OPERATIONAL AND INNOVATION COLLABORATION AND CLOUD COMPUTING

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Abstract

A major trend in the modern economy is the increasing collaboration among firms having complementary resources, both at the operational and at the product/service and process innovation level. At the same time another major trend in the area of information and communication technologies (ICT) is the emergence of cloud computing (CC), which changes radically the way firms access and use ICT for supporting their activities. It has been argued that there is an association between these two trends: that CC can significantly support and facilitate business collaboration at a low cost. However, there has been no empirical investigation of this association based on large datasets. This paper contributes to filling this research gap, by presenting an empirical investigation of the effects of firm's operational and innovation collaboration with other firms, and also the use of ICT for supporting it, on firm's propensity to adopt CC. It is based on a dataset collected in the e-Business Survey of the European Commission from 676 European firms from the glass, ceramics and cement industries. It has been concluded that innovation collaboration with other firms, and also the use of ICT for supporting it, have positive effects on the propensity to adopt CC; positive effects has also, mainly in the smaller firms, the use of ICT for supporting some forms of operational collaboration with other firms.

Keywords: Cloud Computing, Collaboration, Network, Innovation, Operations.

1 INTRODUCTION

A major trend in the modern economy is the increasing collaboration among firms having complementary resources, both at the operational and the product/service and process innovation level (Rycroft, 2007; Zeng et al., 2010; Xie et al., 2013; Majava et al., 2013). The globalization, the strong competition, the continuous emergence of new technologies, the fast changes that characterise the modern business environment, as well as the high expectations and demands of consumers for high value-added products and services, and also for continuous renewal and improvement of them, make it difficult for individual firms to survive on their own, relying only on their internal resources. This drives firms to enter in various types of collaboration with other firms, in order to gain access to additional resources (e.g. equipment and production facilities, human skills, knowledge). The simplest form of this collaboration is buying products and services from other firms, however there have been

developed more complex forms of collaboration as well, such as business networks, clusters, ecosystems, innovation hubs, keiretsu, and triplehelix (Majava et al., 2013), in which participate suppliers, customers, partners, and even universities and government agencies, and collaborate in order to design, produce and promote innovative products and services. These multiple forms of collaboration among firms necessitate extensive exchange of information, both 'structured' and 'unstructured', among collaborating firms, which can be greatly supported through the use of information and communication technologies (ICT) (Baraldi and Nadin, 2006; Loukis and Charalabidis, 2013).

At the same time a major trend in the area of information and communication technologies (ICT) is the emergence of cloud computing (CC), which changes radically the way firms access and use ICT for supporting their activities (Armbrust et al., 2010; Zhang et al., 2010; Marston et al., 2011; Venders and Whitley, 2012). Marston et al (2011) define CC as "an information technology service model where computing services (both hardware and software) are delivered on-demand to customers over a network in a self-service fashion, independent of device and location'. There are three main categories of CC services currently offered: infrastructure as a service (IaaS) (= remote use of provider's storage and computing facilities), platform as a service (PaaS) (= remote use of provider's platform, including also operating system support and software development environment, for the development and deployment of applications) and software as a service (SaaS) (= remote use of software applications running on provider's systems and supported/maintained by them). CC can provide significant benefits to firms, associated mainly with the reduction of their ICT ownership and operation costs, conversion of related capital investments to operating costs, and also quick and low cost development of the ICT support required for product/service and process innovations. However, CC can pose some risks as well, associated mainly with data security (concerning lack of control of, unauthorized access to or modification of firm's data resources) and performance (e.g. availability). For these reasons the adoption of CC by firms has been lower than the initial expectations (Saya et al., 2010; Benlian and Hess, 2011; Hsu et al., 2014; Oliveira et al., 2014); this has motivated considerable research on the factors affecting positively or negatively CC adoption, which is briefly reviewed in the next section.

It has been argued that there is an association between these two major trends: a recent study conducted by the London School of Economics (LSE) based on interviews with practitioners revealed that CC has a strong potential to support and facilitate business collaboration at a low cost (Willcocks et al., 2014). In particular, the existing business computing paradigm is based on firms' internal information systems (IS), which are protected from the external world through highly secure firewalls, acting as clear and strict borders and 'gates' of the firm, inhibiting electronic collaboration with the external world (requiring complex, costly and inflexible security changes in firewall settings, security upgrades with external communication channels, etc.). On the contrary the new business computing paradigm emerging through CC moves firm's ICT support infrastructure outside its firewall, and enables much easier authorized access to appropriate parts of it (e.g. to some of the data, or some of the functionality) by external entities (e.g. customers, suppliers, business partners, etc.), anytime and from anywhere, as it happens with its employees, without having to make complex security changes in the settings of firm's firewall; this enables and facilitates a much richer collaboration with the external world, easily and at a low cost. The above study argues that this will gradually lead blurr the boundaries of firms, and in general lead to structural changes of them, giving rise to the 'cloud corporation', which has much more 'amorphous' and less stict boundaries with the external world, is much more collaborative with external stakeholders, flexible and 'fluid'. Furthermore, in recent years have been developed a variety of cloud-based collaboration tools (Forbes, 2013; Tan and Kim, 2015; Ross and Blumenstein, 2015), offered through a SaaS model, which enable firms to access and use a rich collaboration support functionalities (e.g. centralized content storage, forums, instant messaging and other interaction and productivity applications, social media type applications, project management, etc.), available to both firm's employees and also external entities anytime and from anywhere, rapidly (requiring only minimal initial settings and customizations) and at a low cost, with high levels of availability and flexibility.

However, there has been no empirical investigation of the association between business collaboration and CC based on large datasets. This paper contributes to filling this research gap, by presenting an

empirical investigation of the effects of firm's operational and innovation collaboration with other firms, and also the use of ICT for supporting them, on firm's propensity to adopt CC. Our research objective is to study CC adoption from a business collaboration perspective, and address the following research question: 'Is operational and innovation collaboration with other firms, and also the use of ICT for this purpose, a driver of CC adoption ?' or equivalently 'Do the firms view the CC as a cost-effective means of supporting operational and innovation collaboration with other firms, and as a means of reducing the cost and increasing the capabilities and flexibility of existing operational and innovation oriented electronic collaboration they have with other firms?'. Our study is based on a dataset collected in the e-Business Survey of the European Commission from 676 European firms from the glass, ceramics and cement industries.

This paper consists of six section. The introduction is followed by section 2 outlining the background of this study. Then the research hypotheses are formulated in section 3, and the data and method are described in section 4. The results are presented and discussed in section 5, and finally section 6 summarizes the conclusions.

2 BACKGROUND

2.1. Business collaboration – networking

As mentioned in the introduction, the globalization and the strong competition that characterise the modern business environment, as well as the continuous emergence of new technologies and the fast changes, and also the high expectations and demands of consumers, lead firms to increasingly collaborate with other firms, in order to gain access to wider range of resources (both hard ones, such as equipment and production facilities, and soft ones, such as human skills and knowledge) beyond their own (Rycroft, 2007; Zeng et al., 2010; Xie et al., 2013; Majava et al., 2013). This can initially take simpler forms, such as buying products and services from other firms. Today firms tend to expand their activities to wider geographical areas, buying, and also selling as well, products and services beyond their regional and country markets, in wider international markets. Furthermore, there is an increase of firms' outsourcing of some parts' production or services provision from other specialised firms all over the world, in order to take advantage of their resources and economies of scale, and focus on their core activities (Gusmano et al., 2009; Navghavi and Ottaviano, 2010; Arvanitis and Loukis, 2013). Then they proceed to more complex forms of collaboration, such as development of business networks, clusters, ecosystems, innovation hubs, keiretsu, and triplehelix structures (Majava et al., 2013), in which participate a variety of stakeholders, such as suppliers, customers, partners, and even universities and government agencies, and collaborate in order to design, produce and promote innovative products and services. Firms are increasingly creating various types of business collaboration structures, which comprise different and heterogeneous organizations, having various types of relationships among them and also economic and social exchanges, which aim at the design, production, marketing and distribution of complex products and services. These collaboration structures have become of critical importance in the modern economy (Rycroft, 2007; Busquets, 2010; Zeng et al., 2010), so competition in many industries tends to be more among such collaboration structures than among individual firms.

The participation of a firm in such collaboration structures offers significant business benefits (Baraldi & Nadin, 2006; Kajikawa et al., 2010; Zeng et al., 2010): access to complementary resources and capabilities, new markets and technologies, diverse knowledge, and also opportunities to achieve economies of scale, to share the costs and risks of firm's activities, and to cope with market and technological complexities. Also, they facilitate learning through transfer of knowledge among participating firms, acting as 'conduits' for moving and processing knowledge, so they increasingly become the 'locus' of combination of diverse knowledge and complementary resources, and collaborative creation of novel knowledge and innovation. Previous research in the innovation domain has shed light on the increasing importance of these business collaboration structures for innovation activity in the last decade (Mancinelli and Mazzanti, 2009; Zeng et al., 2010; Huizingh, 2011; Salavisa et al., 2012). It has revealed that there has been a fundamental change in the way firms design and implement innovation; while previously this has been viewed as a predominantly internal task, in the

last decade it increasingly becomes a more 'open' and collaborative process based on interactions among different firms.

The relationships among firms as part of such structures necessitate specific coordination actions at three layers (Hakansson & Snehota, 1995; Baraldi & Nadin, 2006): 'activity links' (i.e.mutual adaptations in their activities), 'resource ties' (i.e., technical connections and mutual orientations of their physical and organisational resources) and 'actor bonds' (i.e. social interactions between individuals and organisational units of collaborating firms). These coordination actions require extensive exchanges of information, both 'structured' and 'unstructured', which can be greatly supported through the use of appropriate ICT, and especially through the use of appropriate CC services, taking into account the strong potential of the latter to support and facilitate business collaboration at a low cost, as mentioned previously in the Introduction. This has lead to a big growth of the business collaboration software market, which is expected to boom from $0.85 billion in 2011 to $ 4.5 billion in 2016 (Redwood Capital, 2013). Numerous platforms have been recently developed in order to support such collaboration, by providing centralized content storage, forums, instant messaging and other interaction and productivity capabilities, and also project management and social media type capabilities; most of them are offered through a SaaS model (Forbes, 2013; Tan and Kim, 2015; Ross and Blumenstein, 2015). An examination of the recent Forrester report in business collaboration confirms these trends (Koplowitz, 2014). However, the association between business collaboration and CC has not been empirically investigated using large datasets. Our study makes some first contribution towards filling this research gap.

2.2. Cloud Computing Adoption

As mentioned in the Introduction, the adoption of CC by firms has been lower than the initial expectations, and this has motivated considerable research on the factors affecting positively or negatively CC adoption. This research can be divided into three main streams based on the underlying theoretical foundation.

The first stream of empirical CC adoption studies were based on various adaptations of the Technology Acceptance Model (TAM). Wu (2011a) developed an explorative model of SaaS adoption factors, which includes classical 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 lead to the conclusion that the main factors affecting intention to use CC in the future are perceived ease of use, followed by perceived usefulness, which are both affected by social influences (such as mass media, expert opinions and word-of-mouth) and marketing. Wu (2011b) applied data mining techniques (rough set theory) in order to extract relations among the above TAM-based factors of the previous study, based on data collected from 246 Taiwanese managers. It has been concluded that expert opinions are very influential for CC adoption, which is also affected significantly by the perceptions concerning CC effectiveness. Gupta (2013) extend the TAM and develop a five factors model of the inclination of small and medium firms to use CC, which includes perceived ease of use, cost savings, support of collaboration and data sharing, security and privacy reliability, and reliability as independent variables. Using data from 211 small and medium firms a structural equation model has been estimated, which lead to the conclusion that the perceived ease of use has the strongest effect, followed by security and privacy, and cost reduction; on the contrary the perceived reliability and support of collaboration and data sharing did not have statistically significant effects.

A second stream of empirical CC adoption research has been based on a wider theoretical foundation: the Technology, Organization and Environment (TOE) theory (Baker, 2011). This theory identifies three groups of factors that affect 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), and based on 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. 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. Mangula et al. (2014), using data from 147 Indonesian firms, examine the effect of a set of technological factors (relative advantage, compatibility, complexity, trialability, observability), organizational factors (organizational readiness, top management support) and environmental context (market pressure, market competition vendor marketing, trust in vendor, government support) on the adoption of Software as a Service (SaaS) services. They found that compatibility, observability, market competition and government support have a positive correlation with SaaS adoption, while complexity has a negative correlation with it. Oliveira et al. (2014) using data from 369 Portuguese firms examine the effects of three CC innovation characteristics (relative advantage, complexity and compatibility), two organizational context characteristics (top management support, firm size), one technological context characteristic (technological readiness) and two environmental context characteristics (competitive pressure, regulatory support). They conclude that relative advantage, technological readiness, top management support and firm size have positive effects on CC adoption, while complexity has a negative effect.

A third stream of CC adoption empirical studies is based on the synthesis of other theoretical frameworks. Benlian et al. (2009), developed a SaaS adoption model by combining and adapting for SaaS three theoretical perspectives: transaction cost theory (including in their model the application specificity and perceived uncertainty), resource-based view of the firm (including application strategic value and inimitability) and theory of planned bahaviour (including the attitude towards SaaS and also social influence). Using data collected from 297 German firms they estimated structural equation SaaS adoption models, from which it has been concluded that social influence, adoption uncertainty and application strategic value are the most consistent SaaS adoption drivers across all application types. 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 affect 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 and Hess (2009), having as theoretical foundation the theory of reasoned action in combination with previous research on ICT outsourcing and application service provision (ASP), using data collected through a survey of 349 IT executives at German companies, examine the effects of perceived SaaS opportunities (cost advantages, strategic flexibility, focus on core competencies, access to specialised resources and quality improvements) and SaaS risks (performance, economic, strategic, security and managerial ones) on the intention to increase the level of its adoption. They conclude that the perceived cost advantages have the strongest positive effect, followed by strategic flexibility and the quality improvement; the focus on core competencies and the access to specialized resources do not have statistically significant effects. Furthermore, the security risks have the strongest negative effect, followed by the performance, economic and strategic risks; the managerial risks do not have statistically significant effects. 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 dimensions) and the 'information processing view' (IPV) 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 positive effects.

From the above review of previous empirical literature on CC adoption it is concluded that most of the examined factors as to their impact on CC adoption are firms' perceptions concerning the benefits and capabilities of CC, as well as its risks. However, limited empirical research has been conducted on the effect of firm's characteristics on CC adoption, despite their influence of the former on the benefits and risks of CC perceived by the firm. The effects of only a small number of firm characteristics (mainly firm size, top management support, technological readiness and organizational readiness) on CC adoption has been empirically investigated. This study contributes to filling this research gap, by empirically investigating the effects of firm's operational and innovation collaboration with other firms, and also the use of ICT for supporting various forms of them, on firm's propensity to adopt CC.

3 RESEARCH HYPOTHESES

Our first research hypothesis concerns the effect of operational collaboration with other firms on the propensity to adopt CC. As mentioned in the introduction and in 2.1, in the modern economy firms tend to increase their operational collaboration with other firms. On one hand they outsource part of their previously internal activities, in order to focus on their core activities, and take advantage of resources and economies of scale of other firms (Gusmano et al., 2009; Navghavi and Ottaviano, 2010; Arvanitis and Loukis, 2013); this leads to an increase of their external procurement. On the other hand, they are expanding their selling activities in wider geographic areas, in order to increase their sales revenues, economies of scale, and finally profitability. Firms tend to increase the geographing scope of their sales and procurement, moving from regional markets to country, and then to international markets. These increase significantly firms' operational complexity and workload, especially in the cases of international expansion of sales (since selling to customers beyond firm's country necessitates the management of many different legislations, regulations, taxations, specific needs, etc., and also the organization of complex shipments to many geographic locations), and international procurement (sonce having suppliers beyond firm's country poses similar challenges). The above increase the requirements for storage, processing and exchange of relevant information. This leads to high costs for the development, maintenance and operation of supporting IS, and also for interconnecting them with the ones of main customers and suppliers, which can increase firm's operating costs and reduce its competitiveness. CC can be quite valuable in such cases, as it can drastically reduce the above costs, and also transform them to 'operating expenses'. Also, as mentioned in the introduction, CC moves firm's ICT support infrastructure outside its firewall, and enables much easier authorized access to appropriate parts of it (e.g. to some of the data, or some of the functionality) by external entities (e.g. customers, suppliers, business partners, etc.), anytime and from anywhere; this can provide an effective and at the same time easy, rapid to implement and low cost support of operational collaboration with these external entities. For the above reasons we expect that firms having extensive operational collaboration with other firms will have a high motivation and propensity to adopt CC. So our first research hypothesis is:

H1: The extent of firm's operational collaboration with other firms is positively associated with its propensity for cloud computing adoption.

As mentioned above operational collaboration with other firms necessitates extensive storage, processing and exchange of relevant information, which needs various forms of ICT support (e.g. electronic exchange of orders, invoices, inventory levels and other data) in order to be efficient. This ICT support has high operation, support, maintenance and upgrade costs, so it can be highly beneficial to use CC services in order to reduce these costs (e.g. by using IaaS and PaaS services for hosting some of these applications, or even by using SaaS for replacing some older and/or bespoke applications with more modern standard software packages). Also, the electronic exchange of orders, invoices, inventory levels and other data can be conducted much easier and at a lower cost if the firms we are collaborating with are given access to appropriate parts of our cloud based/hosted ICT infrastructure (data and functionality). This can provide an efficient support of operational collaboration with other firms, which has also high flexibity for addressing changes in our business

collaboration networks (new firms can be easily given such access if required, and this will activate immediately electronic collaboration with them). For the above reasons we expect that firms using ICT for supporting various forms of operational collaboration with other firms will have a high motivation and propensity to adopt CC. So our second research hypothesis is:

H2: The use of ICT for supporting firm's operational collaboration with other firms is positively associated with its propensity for cloud computing adoption.

Our third research hypothesis concerns the effect of innovation collaboration with other firms on the propensity to adopt CC. As mentioned in the introduction and in 2.1, in the modern economy innovation becomes increasingly collaborative: firms are increasingly collaborating with other firms, which possess complementary resources (e.g. equipment and production facilities, human skills, knowledge), in order to design, produce and promote innovative products, services, or even production and business processes (Rycroft, 2007; Salavisa et al., 2012; Zeng et al., 2010). This necessitates extensive exchange of information (both structured and unstructured) in all the phases of innovation life-cycle: generation of innovation ideas, selection of the most promising ones, innovation implementation, evaluation, and marketing. This can be significantly supported and facilitated through the use of appropriate ICT. The use of CC services enables the development, operation and maintenance of this ICT support of innovation rapidly, at a low cost, without having to make additional investments. As mentioned in the introduction, in the recent years have been developed a variety of cloud-based collaboration tools (Forbes, 2013; Tan and Kim, 2015; Ross and Blumenstein, 2015), offered through a SaaS model, which provide a wide range of collaboration support functionalities. For the above reasons we expect that firms having innovation collaboration with other firms will have a high motivation and propensity to adopt CC. So our third research hypothesis is:

H3: Innovation collaboration with other firms is positively associated with propensity for cloud computing adoption.

Firms already using ICT for the electronic support of their innovation collaboration with other firms can substantially reduce the operation, support, maintenance and upgrade cost of it, and also gain access to better and more extensive collaboration support functionality, by using appropriate CC services (e.g. by replacing existing on-premises collaboration support IS with the use of cloud-based collaboration tools offered through a SaaS model). For the above reasons we expect that firms using ICT for supporting innovation collaboration with other firms will have a high motivation and propensity to adopt CC. So our fourth research hypothesis is:

H4: The use of ICT for supporting firm's innovation collaboration with other firms is positively associated with its propensity for cloud computing adoption.

4 DATA AND METHOD

The data used in this study has been collected through the "e-Business Survey 2009", which has been conducted by the e-Business Market W@tch (www.ebusiness-watch.org) initiative of the European Commission, from a sample of 676 firms, from the glass, ceramic and cement sectors of 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).

The questions of the aforementioned survey used in this study are shown in the Appendix. As dependent variable has been used the propensity for CC adoption, which is measured in a three levels scale: very relevant, partly relevant or not relevant. We have used four groups of independent variables, which concern operational collaboration, electronic operational collaboration, innovation collaboration and electronic innovation collaboration respectively. The first group includes two independent variables concerning the extent of firm's operational collaboration with other firms: the geographic scope of firm's sales and procurement; they are both measured in a three levels scale: regional, country or international. The second group includes binary (yes/no) variables assessing whether or not the firm is using four types of IS for supporting four particular forms of operational collaboration with other firms: supply chain management (SCM) systems, electronic sharing of

information on inventory levels with suppliers, electronic orders from customers, and electronic invoicing. The third group includes two binary (yes/no) independent variables assessing whether or not in the development of firm's product/service innovations and process innovations respectively are involved other firms or external experts. The fourth group includes one binary (yes/no) independent variable assessing whether or not the firm is using software applications to collaborate with other firms in the development of product/service innovations or process innovations.

In order to test the research hypotheses H1 – H4 we calculated the association between the dependent variable and each of the abovementioned independent variables, using two measures of ordinal variables' association: the Somers' d and the Kendall's tau-b (both ranges from -1 to 1, with their absolute values indicating the strength of association (larger absolute values means stronger association), and their sign indicating the direction of the association. It should be noted that we did not estimate a regression model because there were high correlations between our independent variables (according to the econometric literature (e.g. Greene, 2011; Gujarati, 2008) if we have high levels of correlation between the independent variables of a regression (multi-collinearity problem), then the regression coefficients are not reliable measures of the impact of the independent variables on the dependent variable).

The above association measures were calculated initially for the entire sample, and then for two sub-samples of it: the first one included the small firms (with 1-49 employees – 53,8% of the sample), and the second one the medium and large firms (with 50 or more employees – 46,2% of the sample), in order to examine to whether the effects of the abovementioned collaboration related variables on the propensity to adopt CC depend on firm size. It should be noted that we did not create separate sub-samples for the medium and for the large firms, because they would be much smaller (especially the large firms' one) than the small firms' sub-sample, making comparison difficult, as smaller sample size increases the confidence intervals of the estimated association measures, and therefore affects their significances).

5 RESULTS

We can see the calculated Sommer's D and Kendall tau-b values between the propensity to adopt CC and each of the abovementioned independent variables, initially for the whole dataset in Table 1, and then for the small firms' sub-sample in Table 2 and for the medium and large sub-sample in Table 3. The statisitically significant values (having signicance lower than 10%) are shown in bold.

With respect to the operational collaboration we remark that for both variables there is not statistically significant association with the prospensity to adopt CC (neither in the whole sample, nor in the two sub-samples). Therefore hypothesis 1 is not supported. This indicates that having a wide geographic scope of sales and procurement, which necessitates extensive operational collaboration with a big number and variety of firms, and therefore extensive storage, processing and exchange of relevant information, is not a driver of CC adoption; firms of the three examined sectors do not view CC as a cost effective means of providing or increasing ICT support of their operational collaboration with customers and suppliers. A possible reason might be in the three examined sectors these operational collaboration processes exhibit significant specificities and complexities, leading to high levels of 'asset specificity' (e.g. need of highly specialised and customised software applications in the CC services provider side, and also extensive communication and cooperation between highly knowledgeable personnel of the CC services provider and the CC services user) and 'uncertainty' (as to whether the CC services provider can meet all the special needs with satisfactory service levels and price). This higher asset specificity and uncertainty, according to the transaction cost theory (Williamson, 1985; Benlian and Hess, 2009; Arvanitis and Loukis, 2013), make CC outsourcing of electronic collaboration with customers and suppliers more difficult and costly to manage, and less attractive and beneficial, in comparison with the on-premises alternative. Another possible reason might also be that the adoption of CC for supporting critical everyday activities (such as the operational collaboration with) is risky, and requires a certain level of 'cloud computing maturity' along several technological and organizational dimensions (Oracle, 2011); there is a chance that the three examined sectors do not possess sufficient maturity for this.

On the contrary, there is statistically significant positive association of the use of SCM systems with propensity adoption in the whole sample, and in the two size sub-samples; the same holds for the e-invoicing, but only in the whole sample and in the small firms' sub-sample, and also for the electronic orders from customers, but only in the small firms' sub-sample. However, there is not statistically significant association with the prospensity to adopt CC of the electronic sharing of information on inventory levels with suppliers (neither in the whole sample, nor in the two sub-samples). Therefore hypothesis 2 is only partially supported (only for some types of ICT use for supporting particular forms of electronic collaboration, and mainly for the small firms).

These results indicate that though the firms of the three examined sectors do not view CC as a cost effective means of providing ICT support of their operational collaboration with customers and suppliers, they view it however as a means of reducing the cost and increasing the flexibility of existing ICT support of some particular forms of operational collaboration with other firms, especially highly sophisticated ones, such as the SCM. A possible explanation for this might be that already using ICT for supporting particular forms of electronic collaboration leads to the generation and accumulation of relevant experience, knowledge and maturity within the firms, which makes it easier to define their specialised needs, and communicate them to CC services providers, to evaluate their offerings, and makes it easier to manage their relationships with CC service providers, while it also reduces uncertainty; these reduce the 'transaction costs' with the CC services provider, making this CC outsourcing more attractive and beneficial.

Also, the above results indicate that the small firms view CC as a means of reducing the cost and increasing the flexibility of existing electronic commerce related capabilities, concerning electronic customer ordering and electronic invoicing. A possible reason for this might be that the costs of operating and maintaining on-premises such ICT infrastructures are high for the small firms, as they cannot have the economies of scale that a CC services provider can have; also the small firms do not have sufficient specialised ICT personnel for the required continuous improvement and evolution of these applications, in order to exploit new technologies and satisfy new needs. However, these do not hold for the larger firms (as they can have high levels of economies of scale, and usually have sufficient specialised ICT personnel).

Independent Variable	**Sommer's D**	**Kendall tau-b**	**Research Hypothesis**
Operational Collaboration			
Geographic scope of sales	0.011	0.013	H1
Geographic scope of procurement	0.016	0.018	H1
Electronic Operational Collaboration			
Use of SCM systems	**0.190**	**0.190**	**H2**
Electronic sharing of information on inventory levels with suppliers	0.052	0.052	H2
Electronic orders from customers	0.053	0.054	H2
Electronic invoicing	**0.124**	**0.131**	**H2**
Innovation Collaboration			
Involvement of other firms in product/ service innovations	**0.130**	**0.131**	**H3**
Involvement of other firms in process innovations	**0.162**	**0.166**	**H3**
Electronic Innovation Collaboration			
Use of software applications to collaborate with other firms for product/ service or process innovations	**0.153**	**0.153**	**H4**

Table 1. Sommer's D and Kendall tau-b values between propensity to adopt CC and independent variables (for the whole sample)

Independent Variable	Sommer's D	Kendall tau-b	Research Hypothesis
Operational Collaboration			
Geographic Scope of Sales	-0.069	-0.084	H1
Geographic Scope of Procurement	-0.003	-0.004	H1
Electronic Operational Collaboration			
Use of SCM systems	**0.110**	**0.110**	**H2**
Electronic sharing of information on inventory levels with suppliers	0.090	0.091	H2
Electronic orders from customers	**0.113**	**0.117**	**H2**
Electronic invoicing	**0.190**	**0.208**	**H2**
Innovation Collaboration			
Involvement of other firms in product/ service innovations	**0.117**	**0.118**	**H3**
Involvement of other firms in process innovations	**0.216**	**0.220**	**H3**
Electronic Innovation Collaboration			
Use of software applications to collaborate with other firms for product/ service or process innovations	**0.119**	**0.120**	**H4**

Table 2. Sommer's D and Kendall tau-b values between propensity to adopt CC and independent variables (for the small firms'sub- sample)

Independent Variable	Sommer's D	Kendall tau-b	Research Hypothesis
Operational Collaboration			
Geographic Scope of Sales	0.041	0.044	H1
Geographic Scope of Procurement	0.014	0.015	H1
Electronic Operational Collaboration			
Use of SCM systems	**0.216**	**0.217**	**H2**
Electronic sharing of information on inventory levels with suppliers	0.009	0.009	H2
Electronic orders from customers	-0.008	-0.007	H2
Electronic invoicing	0.043	0.045	H2
Innovation Collaboration			
Involvement of other firms in product/ service innovations	**0.112**	**0.113**	**H3**
Involvement of other firms in process innovations	**0.093**	**0.095**	**H3**
Electronic Innovation Collaboration			
Use of software applications to collaborate with other firms for product/ service or process innovations	**0.159**	**0.160**	**H4**

Table 3. Sommer's D and Kendall tau-b values between propensity to adopt CC and independent variables (for the medium and large firms'sub- sample)

With respect to the innovation collaboration, from the above Tables 1, 2 and 3 we can see that it is much stronger associated with propensity to adopt CC than the operational collaboration. In particular, there is statistically significant positive association of innovation collaboration, both for product/service innovation and for process innovation, and also of the use of ICT for supporting it, with propensity for CC adoption, in the whole sample, and in the two size sub-samples. Therefore hypotheses 3 and 4 are both supported. These results indicate that firms of the three examined sectors view CC as a cost-effective means of providing electronic support of innovation oriented collaboration with other firms and external experts, and also as a means of reducing the cost and increasing the capabilities and flexibility of existing ICT support of innovation collaboration. A possible explanation for these is that innovation collaboration has a much smaller scale and is less critical for the everyday operation of the firms (though quite important for their future performance, or even survival) in comparison with the operational collaboration with other firms; therefore the business uncertainty generated from the use of CC services is lower for the innovation collaboration support than for the operational collaboration support. This, according to the transaction cost theory (Williamson, 1985; Benlian and Hess, 2009; Arvanitis and Loukis, 2013), leads to higher propensity for CC adoption for the former than for the latter.

6 CONCLUSIONS

Two important and widely debated trends in the modern economy is the increasing collaboration among firms, leading to the development of extensive business networks and the increase of their importance, and also the emergence of cloud computing (CC), as a new more efficient paradigm/ model of business computing (i.e. of using ICT for supporting firms' activities). In the previous sections of this paper has been presented an empirical investigation of the association between these two trends. Four research hypotheses have been formulated concerning the effects of firm's operational and innovation collaboration with other firms, and also the use of ICT for supporting it, on firm's propensity to adopt CC. They have been tested using a dataset collected from 676 European firms from the glass, ceramics and cement industries through the e-Business Survey of the European Commission.

Our results provide some first evidence concerning the existence of association between the above important trends: we have found that collaboration, mainly innovation oriented, has positive impact on propensity for CC adoption. In particular, it has been concluded that innovation oriented collaboration with other firms (for the development of product, service and process innovations), and also the use of ICT for supporting it, are drivers of CC adoption; this holds for both smaller and larger firms. On the contrary, the operational collaboration with other firms is not a driver of CC adoption in the three examined sectors; however, the use of ICT for supporting some forms of operational collaboration with other firms is a driver of CC adoption, mainly in the small firms.

Our results indicate that firms of these sectors view CC as a cost-effective means of supporting collaboration with other firms in their innovation development activities, but not in their critical every day operations. This might be due to specificities and complexities of the processes and collaboration practices of the three examined manufacturing sectors, which result in limited supply of corresponding specialised SaaS applications by CC providers. Also, the importance of this operational collaboration with suppliers and customers for the everyday activities of these firms makes them hesitant to use external providers of ICT support of them. However, the firms of these sectors view CC as a means of reducing the cost and increasing the capabilities and flexibility of existing ICT support of innovation oriented collaboration, and also of highly sophisticated forms of operational collaboration, such as SCM; furthermore, the small firms view CC as a means of reducing the cost and increasing the flexibility of their electronic commerce capabilities (e.g. concerning electronic customer ordering and electronic invoicing).

Further empirical and theoretical research is required on the association between business collaboration and CC. It should investigate on one hand different forms of business collaboration (both operational and innovation oriented ones), and on the other hands adoption of different categories of CC services (e.g. IaaS, PaaS, SaaS), in various sectoral and national contexts. Also, future relevant

research should use a more detailed measurement of the extent of CC services adoption than the binary one used in this study. Furthermore, it would be useful to conduct research for identifying moderators of the relationship between business collaboration and CC adoption (e.g. various characteristics of the firm, including firm's 'cloud computing maturity' along various technological and organizational dimensions (Oracle, 2011), and also its external environment, that increase or decrease the strength of this relationship).

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Appendix: Variables Definitions – Questions

Variable	Definition
Dependent variable	
Propensity for cloud computing adoption	How relevant is cloud computing for your company ?
Independent variables: operational collaboration	
Geographic scope of sales	What is your company's most significant sales market?
Geographic scope of procurement	Do you procure primarily from suppliers in your region, in your country of from an international supplier base?
Independent variables: electronic operational collaboration	
Use of SCM systems	Do you use an SCM system (Supply Chain Management) ?
Electronic sharing of information on inventory levels with suppliers	Does your company share information on inventory levels electronically with suppliers?
Electronic orders from customers	Can customers order goods or services from your company online on the internet or through other computer networks, not counting manually typed e-mails?
Electronic invoicing	Does your company use e-invoicing, that is sending or receiving invoices electronically?
Independent variables: innovation collaboration	
Involvement of other firms in product/ service innovations	Were external experts or business partners involved in developing new products or services?
Involvement of other firms in process innovations	Were external experts or business partners involved in developing new processes?
Independent variables: electronic innovation collaboration	
Use of software applications to collaborate with other firms for product/ service or process innovations	Does your company use online software applications other than e-mail to collaborate with business partners in the development of new products, services or processes?