delivered as services over the Internet and the hardware and systems software in the data centers that provide those services', which focuses on one of the main categories of CC services, the Software as a Service (SaaS). Additionally, two more categories of 'lower level' CC services have been developed, the IaaS (Infrastructure as a Service) and the PaaS (Platform as a Service).

The above literature also emphasizes that one of its biggest advantages is that an important part of ICT costs is transformed from capital expenditure (i.e. investment for hardware and software acquisition) to operating expenditure, as user firms pay for the CC services they get, based on the real use they make of them; furthermore, user firms having to incur operation, support and maintenance costs. According to Etro (2009) the introduction of CC is expected to have a positive impact on entry and competition in many sectors with high ICT infrastructure requirements, as it can reduce drastically the fixed costs of entry and production, turning some of them into variable costs, and this can have a strong effect on the market structure of many sectors and on the global macroeconomic performance.

CC is expected to lead to new highly beneficial models of information and communication technologies (ICT) acquisition and management in firms, as it provides to them substantial benefits: lower cost of ICT support, decrease of required ICT capital investment, rapid deployment, and high flexibility and scalability (it can be adapted to changing needs and loads) (Hugos and Hulitzky, 2010; Saya et al., 2010; Marston et al., 2011; Venders and Whitley, 2012). Also, according to Armbrust et al. (2010) CC enables the quick implementation of new ICT-based ideas, as 'developers with innovative ideas for new Internet services no longer require the large capital outlays in hardware to deploy their service or the human expense to operate it'. However, despite the above significant benefits the adoption of CC has been below expectations, as there are some barriers, such as data security risks, performance risks and service availability, which prevent its adoption (Saya et al., 2010; Wu, 2011a and 2011b; Benlian and Hess, 2011; Hsu et al., 2014). Therefore, it is important to conduct further research in order to understand better CC adoption and identify factors affecting it positively or negatively. The characteristics of the firm and its external environment are expected to affect the magnitude of both the benefits generated by CC and also the risks posed by it, and therefore finally CC adoption propensity. So it is particularly interesting to examine the effects of such characteristics on firm's propensity to adopt CC, as this will reveal contexts for which CC is viewed as more suitable (so it is on them that the promotion efforts of the CC services providers might have to focus), and also context for which CC is viewed as less suitable (so that both the research community and the CC services providers should develop improvements in CC services for increasing their benefits, increasing their risks, and finally making them more suitable and attractive for such contexts).

This paper makes a contribution in this direction. It empirically investigates the effects of two important firm's characteristics associated with its ICT infrastructure, the sophistication and the electronic interconnection of it with suppliers and customers, on firm's propensity to adopt CC. It is based on a large dataset collected from 676 European firms from the glass, ceramics and cement industries through the e-Business W@tch Survey of the European Commission. Our study aims to investigate empirically the following research questions:

- to what extent the promises of CC to enable firms having a weak ICT infrastructure to obtain a more sophisticated one based on CC services are fulfilled ?

- is it the firms lacking a highly sophisticated and interconnected ICT infrastructure that have more interest and propensity to use CC services, or on the contrary the firms having a strong, sophisticated and interconnected ICT infrastructure (since the latter already have an extensive knowledge base concerning the ICT support of their functions and processes, and at the same time high ICT costs, therefore have a strong motivation to reduce it by using CC services) ?

We expect that both CC services providers and users will be interested in and benefit from the findings of this study. It will enable the former to better focus their promotion efforts on the appropriate segments of firms, to optimize their marketing activities, and also to make the required improvements of their offerings, and the latter to make better and more informed decisions concerning CC related issues.

The structure of this paper consists of six sections. In section 2, a literature review is provided while the following section 3 formulates the research hypotheses of this study. In section 4 our data and method are presented, while in section 5 the results of our research are described and discussed. Finally, in section 6, our conclusions are summarized, and future research directions are proposed.

2 LITERATURE REVIEW

As mentioned in the introduction, the lower level of CC adoption by firms in comparison with the high initial expectations (Saya et al., 2010; Wu, 2011a and 2011b; Benlian and Hess, 2011; Hsu et al., 2014) has motivated some research in order to identify factors affecting positively or negatively CC adoption.

There is one stream of CC adoption empirical research based on the Technology, Organization and Environment (TOE) theory (Baker, 2011); the latter identifies three groups of factors affecting the adoption of technological innovations by firms: technological (= perceived characteristics of the technological innovation), organizational (= firm's characteristics) and environmental (= characteristics of firm's external environment) ones. Using TOE theory as their theoretical foundation Low et al. (2011), using data from a sample of 111 Taiwanese high-tech industry firms, examine the effect of a set of technological factors (relative advantage, complexity and compatibility), organizational factors (top management support, firm size and technology readiness) and environmental factors (competitive pressure and trading partner pressure) on CC adoption. They found that perceived relative advantage, top management support, firm size, competitive pressure and trading partner pressure have statistically significant effects on CC adoption. Alshamaila et al (2013), based on TOE theory as well, examined the effect of a wider set of technological factors (relative advantage, uncertainty, privacy risk, compatibility, observability, complexity and trialability), organizational factors (top management support, innovativeness and prior similar technology experience) and environmental factors (competitive pressure and external support) on the propensity to adopt CC, using data from a sample of 104 Greek firms, mainly SMEs. From all the above examined factors, only the perceived relative advantage of CC was found to have a statistically significant impact on CC adoption decisions. Another TOE-based study has been conducted by Hsu et al. (2014), which examines the effect of perceived benefits and business concerns (technological factors), IT capability (IT personnel and budget - organizational factor) and external pressure (environmental factor) on CC adoption intention, using data from 200 Taiwanese firms. It concluded that the first three of these factors are significant determinants of CC adoption while the fourth is not.

Another stream of CC adoption empirical research is based on various adaptions of the Technology Acceptance Model (TAM). Wu (2011b) has developed an explorative model of SaaS adoption factors, which includes factors from TAM (perceived usefulness, perceived benefits, perceived ease of use, attitude, behavioral intention of future use) and its extensions (social influence, marketing efforts), and also CC specific factors (security and trust). Using data collected from 42 Taiwanese managers, a structural equation model was estimated connecting the above factors. It leads to the conclusion that the main factors affecting intention to use CC in the future is perceived ease of use, followed by perceived usefulness, which are both affected by social influences and marketing. Furthermore, Wu (2011b) used data mining techniques (rough set theory) in order to extract relations among the above TAM-based factors of the previous study, using data collected from 246 Taiwanese managers, and concluded that expert opinions are very influential for CC adoption, which is also affected significantly by the perceptions concerning CC effectiveness.

Furthermore, there are CC adoption empirical studies based on the synthesis of different theoretical frameworks. Saya et al. (2010), based on the institutional theory and the real options theory, and using data collected from 101 ICT professionals from Singapore and Japan, formulated and estimated a four layers structural equation CC adoption model. They conclude that institutional influences (e.g. from government, customers, suppliers, competitors, strategic partners, industry and trade organizations, professional bodies) affect organizations perceptions about the technological characteristics of CC (perceived accessibility, scalability, cost effectiveness and lack of security), and through them the perceptions on the provided real options by CC adoption (concerning ICT applications growth,

abandonment and deferral) and finally the intention to adopt CC. Benlian et al. (2009) the effects of perceived SaaS opportunities (cost advantages, strategic flexibility, focus on core competencies, access to specialised resources and quality improvements) and risks (performance, economic, strategic, security and managerial ones) on the intention to increase the level of its adoption, having as theoretical foundations the theory of reasoned action in combination with previous research on ICT outsourcing and application service provision (ASP). They conclude that the perceived cost advantages have the strongest effect on the perceived level of positive opportunities provided by SaaS, followed by strategic flexibility and the quality improvement; on the contrary the focus on core competencies and the access to specialized resources do not have statistically significant effects. Furthermore, the security risks have the strongest effect on the perceived level of risk posed by SaaS, followed by the performance, economic and strategic risks; on the contrary the managerial risks do not have statistically significant effects. Finally, the perceived opportunities have a strong positive effect on the intention to increase SaaS adoption while the perceived risks have a moderate negative effect on it. Wu et al. (2013) study empirically the effects of two information processing requirements related factors (business process complexity and entrepreneurial culture) and two information processing capacity related factors (applications‟ functionality and compatibility) on the intention to adopt CC, using data from 289 USA manufacturing and retail firms. The theoretical foundations of this study are the innovation diffusion theory (DOI) (focusing mainly on its relative advantage and compatibility perspectives) and the information processing view of the firm. They conclude that business process complexity and also applications compatibility have negative effects on CC adoption intention while, on the contrary, entrepreneurial culture and applications functionality have negative effects.

Our study makes a contribution to this existing empirical literature on CC adoption factors, by empirically investigating the effects of two important firm's characteristics associated with its ICT infrastructure, the sophistication and the electronic interconnection of it with suppliers and customers, which have been investigated only to a very limited extent, on firm's propensity to adopt CC, based on a large dataset from 676 European firms from the glass, ceramics and cement industries.

3 RESEARCH HYPOTHESES

Our first research hypothesis concerns the impact of firm's ICT infrastructure sophistication on its propensity for CC adoption. In previous literature (Hugos and Hulitzky, 2010; Marston et al., 2011; Venders and Whitley, 2012) there are arguments concerning the usefulness of CC for firms not having sophisticated ICT infrastructures, as it enables them to gain access to more ICT capabilities and functionalities (e.g. using SaaS services) at a low cost, without the need for ICT investments, and in a short time. So we would expect that firm's having weak ICT infrastructures with limited capabilities and sophistication have a stronger motivation to adopt CC than the ones having highly sophisticated ICT infrastructures; as the latter have already extensive ICT support of their business processes, it is less likely to be interested in CC services. However, there are some arguments pointing to the other direction: firms having highly sophisticated ICT infrastructures usually have high ICT operations, support, maintenance and upgrade costs, so they have a strong motivation to use CC services in order to reduce these costs (e.g. by using IaaS and PaaS services for hosting some of their applications, or even by using SaaS for replacing some older and/or bespoke applications with more modern standard software packages). So firms having more sophisticated (and therefore more costly) ICT infrastructures have a stronger motivation to use an appropriate mix of CC services for reducing their ICT related costs than firms with less sophisticated (and therefore less costly) ICT infrastructures. For these reasons, we have formulated two alternative research hypotheses on this:

H1a. The degree of sophistication of firm's ICT infrastructure has a negative impact on its propensity for Cloud Computing adoption.

H1b. The degree of sophistication of firm's ICT infrastructure has a positive impact on its propensity for Cloud Computing adoption.

The second hypothesis concerns the impact of the electronic interconnection with firm's customers or suppliers on its propensity for CC adoption. Previous research on the adoption of ICT outsourcing in general (e.g. Arvanitis and Loukis (2013)), and CC in particular (e.g. Nuseibeh (2011)), has concluded that asset specificity (defined as the degree or customization vs. standardization of providers' assets used for providing the service) reduces the propensity for both. Asset specificity is associated on one hand with the ability of the service provider to redeploy the particular assets, and on the other hand with the ability of the service user firm to migrate smoothly to another provider. Higher assets specificity leads to higher risks for the provider not to be able to use these assets when the particular contract is terminated, and also for the user firm to have difficulty of migrating to another provider (e.g. in case of prices increase or poor service); these result in lower propensity for CC services provision/use respectively. In the case of CC services problems of asset specificity will arise if the user firm requires highly customized services (and not the standardized or partially customized services usually offered by CC providers), which will have negative impact on CC services provision/use (Nuseibeh, 2011). Therefore we expect that electronic interconnection of firm's ICT infrastructure with the ones of suppliers and customers will increase the corresponding provider's assets specificity, so it will have a negative effect on firm's propensity for CC adoption. However, there are some arguments pointing to the other direction: CC providers increasingly develop infrastructures for integration with various standardised software applications (using the Application Programming Interfaces (APIs) the latter provide), and also maintain them (in cases of new versions/releases of these applications or their APIs). These are quite costly, so firms having high degree of electronic interconnection of their ICT infrastructures with the ones of suppliers and customers have to bear these high costs; therefore they have strong motivation to use CC services, if they also include such interconnections and also their maintenance, at a lower cost. Therefore, we have formulated two alternative research hypotheses on this as well:

H2a. The degree of electronic interconnection with suppliers and customers has a negative impact on the propensity for Cloud Computing adoption.

H2b. The degree of electronic interconnection with suppliers and customers has a positive impact on the propensity for Cloud Computing adoption.

4 DATA AND METHOD

The data for this study were collected through the "e-Business Survey 2009", which was conducted by the e-Business Market W@tch (www.ebusiness-watch.org), under the auspices of the European Commission. The aim of this survey was to collect data concerning the use of various ICT types, and also ICT skills and investment in the European glass, ceramic and cement industries. Data were collected through computer-assisted telephone (CATI) interviews from a sample of 676 firms from six European countries (Germany, France, Italy, Poland, Spain, UK); 53.8% of the sample firms were small (with 1-49 employees), 33.6% were medium (with 50-249 employees) and the remaining 12.6% were large firms (with more than 250 employees).

Our dependent variable is the propensity for CC adoption (Prop_Cloud) and concerns the relevance or not of CC for the firm; it has three possible values: very relevant, partly relevant, or not relevant. For measuring the degree of sophistication of firms' ICT infrastructure (hypothesis H1) we use two measures: one for the degree of sophistication of administrative support ICT infrastructure (calculated as the average of three binary variables: use of ERP systems (yes/no), use of SCM systems (yes/no) and use of CRM systems (yes/no)), and another one measuring the degree of sophistication of production support ICT infrastructure (calculated as the average of two binary variables: use of CAD systems (yes/no) and use of CAM systems (yes/no)). For measuring the degree of electronic interconnection with suppliers and customers (hypothesis H2) we also used two measures: one for the degree of electronic interconnection with suppliers (calculated as the average of three binary variables: EDI connections with suppliers (yes/no), ERP connected with suppliers' one (yes/no) and share information on inventory levels or production plans with suppliers (yes/no)), and another one measuring the degree of electronic interconnection with customers (calculated as the average of three binary variables: EDI connection with customers (yes/no), ERP connected with customers' one

(yes/no) and share information on inventory levels or production plans with customers (yes/no)). In the Appendix are shown all e-Business Survey questions used in this study, providing the exact definitions of all our variables.

In order to test our aforementioned research hypotheses H1 – H2 we perform X^2 tests and also calculate two measures of association between ordinal variables, the Somers' d and the Kendall's tau-b), proposed by classical statistical literature. In particular, both measures range from -1 to 1, with values close to an absolute value of 1 indicating a strong relationship between the two variables, and values close to 0 indicating little or no relationship between the variables.

5 RESULTS AND DISCUSSION

In Table 1 we can see for each of our four independent variables the significance of the X^2 test with the propensity for CC adoption (Prop_Cloud) dependent variable (in the second column), the corresponding Sommers' D coefficient (in the third column) and the Kendall tau-b coefficient (in the fourth column). We can see that for all four independent variables the significance of X^2 tests is less than 5%; also all the calculated Sommers' D and Kendall tau-b coefficients are statistically significant (shown in bold), and have all positive values. In the Appendix Tables A2 to A5 we can see the cross-tabulation tables of our four independent variables with the CC adoption variable, which confirm the above conclusions: we remark that for lower values of these four variables the percentages of firms finding CC not relevant (value 0) are much higher than for the higher values. Therefore we can conclude that in the examined industries (glass, ceramics and cement) the degree of sophistication of firm's ICT infrastructure and the degree of its electronic interconnection with suppliers and customers has a positive impact on firm's propensity for CC adoption. So research hypotheses H1b, and H2b are supported. Among the two examined ICT sophistication measures, we remark that the one concerning administrative support has a stronger association with propensity for CC adoption than the one concerning production support. The two examined measures of ICT infrastructure electronic interconnection (with suppliers and customers respectively) have similar levels of association with propensity for CC adoption.

Variable	Significance of X^2 test	Sommer's D	Kendall tau-b
Sophistication of administrative support ICT Infrastructure	0.000	**0.144**	**0.163**
Sophistication of Production Support ICT Infrastructure	0.003	**0.081**	**0.091**
Electronic Interconnection with Suppliers	0.000	**0.133**	**0.139**
Electronic Interconnection with Customers	0.001	**0.141**	**0.143**

Table 1. Sommer's D and Kendall tau-b coefficients of independent variables with the propensity for CC adoption

Our results indicate that despite the initial expectations and promises that CC would enable firms having a weak ICT infrastructure in order to obtain a more sophisticated one at a low cost, it is on the contrary the firms having a strong, sophisticated and interconnected ICT infrastructure that show higher propensity to adopt CC. This is because the latter already have an extensive knowledge base concerning the ICT support of their functions and processes, and at the same time high ICT operations, support, maintenance and upgrade costs, and also high costs of electronic interconnections' maintenance and further upgrade if required, therefore they have a strong motivation to reduce it by

using CC services. This can happen by using IaaS and PaaS services for hosting some of their existing applications, or even by using SaaS for replacing some older and/or bespoke applications with more modern standard software packages; also, by using CC services from providers who have developed infrastructures for integration with various standardised software applications (using their APIs), and systematically maintain them (in cases of new versions/releases of these applications or their APIs). It would make sense for a firm that is already quite familiar with ICT to be more receptive to new technologies such as the CC, as it can understand them in-depth, select the most appropriate of them, and manage the relationship with the CC provider(s). Firms having less sophisticated ICT infrastructures have limited experience and capabilities in supporting electronically their business functions and processes. So they probably feel that they do not have the capabilities to examine existing CC services offered by various providers, select the most appropriate of them that fulfil their needs, and manage the relationship with the CC provider(s). For such firms making a progress in this direction seems risky, so they probably do not want the additional risk of using CC services from an external provider (since, as mentioned in the first two sections, CC has not only benefits, but also some risks as well).

6 CONCLUSION

Cloud computing constitutes a major development in the area of business exploitation of ICT, which is expected to lead to a new paradigm of ICT resources acquisition and management by firms. It enables firms having weak ICT support to create sophisticated ICT infrastructures rapidly and at a low cost. However, although it comes with great advantages, it also poses some risks as well, which build barriers to its adoption. For these reasons the adoption of CC has been below expectations. Therefore, it is of great importance to investigate the factors that affect positively or negatively the adoption of CC by firms. This research will be useful for both CC services providers and users, as it will provide a basis for the former in order to focus better their promotion efforts on the appropriate segments of firms, to optimize their marketing activities, and to make the required improvements of their offerings, and also for the latter in order to make better and more informed decisions concerning CC related issues.

In this direction, the previous sections of this paper have presented an empirical study of two important firm's characteristics associated with its ICT infrastructure, the sophistication and the electronic interconnection of it with suppliers and customers, on firm's propensity to adopt CC. These factors have not been studied in previous relevant empirical literature. Our study has been based on data that collected through a European Commission survey named e-Business W@tch Survey. Data consists of 676 European firms from three sectors (glass, ceramic, cement). It has been concluded that in these industries both the sophistication and the electronic interconnection of firm's ICT infrastructure have a positive effect on its propensity to adopt CC. This finding is not in agreement with the high expectations from and promises of CC: in these industries it is not the firms lacking a highly sophisticated and interconnected ICT infrastructure that have more interest and propensity to use CC services in order to obtain it, but on the contrary the firms having such a strong infrastructure in order to reduce its cost.

Further research is required on the effects of various characteristics of firm's ICT infrastructure on its propensity to adopt CC, and also on the real adoption of CC services, in various sectoral and national contexts. This research should discriminate between different categories of CC services (IaaS, PaaS, SaaS), as the adoption of each might be affected differently by various characteristics of firm's ICT infrastructure.

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APPENDIX

Variable	**Definition**
Prop_Cloud	How relevant is cloud computing for your company (very relevant, partly relevant, or not relevant)?
Sophistication of administrative support ICT Infrastructure	Do you use an ERP system, that is Enterprise Resource Planning?
	Do you use an SCM, that is Supply Chain Management?
	Do you use a CRM system, that is Customer Relationship Management?
Sophistication of Production Support ICT Infrastructure	Do you use a CAD system, that is Computer Aided Design?

	Do you use a CAM system, that is Computer Aided Manufacturing?
Electronic Interconnection with Suppliers	Does your company maintain EDI connections with suppliers?
	Is your ERP system connected with that of a supplier?
	Does your company share information on inventory levels or production plans electronically with suppliers?
Electronic Interconnection with Customers	Are you connected with customers through EDI?
	Is your ERP system connected with that of a customer?
	Do you have customers who share information on their inventory levels or production plans electronically with you?

Table A1. e-Business Survey questions used for this study

		Sophistication of Administrative Support ICT Infrastructure			
		.00	.33	.67	1.00
Cloud	.00	91.8%	86.7%	80.6%	65.7%
	1.00	7.70%	10.9%	18.4%	28.6%
	2.00	0.50%	2.40%	1.00%	5.70%
Total		100.0%	100.0%	100.0%	100.0%

Table A2. Cross-tabulation table between the Prop_Cloud variable and the Sophistication of Administrative Support ICT infrastructure variable

		Sophistication of Production Support ICT Infrastructure		
		.00	.50	1.00
Cloud	.00	89.7%	88.7%	75.9%
	1.00	8.50%	10.5%	23.0%
	2.00	1.80%	0.80%	1.10%
Total		100.0%	100.0%	100.0%

Table A3. Cross-tabulation table between the Prop_Cloud variable and the Sophistication of Production Support ICT infrastructure variable

		Electronic Interconnection with Suppliers			
		.00	.33	.67	1.00
Cloud	.00	90.4%	75.8%	91.2%	71.4%
	1.00	8.80%	20.2%	8.80%	28.6%
	2.00	0.80%	4.00%	.00%	.00%
Total		100.0%	100.0%	100.0%	100.0%

Table A4. Cross-tabulation table between the Prop_Cloud variable and the Electronic interconnection with suppliers

		Electronic Interconnection with Customers			
		.00	.33	.67	1.00
Cloud	.00	89.6%	80.6%	64.3%	50.00%
	1.00	9.50%	16.3%	28.6%	50.00%
	2.00	0.90%	3.10%	7.10%	.00%
Total		100.0%	100.0%	100.0%	100.0%

Table A5. Cross-tabulation between the Prop_Cloud variable and the Electronic interconnection with customers