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ORIGINAL ARTICLE

An empirical investigation of the effects of firm characteristics on the propensity to adopt cloud computing

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Abstract Cloud computing (CC) is emerging as a new paradigm of resource acquisition and management of information and communication technologies (ICT) by firms, which can offer significant benefits, but at the same time can pose significant risks as well, so its adoption by firms has been lower than the initial expectations. Therefore, it is quite important to gain a better understanding of the factors affecting positively or negatively the adoption of CC. This paper presents an empirical investigation of the effects on a firm's propensity to adopt CC of a set of firm characteristics referring to technological infrastructure, strategy, personnel skills, size and competition. Its conceptual foundation is the Technology, Organization and Environment theory of technological innovation adoption. Our study is based on data from 676 European manufacturing firms from the glass, ceramics and cement sectors, which have been collected through the e-Business Survey of the European Commission. The results indicate that in the above sectors ICT infrastructure sophistication has the strongest positive effect on CC adoption propensity among all examined firm characteristics. Furthermore, we have found that the existence of an ICT investment reduction strategy, the employment of specialized ICT personnel and the existence of previous experience of ICT outsourcing also have positive effects on a firm's propensity to adopt CC. On the contrary, employees

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ICT skills, price and quality competition do not affect CC adoption propensity. Finally, our results also indicate that in the three examined sectors firm size has no significant influence on the propensity to adopt CC.

Keywords Cloud computing · Innovation · Strategy · Personnel · Infrastructure · Competition

1 Introduction

Cloud computing (CC) is emerging as a new paradigm of resource acquisition and management of information and communication technologies (ICT) by firms (Marston et al. 2011; Zhang et al. 2010; Venders and Whitley 2012; Hoberg et al. 2012; Willcocks et al. 2013, 2014; Müller et al. 2015). It has been defined by the US National Institute for Standards and Technology (NIST) 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' (Mell and Grance 2010). Marston et al. (2011) provide a more detailed definition of CC as a novel ICT service model, where the computing services (both hardware and software) required by a firm are delivered by external providers on an on-demand basis over the Internet, thus independent of device and location. User firms pay for the ICT services they really use as an operating expense, without having to make significant ICT capital expenditures (e.g., for servers and software), and also without having to incur ICT operation, support and maintenance costs. The cloud services currently offered can be grouped into three categories: Infrastructure as a Service (IaaS) (=use of providers' remote storage and computing facilities), Platform as a Service (PaaS) (=remote use of providers' platform including, the services already mentioned for IaaS and also data base management systems, software development languages and tools for the development and deployment of applications) and Software as a Service (SaaS) (=remote use of software applications running on providers' systems and supported/maintained by them; Marston et al. 2011; Zhang et al. 2010).

There is a growing recognition that CC can offer significant benefits to firms: lower cost of ICT support (in comparison with 'in-house' provision of ICT services, mainly due to economies of scale achieved by providers), decrease of required upfront ICT capital investments (and conversion of them to operational expenses), access to specialized ICT resources, rapid deployment of required ICT services, scalability (dynamic adjustment of these services in order to meet changing needs), enablement, support and reduction of cost—and in general barriers—to innovation, and wide accessibility (from anywhere and with any kind of device). It is widely recognized that these benefits will be higher for the small and medium enterprises (SME; Benlian and Hess 2011; Marston et al. 2011; Venders and Whitley 2012; Berman et al. 2012; Hoberg et al. 2012; Willcocks et al. 2013, 2014; Müller et al. 2015). According to Venders and Whitley (2012), the CC is expected to offer three main types of benefits to firms, which are associated with efficiency (reduction of

ICT and in general operational costs), creativity and innovation (reduction of the time and cost required for their ICT support), and simplicity (provision of ICT services that are simple to set-up, understand and use), respectively. Müller et al. (2015) distinguish between three levels of benefits that CC can offer to firms: the first one is associated with costs reduction and business efficiency improvements; the second one with business effectiveness improvements through internal business process innovation and integration; the third level of benefits is associated with business transformation through innovations in products, services and business models. However, at the same time there is a growing recognition that CC can pose some risks as well, which act as barriers to its adoption, such as data security risks (concerning unauthorized access to or modification of firm's data resources), service availability and in general performance risks, lack of relevant standardization and vendor lock-in risks. Such barriers have resulted in lower adoption of CC by firms below initial expectations (Benlian and Hess 2011; Low and Chen 2011; Hsu et al. 2014; Kung et al. 2015; Siepermann et al. 2016).

It is therefore necessary to investigate and understand better the factors that affect positively or negatively the adoption of CC by firms. Considerable empirical research has been conducted in this direction, which is reviewed in the following Sect. 2. However, this research has examined the effects of only a limited number of firm's characteristics (mainly firm's size, readiness and top management support) on CC adoption decision, but has neglected important firm's characteristics such as its technological infrastructure, strategy and human resources. These firm characteristics are expected to shape to a significant extent the magnitudes of both the benefits the firm can gain from CC and also the risks and problems that CC poses to it, which are both affecting a firm's propensity to adopt CC. The findings of such research can shed light on the types of firms with respect to technological infrastructure, strategy and human resources, in which CC is perceived as more suitable and useful, and also those for which CC is perceived as less beneficial. At the same time, these findings could provide useful insights as to the types of technological infrastructures and strategies, for which CC is perceived more appropriate for, and the importance of various aspects of a firm's human resources for CC adoption. Therefore, this research can be quite useful, first, for CC services providers in order to optimize their marketing activities by focusing on firms' segments that have high levels of CC adoption propensity, and at the same time make the necessary improvements and enrichments of their services in order to expand into new firms' segments currently having limited propensity to use CC. Second, potential CC user firms could also benefit from this research for making better decisions with respect to CC adoption and use by taking into account useful relevant knowledge extracted from large numbers of other firms.

This paper makes a contribution towards filling the abovementioned research gap. It presents an empirical investigation and comparison of the effects of a set of firm characteristics referring to technological infrastructure, strategy and personnel skills—characteristics that have not been examined in previous empirical research on CC adoption—as well as size and external environment on the propensity to adopt CC. Its theoretical foundation is the Technology, Organization and Environment (TOE) theory of technological innovation adoption (Tornatzky and

Fleischer 1990; Baker 2011). For this study we have used data collected through the e-Business Survey of the European Commission from 676 European manufacturing firms from the glass, ceramics and cement sectors. Previous research on the adoption of various ICT focuses mainly on high-tech and in general highly innovative manufacturing or service sectors, but our study on the contrary focuses on economically important manufacturing sectors, which are rather conservative in terms of adoption of new ICT and innovative business practices in general. We find that the investigation of CC adoption factors in such technologically rather conservative sectors is particularly important for understanding the motives and barriers for the dissemination of new ICT technologies on wider base all over the economy, which is a precondition for fully exploiting the potential of ICT.[1]

The paper is structured in six sections. In the following Sect. 2, a literature review is provided, while in Sect. 3 the conceptual background of this study and the research hypotheses are presented. In Sect. 4 our data and method are described. Then in Sect. 5 the results are presented, and a discussion of them is provided in Sect. 6, while finally in Sect. 7 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, below the high initial expectations, has motivated considerable research for the identification of factors that affect positively or negatively CC adoption. The initial empirical firm level research has been based on the Technology Acceptance Model (TAM) and its extensions (Davis 1986; King and He 2006; Turner et al. 2010). This approach focused on firms' perceptions concerning the usefulness/benefits of CC and its ease of use as possible determinants of CC usage intention as well as adoption, often with some adaptations to the particular characteristics of CC.

In this direction Wu (2011a) has developed an explorative model of SaaS adoption factors, which includes the 'classical' factors proposed by TAM (perceived usefulness, perceived benefits, perceived ease of use, behavioral intention of future use), and also its extensions (social influence, marketing efforts, attitude toward technological innovation), and additionally some CC-specific factors (security and trust). Using data collected from 42 Taiwanese managers, a structural equation model was estimated connecting the above factors, leading to the conclusion that the main factor affecting intention to use CC is 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.

In a study conducted by Wu (2011b) data mining techniques (rough set theory) are used in order to extract relations among the abovementioned TAM-based factors of the previous study, using data collected from 246 Taiwanese managers. It has

[1] The glass, ceramics and cement sectors are long-established and mature manufacturing sectors in the European Union (EU), in which EU has a trade surplus in international trade. These sectors are important suppliers of the construction sector. Further, they provide inputs to aerospace, automobile and electronics sectors and produce themselves household consumer goods (Empirica GmbH 2009).

been concluded that expert opinions are very influential for CC adoption, which is also affected significantly by the perceptions concerning CC effectiveness.

Gupta et al. (2013) extend the TAM and develop a five-factor 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, mainly from India, Malaysia and Singapore, a structural equation model has been estimated, which led to the conclusion that the perceived ease of use has the strongest effect, followed by perceived security and privacy, and cost reduction. On the contrary, the perceived reliability and support of collaboration and data sharing did not show statistically significant effects.

Later empirical research on firm level CC adoption uses the Technology, Organization and Environment (TOE) theory of technological innovation adoption (Tornatzky and Fleischer 1990; Baker 2011) as its main theoretical foundation, which is more multi-dimensional and comprehensive with respect to the examined types of adoption factors. Based on TOE three main types of possible CC adoption factors have been investigated: technological factors (perceived technological characteristics of CC), organizational factors (firm internal characteristics) and environmental factors (characteristics of firm's external environment). In order to define the technological factors to be examined, this research makes mostly use of the Diffusion of Innovation (DOI) theory (Rogers 2003), and in particular of the five critical characteristics of an innovation, which according to this theory determine the degree of its adoption: relative advantage, compatibility, complexity, trialability and observability.

Based on the above two theoretical foundations Low and Chen (2011) examine the effect of a set of technological factors (CC 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, using data from a sample of 111 firms from the Taiwanese high-tech industry. They conclude that perceived relative advantage, top management support, firm size, competitive pressure and trading partner pressure affect positively 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 (organizational factor) and external pressure (environmental factor) on CC adoption intention, based on data from 200 Taiwanese firms from ICT manufacturing and services sectors as well as general manufacturing and services sectors. It concludes that the first three of these factors are significant determinants of CC adoption, while the fourth is not.

Mangula et al. (2014) focus on SaaS, and examine the effects of a set of technological factors (relative advantage, compatibility, complexity, trialability, observability), organizational factors (organizational readiness, top management support) and environmental ones (market pressure, market competition, vendor marketing, trust in vendor, government support) on SaaS adoption. Using data from 147 Indonesian firms they estimate a logistic regression model, which leads to the conclusion that compatibility, observability, market competition and government

support have positive effect on SaaS adoption, while complexity has been found to have the negative effect.

Oliveira et al. (2014) examined the effects of three CC technological characteristics (relative advantage, complexity and compatibility), three organizational context characteristics (top management support, firm size, technological readiness) and two environmental context characteristics (competitive pressure, regulatory protection/support), using data from 369 Portuguese manufacturing and services firms. They found that relative advantage, technological readiness, top management support and firm size have positive effects on CC adoption, while complexity has a negative effect.

Another similar study has been conducted by Gutierrez et al. (2015), who examined the effects of a set of technological factors (CC relative advantage, complexity and compatibility), organizational factors (top management support, firm size, technological readiness) and environmental factors (competitive pressure, trading partners pressure) on CC adoption, using data collected from 257 mid-to-senior level decision-making business and ICT professionals from UK firms. It has been concluded that complexity, technology readiness, competitive pressure and trading partner pressure significantly influence the adoption of CC services.

Gangwar et al. (2015), combining the TOE theory with the TAM, and based on data from 280 companies of the Indian IT, manufacturing and finance sectors, found that CC relative advantage, compatibility and complexity as well as organizational readiness, top management commitment and CC training/education affect CC adoption intention through 'perceived ease of use' and 'perceived usefulness' as mediating variables. Also, competitive pressure and CC services providers' support were found directly affecting CC adoption intentions.

Hsu and Lin (2015) conducted another similar investigation of the effects of six technological factors (CC relative advantage, ease of use, compatibility, trialability, observability and security), three organizational factors (firm size, global scope, satisfaction with existing IS and cost reduction potential of CC) and two environmental factors (competition intensity and regulatory environment) on CC adoption intensity, using data collected from 98 Taiwanese firms. They conclude that relative advantage, observability, cost reduction potential, satisfaction with existing IS and competition intensity affect firms' intention to adopt CC.[2]

Furthermore, there are smaller numbers of empirical studies of CC adoption that are based on other theoretical foundations, such as the transaction-cost economics (TCE) theory (Benlian et al. 2009; Yigitbasioglu 2014), the institutional theory (Saya et al. 2010; Kung et al. 2015) and the theory of reasoned action in combination with previous research on ICT outsourcing (Benlian and Hess 2011), which however do not investigate the effects of any firm characteristics on CC adoption propensity.

Summarizing, the main empirical studies that investigate the factors determining CC adoption at firm level, particularly a series of firm characteristics, are shown in

[2] The TOE approach has been used as theoretical background also in part of earlier empirical literature on firm level adoption of various ICT, which we do not pursue further here; see, e.g., Hong and Zhu (2006), Pan and Jang (2008), Chong and Ooi (2008), Oliveira and Martins (2010), Thiesse et al. (2011), also see review by Baker (2011).

Table 1 Previous empirical studies examining the effects of firm characteristics on CC adoption

Study	Factors	Data
Low and Chen (2011)	**Relative advantage** (+), compatibility, complexity, trialability, observability, **top management support** (+), **firm size** (+), technology readiness, **competitive pressure** (+), **trading partner pressure** (+)	111 firms from the Taiwanese high-tech industry
Hsu et al. (2014)	**Perceived benefits and business concerns** (+), **IT capability** (+), external pressure	200 Taiwanese firms from ICT manufacturing and services sectors, and the general manufacturing and services sectors
Mangula et al. (2014)	Relative advantage, **compatibility** (+), complexity, trial-ability, **observability** (+), organizational readiness, top management support, market pressure, **market competition** (+), vendor marketing, trust in vendor, **government support** (+)	147 Indonesian firms
Oliveira et al. (2014)	**Relative advantage** (+), **complexity** (−), compatibility, **top management support** (+), **firm size** (+), **technological readiness** (+), competitive pressure, regulatory support	369 Portuguese manufacturing and services firms
Gutierrez et al. (2015)	Relative advantage, **complexity** (−), compatibility, top management support, firm size, **technological readiness** (+), **competitive pressure** (+), **trading partners pressure** (+)	257 UK firms
Gangwar et al. (2015)	**Relative advantage** (+), **compatibility** (+), **complexity** (+), **organizational readiness** (+), **top management commitment** (+), **training/education** (+), **competitive pressure** (+), **CC services providers' support** (+)	280 companies from the Indian IT sector
Hsu and Lin (2015)	**Relative advantage** (+), ease of use, compatibility, trialability, **observability** (+), **security** (+), firm size, global scope, **satisfaction with existing IS** (−), **cost reduction potential of CC** (+), **competition intensity** (+) and regulatory environment	98 Taiwanese firms

Table 1 (the factors found to have statistically significant effect on CC adoption are shown in bold). We can conclude that limited research has been done on the effects of firm characteristics on the CC adoption decision, focusing mainly on firm size, readiness and top management support. However, the characteristics of a firm are expected to shape to a significant extent the magnitudes of both the benefits of CC and the risks and problems that CC can pose to it as well, and therefore are expected to affect its propensity to adopt CC.

Our study contributes to filling the above research gap by presenting an empirical investigation and comparison of the effects on the propensity to adopt CC of a set of characteristics of the firm, which refer to its technological infrastructure, strategy and personnel skills, that have not been examined in previous CC adoption empirical research, in addition to the standard determinants of adoption size and external environment. There is an additional advantage of our study being based on data from European firms, for which only few studies are available (see Table 1).

3 Conceptual background and research hypotheses

As theoretical foundation of our study we have used the Technology, Organization and Environment (TOE) theory of technological innovation adoption (Tornatzky and Fleischer 1990; Baker 2011). It is a multi-dimensional approach, which defines three different types of factors affecting the adoption of technological innovations by firms: (a) technological factors concerning the perceived properties of the specific technological innovation, as well as the technologies currently used in the firm; (b) organizational factors concerning characteristics and resources of the firm; and (c) environmental factors concerning characteristics of firm's external environment. However, previous literature has emphasized that the TOE theory provides primarily a general framework in form of a typology of factors for studying the adoption of various technological innovations, that has to be elaborated and adapted to the specific technological innovation under study (see on this point Baker 2011 for a review of previous studies on the adoption of various ICT using the TOE theory as theoretical foundation). This necessitates the identification—based on previous related literature—of factors for each of these three categories of adoption determinants that are appropriate to the specific technological innovation under investigation.

In this direction, for each of the three types of factors that according to TOE theory determine a firm's decision to adopt a technology (technological, organizational and environmental) we reviewed previous CC literature in order to identify particular characteristics of a firm that might have an impact on CC adoption propensity, and based on them we have developed our research model (shown in Fig. 1) and our research hypotheses. With respect to the technological factors, though previous empirical CC adoption research focuses on firms' subjective perceptions concerning the five characteristics of CC proposed by the DOI theory (relative advantage, compatibility, complexity, trialability and observability), we have focused on objective technological factors that concern characteristics of the ICT currently used by firm (see previous paragraph). From previous CC literature we identified one such factor: the degree of sophistication of firm's ICT infrastructure (see Sect. 3.1 below); the effect of it on CC adoption has not been investigated in previous CC adoption empirical research. Furthermore, with respect to organizational factors, we identified the following six firm characteristics that are expected to affect positively the propensity for CC adoption: the existence of an ICT investment reduction strategy, the existence of an innovation strategy, the employment of CC personnel, the ICT skills of firm's employees, the existence

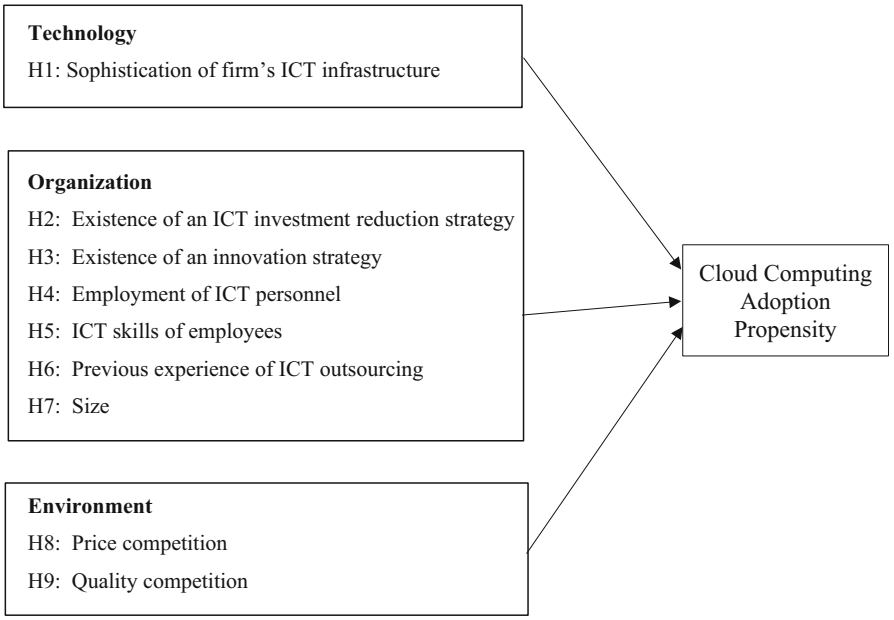

Fig. 1 Research model

of previous experience of ICT outsourcing, and firm's size (see Sects. 3.2, 3.3, 3.4, 3.5, 3.6); the effects of the first five of them on CC adoption have not been investigated in previous CC adoption empirical research. Finally, we identified two characteristics of firm's external environment that we expect to affect its propensity for CC adoption: the intensity of the price competition and the intensity of quality competition the firm faces (see Sect. 3.7). The above thoughts led to the development of our research model shown in Fig. 1. The corresponding research hypotheses H1–H9 are presented in more detail in the next Sects. 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7.

3.1 ICT infrastructure sophistication

Our first research hypothesis concerns the effect of firm's ICT infrastructure sophistication on its propensity to adopt CC. In previous CC literature (Marston et al. 2011; Venders and Whitley 2012; Müller et al. 2015) we find arguments concerning the high usefulness and value of CC for firms not having sophisticated ICT infrastructures, as it enables them to easily and rapidly gain access to more ICT capabilities and functionalities, at a low cost without the need for ICT investments. So we would expect that firms having weak ICT infrastructures with limited capabilities and sophistication might have a stronger motivation to adopt CC than the ones having highly sophisticated ICT infrastructures. However, there exist also arguments pointing to the opposite direction: CC can be quite useful and valuable also for firms having highly sophisticated ICT infrastructures, as it enables them to

reduce their high ICT operations, support and maintenance costs. For instance, it might be beneficial for them to use IaaS and PaaS services for hosting some of their applications, or even use SaaS for replacing some older applications with more modern standard software packages. So based on these arguments we would expect that firms having more sophisticated—and therefore more costly—ICT infrastructures might 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, so the empirical analysis will show which of them is confirmed:

H1a: The degree of sophistication of a firm's ICT infrastructure has a positive effect on its propensity to adopt CC.

H1b: The degree of sophistication of a firm's ICT infrastructure has a negative effect on its propensity to adopt CC.

3.2 ICT investment reduction strategy

Our second research hypothesis concerns the effect of having an ICT investment reduction strategy on firm's propensity to adopt CC. In many countries all over the world, mainly due to unfavorable economic conditions (e.g., overall recession or sectoral economic problems), firms have to adopt to a greater or lesser degree strategies of investment reduction, which usually include reduction of ICT investment. This can have a negative impact on firms' long-term competitiveness, as it does not allow them to make the required investments for upgrading and enhancing their ICT infrastructures (e.g., for increasing their computing power and/or their functionality) in order to meet new business needs or take advantage of emerging new ICT. CC can be very useful for coping with this problem, as it enables firms to transform the ICT capital investments (cap-ex) required for meeting the above needs into operating expenses (op-ex; Marston et al. 2011; Venders and Whitley 2012; Müller et al. 2015). In particular, CC enables firms to upgrade the computing power of their ICT infrastructures (e.g., by using Infrastructure as a Service (IaaS)), upgrade their functionality (e.g., by using Software as a Service (SaaS)), and also to exploit new emerging ICT, without having to make additional upfront ICT investments, transforming them into operational expenses, which are based on the real use they make of these services (through a 'pay as you go' model). So we expect that firms that have an ICT investment reduction strategy will have a good motivation to adopt CC. Hence our second research hypothesis is:

H2: The existence of an ICT investment reduction strategy has a positive effect on firm's propensity to adopt CC.

3.3 Innovation strategy

Our third research hypothesis refers to the effect of having an innovation-oriented strategy on the propensity to adopt CC. Previous CC literature argues that this new

paradigm of ICT services acquisition can provide benefits associated not only with ICT investment and in general costs reduction (which has been the initial 'value proposition' of CC), but also with the support and facilitation of innovation (Marston et al. 2011; Venders and Whitley 2012; Berman et al. 2012; Willcocks et al. 2013, 2014; Müller et al. 2015). Innovation is becoming increasingly important in modern economy for the competitiveness of firms. However, innovations in firms' processes, products or services very often require the development of extensive ICT infrastructures, which can be quite expensive and also time consuming, when using the traditional 'in-house' ICT development and operation paradigm. The use of CC enables a reduction of costs and time required for these ICT developments, and therefore a reduction of the cost and time-to-market of these innovations. In this direction Brynjolfsson et al. (2010) argue that 'an overly simplistic reliance on the utility model risks blinding us to the real opportunities and challenges of cloud computing', concluding that 'the real strength of cloud computing is that it is a catalyst for more innovation'. According to Berman et al. (2012) the CC has a great potential to enable and support ICT-based transformations of firms' internal operations, customer relationships, products and services, and even business models and industry value chains at low cost and rapidly. They further argue that CC can digitally facilitate and support the creation of new products and services, and the utilization of new channels or payment methods, in order to attract existing or adjacent customer segments and finally generate significant new revenues. At the same time firms can also use CC in order to create new demand and potentially new markets, and finally attract new customer segments and generate entirely new revenue streams. Willcocks et al. (2013), based on a series of surveys and interviews, conclude that CC facilitates initially 'ICT-operational' innovations (i.e. changes in ICT operations and personnel that do not impact firm-specific business processes), in a second step 'business process innovations' (changing substantially the way the business operates), and in a third step 'market (product/service) innovations' (enhancing significantly a firm's product/service offerings for existing customers, or enabling entry into new markets). All the above arguments indicate that CC can be not only a means of ICT investment and cost reduction, but also a strong and cost-efficient support and facilitator of innovation. Therefore, we expect that the existence of an innovation oriented strategy would increase firm's motivation for CC adoption. Thus, our third research hypothesis is:

H3: The existence of an innovation oriented strategy has positive effect on firm's propensity to adopt CC.

3.4 Employment of ICT personnel—ICT skills of employees

Our fourth and fifth research hypotheses refer to the effects of the employment of ICT personnel and the ICT skills of a firm's (non-ICT) employees (ICT users or potential users) on its propensity for CC adoption. The human capital of firms has been widely recognized as being of critical importance for innovation, as it is the main determinant of firms' knowledge 'absorptive capacity', which enables them to

identify and absorb useful knowledge and technology from their external environment, to assimilate it and use it for the enrichment of firm's knowledge base, and finally to exploit it for innovations in a firm's processes, products and services (Vandenbussche et al. 2006; Vinding 2006; Lopez-Garcia and Montero 2012). The adoption of CC by a firm is an important innovation in the way it acquires and sources ICT services for supporting its activities, so of critical importance for it is the 'relevant' human capital of the firm: on one hand its ICT personnel (i.e. employees having specialized studies in ICT, being responsible for the provision of the required ICT services throughout the firm), and on the other hand its non-ICT personnel (i.e. employees being responsible for executing parts of any other function of the firm, except ICT services provision, such as sales, procurement, production, financial management, etc.), who use ICT—or might potentially use ICT—for their work.

Previous literature (e.g., see Fink and Neumann 2007; Arvanitis et al. 2013) has emphasized the importance of the employment of specialized ICT personnel for ICT-related innovation. It has a critical role in the acquisition of external knowledge on new ICT, the transfer of it to firm's employees of various business units, the combination of it with domain specific knowledge (e.g., concerning firm's business processes, customer needs, competition), and finally the exploitation of it for the design and implementation of relevant innovations. In this vein, ICT personnel through their technical and business knowledge and skills can be quite useful for the effective and beneficial introduction of this innovative CC-based paradigm of acquisition/sourcing and management of ICT resources (Willcocks et al. 2013, 2014). In particular, the ICT personnel is important for identifying the existing CC services and providers in the market, and for analyzing them in relation to the relevant needs of the firm. Further, it is important for transferring this knowledge to the business units of the firm, and—in cooperation with them—for the selection of the most appropriate CC services and providers, for the formulation of the contacts, and for monitoring and managing these relations. Finally ICT personnel is quite important for the integration of various CC services from different providers with existing in-house ICT infrastructures, which is a critical success factor of CC deployment (Garrison et al. 2012). On the contrary, weaknesses in the above activities can give rise to uncertainties concerning CC, the existing CC offerings in the market, the benefits they can provide to the firm, and also the risks they really pose, which might have negative impact on firm's propensity to adopt CC.

At the same time, according to a recent study conducted by the London School of Economics (LSE) based on numerous interviews with practitioners all over the CC supply chain (Willcocks et al. 2014), the non-ICT personnel of firms (ICT users or potential users) has a much stronger role and involvement in the adoption and exploitation of CC than in the 'on-premises' ICT paradigm. For example, quite important is their contribution for filtering large amounts of information concerning existing CC offerings in the market and capabilities provided by them, and finally for selecting the most appropriate ones for meeting the particular needs of the firm. Therefore, for the rational selection and the full exploitation of the benefits of CC it is necessary that non-ICT employees have sufficient ICT skills, and this can

enhance a firm's CC adoption propensity. For all the above reasons our fourth and fifth research hypotheses are:

H4: The employment of specialized ICT personnel has a positive effect on a firm's propensity to adopt CC.

H5: Sufficient ICT skills of a firm's employees have a positive effect on its propensity to adopt CC.

3.5 ICT outsourcing

The sixth research hypothesis concerns the effect of having previous experience of ICT outsourcing on firm's propensity to adopt CC. As CC is a type of ICT outsourcing (Benlian and Hess 2011), if a firm's personnel has previous experience and skills concerning any type of ICT outsourcing, this can be useful for the effective adoption and use of CC. In particular, previous experience of other types of ICT outsourcing creates awareness and trust concerning external ICT services provision, and also knowledge of how to monitor and manage such relations, as well as respective internal processes and practices, which can be quite useful for the effective and beneficial introduction and use of CC. Previous ICT outsourcing literature (Lacity et al. 2009, 2010) has revealed that critical for its success is the 'supplier management capability' of the client firm, defined as the extent to which the client firm is able to effectively manage ICT outsourcing suppliers. If this capability has been developed in the past through experience gained from any type of ICT outsourcing, it can also be useful in the future for managing other types of ICT outsourcing, such as the use of CC. This past experience will increase a firm's confidence and motivation to move in this direction and also reduce relevant uncertainties. For the above reasons we expect that if the firm has previous experience of ICT outsourcing, this would increase the propensity for CC adoption. Therefore our sixth research hypothesis is:

H6: Previous experience of ICT outsourcing has a positive effect on a firm's propensity to adopt CC.

3.6 Size

We also investigated the effects of size on CC adoption propensity, a question on which there has been extensive debate and opposing arguments. There is extensive CC literature arguing that the benefits that CC can offer are higher for the smaller firms (Gupta et al. 2013; Marston et al. 2011; Venders and Whitley 2012; Müller et al. 2015; Johansson et al. 2015). Due to economies of scale that CC providers can achieve through the development and highly professional operation of big data centers that serve numerous user firms, this technology can offer to CC-users ICT cost reductions (in comparison with the traditional 'in-house' ICT services provision paradigm), and access to specialized ICT resources, personnel and applications, which would be too costly otherwise. However, some large firms due to their size might already have—or can have—such big data centers, specialized

ICT resources, personnel and applications (even if at a little higher cost than the CC provider), and can achieve significant economies of scale in their ICT operations. Therefore smaller firms are expected to have higher benefits from the adoption of CC than the larger ones. Also, the reduction of the need for upfront ICT investments that CC offers is much more important for the smaller firms in comparison with the larger ones, as it is much more difficult for the former to raise capital (e.g., from banks or investors) than for the latter (Saedi and Iahad 2013; Alshamaila and Papagiannidis 2014). However, there exist also previous studies providing arguments and also empirical evidence pointing to the opposite direction (Low and Chen 2011; Oliveira et al. 2014). According to them large firms have an advantage with respect to CC adoption (and innovation in general) over the small ones, because they have more resources for this, can take greater risks, and have more skills, experience, and also resources in order to survive any potential failures than small firms. For these reasons we have formulated two alternative research hypotheses on this, so the empirical analysis will show which of them is confirmed:

H7a: Firm size has a positive effect on the propensity to adopt CC.

H7b: Firm size has a negative effect on the propensity to adopt CC.

3.7 Competition

Our final research hypotheses concern the effect of the competition a firm faces on its propensity to adopt CC. Previous research in economics has concluded that competition fosters innovation (though too high competition might lead to opposite effects). Since firms' incentives for innovation depend mainly on the profitability increment that can be achieved through innovation, i.e. the difference of 'post-innovation' profitability from 'pre-innovation' profitability, competition reduces the pre-innovation profitability by more than it reduces the post-innovation one, so it increases the above profitability increment, and therefore incentives for innovation (see, e.g., Aghion et al. 2005). As the adoption of CC is a kind of innovation in the way a firm acquires and sources ICT services for supporting its activities, we expect that it will be fostered by higher levels of competition. Also, previous ICT literature has concluded that competition is an important driver for the adoption of various ICT (Zhu et al. 2003, 2004; Oliveira and Martins 2010; Arvanitis et al. 2016). Economic literature distinguishes two main types of competition: price competition (in which a firm tries to distinguish its product/service from those of its competitors on the basis of low price) and non-price (or quality) competition (in which a firm tries to distinguish its product/service from those of its competitors on the basis of attributes such as design, materials, workmanship, customer-focus, etc., in general offering higher product/service quality; e.g., McConnell et al. 2011). Firms facing intense price competition have a strong pressure to reduce their operating costs, so they have a strong motivation to use CC in order to reduce the operational, support and maintenance costs of their existing ICT infrastructures, and also to extend them at a low cost with new applications that automate manually executed tasks, and therefore reduce their cost. Also, firms facing intense quality competition have a

strong pressure to increase the quality of their products/services, and this very often requires additional ICT support; the use of CC might be a very good solution for achieving this at a low cost and rapidly. For all these reasons, we expect that facing high price or quality competition will increase a firm's motivation and therefore propensity to adopt CC. So our final two research hypotheses are:

H8: Price competition has a positive effect on a firm's propensity to adopt CC.

H9: Quality competition has a positive effect on a firm's propensity to adopt CC.

4 Data and methods

Our study is based on data collected through the "e-Business Survey", which has been conducted as part of the Sectoral e-Business Watch (www.ebusiness-watch.org) initiative of the European Commission, Enterprise and Industry Directorate General. The objectives of this survey were to collect data on the use of various types of ICT, the ICT skills, the ICT investment and the innovation activity of firms in the European glass, ceramic and cement manufacturing sectors. As mentioned in the introduction these are important long-established and mature manufacturing sectors in the European Union, which are rather conservative in terms of adoption of new ICT, and innovative business practices in general (Empirica GmbH 2009), and therefore more representative of 'traditional' manufacturing than the high-tech and highly innovative services and manufacturing sectors in which most previous empirical research on the adoption of various ICT has been conducted. For this survey a questionnaire was used, which contained 90 questions structured into the following eight modules: (A) Use of ICT systems and e-business software; (B) E-Commerce and automated data exchange; (C) E-Standards and interoperability issues; (D) Innovation activity and the role of ICT; (E) ICT skills requirements; F. ICT investments; (G) ICT, energy efficiency and emissions; and (H) Background information about the company. Pilot interviews were initially conducted by the main contractor of this survey with 15 firms in order to test the questionnaire (with respect to structure, comprehensibility of questions, average interview length), which lead to some small improvements of it. Data were collected through interviews conducted using computer-assisted telephone interview (CATI) techniques with the main ICT decision makers (who were usually either heads of the ICT department, or had higher management positions, so they had a complete and deep knowledge about the use of various ICT in the firm) of 676 firms from six European countries: Germany, France, Italy, Poland, Spain and UK. In each country the data collection was conducted by the local subsidiary of the contractor, and only in Italy and Poland other local partner firms were used; in all six countries the same questionnaire in English was used (there was no problem with this, as the interviewees—firms' main ICT decision makers—had a good command of the English language). The composition of the sample of our study by size, sector and country is shown in Table 2.

Table 2 Composition of the sample of the study by size, sector and country

Size		Sector		Country	
Small (10–49)	53.8%	Glass	23.5%	Germany	26.6%
Medium (50–249)	33.6%	Ceramic	22.9%	Spain	18.5%
Large (250+)	12.6%	Cement	53.6%	France	12.7%
				Italy	14.9%
				UK	9.5%
				Poland	17.8%

In order to test the abovementioned research hypotheses H1–H9, we estimated the following multivariate model:

$$\begin{aligned} Prop\_Cloud = {} & b_o + b_1 * ICT\_Infr\_Soph + b_2 * ICT\_Invest\_Red + b_3 * Innov \\ & + b_4 * ICT\_Pers + b_5 * Empl\_ICT + b_6 * ICT\_Outs + b_7 * Pr\_Comp \\ & + b_8 * Qual\_Comp + b_9 * D\_Large + b_{10} * D\_Medium + e_i \end{aligned} \quad (1)$$

where Innov = (Prodserv_Inn; Proc_Inn); b_o to b_{1o}: parameters that have to be estimated.

In the Appendix 1 are shown the exact definitions of all these variables, which correspond to the e-Business Survey questions we have used. The dependent variable Prop_Cloud is a measure of the propensity to adopt CC, which initially was a three-level variable assessing how relevant the respondent firm finds CC, having as possible values: very relevant, partly relevant, or not relevant; but as we can see in Table 3 the relative frequency of the first value is so small (1.3%) that we had to merge the two levels 'very relevant' and 'partly relevant' to one (having the relative frequency of 12.4%). So the Prop_Cloud variable we use in the model estimations is a binary one, which takes the value 1 if a firm reports relevance (even partial) of CC for their activities, and 0 if it replies that CC is not relevant for them.

As independent variables we have included six binary ones (1/0): existence of ICT investment reduction strategy (ICT_Invest_Red); two innovation strategy variables, one concerning the existence of product/service innovation strategy (Prodserv_Inn), and another one concerning the existence of process innovation strategy (Proc_Inn)[3]; ICT personnel employment (ICT_Pers); sufficiency of firm employees' ICT skills (Empl_ICT); and previous experience of ICT outsourcing (ICT_Outs).

Also we have constructed and inserted as independent variable a measure of a firm's ICT infrastructure sophistication (ICT_Infr_Soph), which is calculated as the average of four binary variables concerning the use of four important types of enterprise systems: ERP (enterprise resource planning) system, SCM (supply chain

[3] As there is high level of correlation between them and in order to avoid multi-collinearity problems (Greene 2011; Sreejesh et al. 2014) we did not include both of them in the same model, but we estimated the above model separately for product and for process innovation.

management) system, CRM (customers relationships management) system and SRM (suppliers relationships management) system.

Finally, we have used two competition variables (Pr_Comp and Qual_Comp), which measure the intensity of the price competition and the quality competition respectively that the respondent firm faces; both of them are three-level ordinal variables, having as possible values: 'not so important', 'important', or 'very important'.

We have also included two dummy variables for firm size: D_Large and D_Medium; these variables are set according to the number of employees of the firm: variable D_Large takes the value of 1 for large firms with more than 250 employees and value 0 for all other firms, while variable D_Medium takes the value of 1 for medium-sized firms with 50–249 employees and value 0 for all others (so small firms with 10–49 employees are our reference group). Furthermore, our model contains controls for sector and country, as the survey covered three sectors and six countries: two sectoral dummy variables (reference sector: cement industry) and five country dummy variables (reference country: Poland).

Since the dependent variable is binary, for estimating the above multivariate model (1) we used binary logistic regression, which is the most appropriate estimation method when the dependent variable is binary according to relevant econometric literature (Gujarati 2009; Greene 2011; Sreejesh et al. 2014). For validation purposes we calculated for each estimated model the value of the 'pseudo' R^2 of Nagelkerke (Scott Long 1997), which are analogous to the R^2 calculated in the Ordinary Least Squares (OLS) estimation.

Given the cross-section character of our model we do not raise any claims for causality of our estimates, which from the econometric point of view are primarily conditional correlations; however, they might yield useful insights for possible causality effects in the sense of our hypotheses.[4]

5 Results

In Table 3 are shown for all binary variables the relative frequencies of the 'yes' value (i.e. the percentages of the sample firms having the particular characteristic), and for our three levels variables the relative frequencies of the two 'highest' values, in the second column, and also the correlations with the dependent variable (propensity to adopt CC) in the third column (the statistically significant correlations are shown in bold). We can see that 12.4% of the sample firms have a propensity for CC adoption (with 1.3% of them finding CC very relevant, and 11.1% finding it partly relevant); 23.2% of them adopt ICT investment reduction strategy, while 36.5% adopt product/service innovation strategy, and 43% adopt process innovation strategy. Also, most of the independent variables have positive and statistically significant correlations with the dependent variable, with the exception of the employees ICT skills, price competition and quality competition ones, as well as the medium firms' dummy one. We remark that ICT infrastructure sophistication has the highest correlation with the propensity to adopt CC (0.191), followed by the ICT

[4] It is also almost impossible to find valid instruments for endogeneity tests (see, e.g., Rivers and Vuong 1988) in our cross-section data.

Table 3 Relative frequencies and correlations

	Relative frequency (%)	Pearson correlation
Prop_Cloud	1.3 (very relevant)–11.1 (partly relevant)	–
ICT_Infr_Soph		**0.191**
ICT_Invest_Red	23.2	**0.165**
Prodserv_Inn	36.5	**0.115**
Proc_Inn	43.0	**0.098**
ICT_Pers	26.5	**0.160**
Empl_ICT	46.4	0.063
ICT_outs	16.4	**0.124**
Pr_Comp	70.7 (very important)–24.0 (important)	−0.007
Qual_Comp	81.5 (very important)–16.1 (important)	0.005
D_Large	12.6	0.**101**
D_Medium	33.6	0.055
ERP	32.0	**0.146**
SCM	13.5	**0.193**
CRM	23.5	**0.107**
SRM	12.1	**0.121**

Statistically significant correlations are shown in bold

investment reduction strategy (0.165) and ICT personnel employment (0.160); lower are the correlations of the previous experience of ICT outsourcing (0.124), the product/service innovation strategy (0.115) and the process innovation strategy (0.098). Also, positive and statistically significant are the correlations of the four component variables of the composite ICT infrastructure sophistication variable, which concern the use of ERP, CRM, SCM and SRM systems.

In Table 4 are shown the estimates of model (1). The second column contains the estimates of Eq. (1) with the product/service innovation strategy variable (model version 1), while the third column contains the estimates with the process innovation variable (model version 2). For each independent variable is shown the $\exp(b_i)$, which in the binary logistic regression estimation is equal to the increase of the odds of CC adoption propensity (=probability of having CC adoption propensity/probability of not having CC adoption propensity) if the independent variable increases by one unit (Gujarati 2009; Greene 2011; Sreejesh et al. 2014; in bold are shown the statistically significant b_i).

From these estimates we can see that four out of our totally ten independent variables (without the control variables) have positive (as all $\exp(b_i) > 1$) and statistically significant effects on the propensity to adopt CC. The variable measuring the degree of sophistication of firm's ICT infrastructure (ICT_Infr_Soph) shows the strongest positive and statistically significant effect on CC adoption propensity,[5] and this provides support for research hypothesis H1a.

[5] We estimated also these two versions of our model using instead of the ICT infrastructure sophistication independent variable each of its component variables (use of ERP, CRM, SCM, SRM systems), and found positive statistically significant effects of all four on CC adoption propensity.

Table 4 Estimated models of propensity to adopt cloud computing

	Model version 1	Model version 2
ICT_Infr_Soph	2.854**	2.995**
ICT_Invest_Red	1.638*	1.651*
Prodserv_Inn	1.381	
Proc_Inn		1.122
ICT_Pers	1.544*	1.546*
Empl_ICT	1.171	1.660*
ICT_Outs	1.616*	1.183
Pr_Comp	1.035	1.048
Qual_Comp	0.998	0.992
D_Large	1.168	1.171
D_Medium	1.074	1.062
Sector_Glass	1.808**	1.827**
Sector_Ceramic	1.470	1.515
Country_Germany	0.312***	0.304**
Country_Spain	1.124	1.084
Country_France	1.165	1.102
Country_Italy	1.670	1.655
Country_UK	0.343*	0.335*
N	676	676
Nagelkerke R^2	0.178	0.175
Chi square	66.989***	65.339***

*, **, and *** denote statistical significance at the 10, 5 and 1% test level respectively

Also, the ICT investment reduction strategy variable (ICT_Invest_Red) has a positive and statistically significant effect, and this provides support for research hypothesis H2. Both innovation variables (Prodserv_Inn and Proc_Inn) show positive but statistically insignificant (at the 10%-test level) effects, but their respective standard errors (not shown here) indicate nearness to statistical significance at the 10%-test level. So research hypothesis H3 is not confirmed according to standard statistical criteria, but it is not far away from confirmation.

The variables for ICT-personnel (ICT_Pers) and for ICT outsourcing (ICT_Outs) also have positive and statistically significant coefficients. On the contrary, the variable for ICT skills and—rather unexpectedly—the variables for firm size show no statistically significant effect on the CC adoption propensity. Therefore hypotheses H4 and H6 receive empirical support, contrary to the Hypotheses H5 and H7, which are not confirmed by our estimates.

Finally, the external environment seems to exercise no influence on the propensity to adopt CC; both competition variables (Pr_Comp and Qual_Comp) have positive but statistically insignificant coefficients. So research hypotheses H8 and H9 are not supported. Our findings are summarized in Table 5.

Table 5 Summary of findings

Research hypothesis	Independent variable	Support	Sign
H1	Degree of sophistication of firm's ICT infrastructure	√	+
H2	Adoption of ICT investment reduction strategy	√	+
H3	Adoption of an innovation oriented strategy		
H4	Employment of specialized ICT personnel	√	+
H5	Sufficiency of ICT skills of firm's employees		
H6	Previous experience of ICT outsourcing	√	+
H7	Size		
H8	Price competition		
H9	Quality competition		

6 Discussion

As mentioned in Sect. 5, the comparison of the coefficients of the independent variables indicates that the strongest effect on CC adoption propensity among all the examined firm characteristics has the sophistication of firm's ICT infrastructure. Therefore in the examined sectors firms with highly sophisticated ICT infrastructures have a stronger propensity to use CC services, probably in order to reduce their high ICT operations, support and maintenance costs. Then follow the effects of the adoption of ICT investment strategy, the employment of ICT personnel and the existence in the firm of previous experience of ICT outsourcing, which are of similar magnitude and can be compared to each other because the underlying variables are binary.[6] These results indicate that firms of these three manufacturing sectors (glass, ceramics and cement) view CC as a means mainly to reduce the operations, support and maintenance costs of their ICT infrastructures, and to a lower extent as a means to reduce ICT investment (and to an even lower extent as a means to support and facilitate innovation, if we allow the weak effects of the innovation variables to be worthy to be taken into consideration). These sectors, being rather conservative in terms of adoption of new ICT, and innovative business practices in general are oriented more towards lower risk uses of CC (such as hosting existing applications in order to reduce their operations, support and maintenance costs), and less towards higher risk uses of CC (e.g., for accessing new applications through CC SaaS services or for supporting innovations). Also, our results provide evidence that a firm's ICT personnel is important for the adoption of CC, as it has a critical role, initially for the development of awareness in the business units of the firm concerning possible benefits and risks of CC for the particular firm, and also for the identification of CC services and providers in the market that can be useful for the firm, and the final the selection among them, as well as for monitoring and managing relevant contracts and relations. On the contrary, in these sectors the (non-ICT) employees (ICT users or potential users) and their ICT skills do not seem to play an important role for CC adoption.

[6] For this reason we do not need to estimate marginal effects.

Furthermore, our results reveal the importance of a firm's previous experience of ICT outsourcing for the adoption of CC. This experience creates on one hand awareness and trust in the firm concerning external ICT services provision and on the other hand knowledge, skills and processes concerning the effective monitoring and management of such external services. Finally, high intensity of price and quality competition are not drivers of CC adoption in these sectors.

As mentioned in Sect. 2 most previous empirical studies examining effects of firm characteristics (internal and environment related ones) on CC adoption have found that competition has a positive impact on the adoption of CC by firms (Low and Chen 2011; Mangula et al. 2014; Gutierrez et al. 2015; Gangwar et al. 2015; Hsu and Lin 2015), while some other studies have not found statistically significant effects of competition on CC adoption (Hsu et al. 2014; Oliveira et al. 2014). So our findings are in agreement with the second group of studies. A possible explanation for this finding is that these three traditional manufacturing sectors, being rather conservative in terms of ICT adoption and also due to the nature of their production processes, which are energy intensive and lead to significant carbon dioxide emissions (see Empirica GmbH 2009 for more details), do not find CC adoption as a major and effective response to high competition. They may focus instead on increasing the efficiency of their production processes through a reduction of energy consumption and carbon dioxide emission, thus avoiding the costs of fluctuating energy prices and pollution taxation. In general, the influence of competition on CC adoption propensity seems to be to a significant extent shaped by the sectoral context.

We have also found that firm size shows no statistically significant effect on firm's propensity to adopt CC. Our findings concerning the effects of size on the propensity for CC adoption in the three examined sectors are not in agreement with the arguments and the empirical evidence provided by the empirical studies of Low and Chen (2011) and Oliveira et al. (2014) that have found positive effects of size on CC adoption. However, our findings are in agreement with the ones of the empirical studies of Gutierrez et al. (2015) and also Hsu and Lin (2015), which found that size has not a significant influence on the adoption of CC services. So, our findings do not confirm the initial expectations that CC would be adopted primarily by the SMEs (Marston et al. 2011; Venders and Whitley 2012; Saedi and Iahad 2013; Alshamaila and Papagiannidis 2014), enabling them to reduce their distance from the larger firms with respect to ICT capabilities, and therefore to become more competitive. Therefore the influence of size on CC adoption propensity also seems to be dependent to a significant extent on the sectoral context.

7 Conclusions

Cloud computing is an emerging new paradigm of ICT resource acquisition and management by firms, which on one hand can offer significant benefits and on the other poses some risks that act as barriers to its adoption. Therefore, it is important to identify the factors that affect the adoption of CC positively or negatively. In the previous sections we presented an empirical investigation of the effects on the

adoption of CC of a set of firm characteristics referring to technological infrastructure, strategy, and personnel skills that have not been examined in previous empirical CC adoption research. The study's conceptual foundation is the Technology, Organization and Environment (TOE) theory of technological innovation adoption. Our study contributes to filling an important research gap, as the impact of a firm's characteristics on CC adoption has been only to a very limited extent investigated in previous empirical literature. The study is based on a large dataset from 676 European firms from the glass, ceramics and cement industries, which has been collected through the e-Business Watch Survey of the European Commission. It focuses on three important manufacturing sectors, which are rather conservative in terms of adoption of new ICT, and innovative business practices in general.

This study has identified an interesting set of firm's characteristics that increase its propensity to adopt CC in these sectors. The most effective of them with respect to CC adoption is the sophistication of a firm's ICT infrastructure: due to the high operating and maintenance costs of sophisticated ICT infrastructures the use of CC services (such as IaaS and SaaS services) can be quite beneficial for reducing these costs. The second most effective characteristic is the adoption of ICT investment reduction strategy: if a firm follows such a strategy, then the use of CC can be a good option for upgrading and enhancing its ICT infrastructure in order to meet new business needs, and also for accessing and using new emerging ICT and novel types of applications (e.g., CRM or business analytics), without having to make additional ICT investments. Furthermore, the employment of specialized ICT personnel and also previous experience of ICT outsourcing have been found to affect positively the propensity to adopt CC. Another interesting finding of our study concerns the effect of a firm's size on CC adoption propensity: despite the expectations that CC would be more beneficial for smaller than larger firms, we could not find any significant effect of size on the propensity of CC adoption in the sectors investigated in this study. Finally, the ICT skills of firm's employees and the price and quality competition do not appear to affect the CC adoption propensity as well.

Our study has interesting implications for both research and practice. With respect to research it makes a contribution to the empirical research literature on factors affecting the adoption of CC by investigating and comparing the effects of an important set of firm's characteristics not dealt with previously, which refer to a firm's strategic orientations, technological and human resources. Therefore, it deepens our understanding of firm-level conditions that promote CC adoption. Furthermore, our study opens up new directions of research on the effects of wider sets of firm characteristics on CC adoption, which can leverage various relevant concepts and frameworks developed in previous management science research, examining their impact on CC adoption and exploitation.

With respect to practice, our findings offer useful guidance to firms' management having to make decisions about the adoption of CC as to the types of firms from a technological infrastructure, strategy, human resources perspective to be viewed as more appropriate for adopting CC. Our results also indicate that firms can start with uses of CC of lower risk (e.g., use CC for hosting existing applications in order to reduce their operations, support and maintenance costs), and then, leveraging the

experience gained from them, proceed to higher risk (and at the same time higher business value) uses of CC (e.g., use CC for accessing new applications, and then for supporting innovations in processes, products and services). Also, firms should not underestimate the importance of ICT personnel for the rational and beneficial adoption of CC (believing that CC makes ICT personnel unnecessary), but they should increase the involvement of their (non-ICT) personnel (ICT users or potential users), leveraging their ICT and business operations related knowledge. Furthermore, our findings offer useful guidance to CC provider firms, as to: i) which types of firms find CC more beneficial and have stronger propensity to adopt it, in order to focus their marketing and sales activity on them; and ii) which firms find CC as less beneficial, in order to improve and enrich their CC services for expanding into these firms' segments. An interesting lesson learnt from our study is that though initially the main target groups of CC were the smaller firms and also the firms with limited and deficient ICT infrastructure, our findings indicate that (at least in the three examined manufacturing sectors) (a) firm size is not a relevant characteristic for CC adoption and (b) firms with highly sophisticated ICT infrastructures show more interest in adopting and using CC. Therefore CC services providers should rethink their offerings and probably transform so as to attract more interest from its initially targeted groups (e.g., through making their offerings more appropriate and easy to use by SMEs).

The main limitation of this study is that it is based on data from only three manufacturing sectors (glass, ceramics and cement), which are rather conservative in terms of adoption of new ICT, and innovative business practices in general, so that findings may have been influenced to some extent by this particular sectoral context. So further research is required concerning the effect of wider sets of firm characteristics on the propensity to adopt CC in various sectoral contexts. However, it remains an advantage of our study that it deals with European firms, for which few studies are available. A second limitation is that, due to the use of an existing dataset (on the collection of which we have not control), our variables have been measured mainly as ordinal or binary variables. So further relevant research is needed, which should be based on more detailed measurements of these variables (using ordinal scales with more levels or interval scales). Also, it would be useful to distinguish between different categories of CC services (IaaS, PaaS, SaaS), as they might differ as to the factors affecting their adoption. Finally, it would be interesting and useful to identify and examine mediating factors of the investigated effects (such as various types of benefits and risks) using structural equations modeling techniques. A third limitation refers as already mentioned to the cross-section character of our data. Thus, data for more points of time are needed for further research.

Appendix 1

See Table 6.

Table 6 E-business survey questions used

Variable	Question/definition
Prop_Cloud	How relevant is cloud computing for your company (very relevant, partly relevant, or not relevant)?
ICT_Infr_Soph	Does your company use an ERP system, that is Enterprise Resource Planning? (yes/no)
	Does your company use a SCM system, that is Supply Chain Management? (yes/no)
	Does your company use a CRM system, that is Customer Relationship Management? (yes/no)
	Does your company use a SRM system, that is Supplier Relationship Management? (yes/no)
ICT_Invest_Red	Have you cancelled or significantly downsized any ICT or e-business projects in the last 12 months? (yes/no)
Prodserv_Inn	During the past 12 months, has your company launched any new or substantially improved products or services? (yes/no)
Proc_Inn	During the past 12 months, has your company launched any new or substantially improved processes? (yes/no)
ICT_Pers	Does your company currently employ ICT practitioners? (yes/no)
Empl_ICT	Do employees have problems because of insufficient ICT skills? (yes/no)
ICT_Outs	In the past 12 months, has your company outsourced any ICT services to external service providers, which were previously conducted in-house? (yes/no)
Pr_Comp Qual_Comp	How important are the following factors for competition in your main market? (very important, important, not so important) (a) price, (b) quality
D_Medium	Dummy variable for medium firms: 50–249 employees
D_Large	Dummy variable for large firms: more than 250 employees

References

Aghion P, Bloom N, Blundell R, Griffith R, Howitt P (2005) Competition and innovation: an inverted-U relationship. Q J Econ 120(2):701–728

Alshamaila Y, Papagiannidis S (2014) Cloud computing adoption by SMEs in the north east of England—a multi-perspective framework. J Enterp Inf Manag 26(3):250–275

Arvanitis S, Loukis E, Diamantopoulou V (2013) The effect of soft ICT capital on innovation performance of Greek firms. J Enterp Inf 26(6):679–701

Arvanitis S, Loukis E, Diamantopoulou V (2016) Are ICT, workplace organization and human capital relevant for innovation? A comparative study based on Swiss and Greek micro data. International Journal of the Economics of Business (published on Taylor & Francis Online—retrieved at http://www.tandfonline.com/doi/full/10.1080/13571516.2016.1186385 at 17/6/2016)

Baker J (2011) The technology–organization–environment framework. In: Dwivedi Y, Wade M, Schneberger S (eds) Information systems theory: explaining and predicting our digital society. Springer, New York, pp 231–246

Benlian A, Hess T (2011) Opportunities and risks of software-as-a-service: findings from a survey of IT executives. Decis Support Syst 52(1):232–246

Benlian A, Hess T, Buxmann P (2009) Drivers of SaaS-adoption—an empirical study of different application types. Bus Inf Syst Eng 1(5):357–369

Berman SJ, Kesterson-Townes L, Marshall A, Srivathsa R (2012) How cloud computing enables process and business model innovation. Strategy Leadersh 40(4):27–35

Brynjolfsson E, Hofmann P, Jordan J (2010) Economic and business dimensions cloud computing and electricity: beyond the utility model. Commun ACM 53(5):32–34

Chong AYL, Ooi KB (2008) Adoption of interorganizational system standards in supply chains: an empirical analysis of RosettaNet standards. Ind Manag Data Syst 108(4):529–547
Davis FD (1986) A technology acceptance model for empirically testing new end-user information systems: theory and results. Doctoral Dissertation, Sloan School of Management, MIT, Cambridge, MA
Fink L, Neumann S (2007) Gaining agility through IT personnel capabilities: the mediating role of IT infrastructure capabilities. J Assoc Inf Syst 8(8):440–462
Gangwar H, Date H, Ramaswamy R (2015) Understanding determinants of cloud computing adoption using an integrated TAM–TOE model. J Enterp Inf Manag 28(1):107–130
Garrison G, Kim S, Wakefield R (2012) Factors leading to the successful deployment of cloud computing. Commun ACM 55(9):62–68
GmbH Empirica (2009) ICT and e-Business Impact in the glass, ceramics and cement industry. European Commission, DG Enterprise & Industry, Bohn/Brussels
Greene WH (2011) Econometric analysis. Prentice Hall Inc, Upper Saddle River
Gujarati DN (2009) Basic econometrics. Mc-Graw Hill Higher Education, New York
Gupta P, Seetharaman A, Rai JR (2013) The usage and adoption of cloud computing by small and medium enterprises. Int J Inf Manag 33(5):861–874
Gutierrez A, Boukrami E, Lumsden R (2015) Technological, organizational and environmental factors influencing managers' decision to adopt cloud computing in the UK. J Enterp Inf Manag 28(6):788–807
Hoberg P, Wollersheim J, Krcmar H (2012) The business perspective on cloud computing—a literature review of research on cloud computing. In: Proceedings of the American conference on information systems (AMCIS) 2012
Hong W, Zhu K (2006) Migrating to internet-based e-commerce: factors affecting e-commerce adoption and migration at the firm level. Inf Manag 43(2):204–221
Hsu CL, Lin JCC (2015) Factors affecting the adoption of cloud services in enterprises. Inf Syst e-Bus Manag 82:11 **(in press)**
Hsu PF, Ray S, Li-Hsieh YY (2014) Examining cloud computing adoption intention, pricing mechanism and deployment model. Int J Inf Manag 34(4):474–488
Johansson B, Alajbegovic A, Alexopoulos V, Desalermos A (2015) Cloud ERP adoption opportunities and concerns: the role of organizational size. In: 48th Hawaii international conference on system sciences (HICSS) 2015, Kauai, Hawaii
King WR, He J (2006) A meta-analysis of the technology acceptance model. Inf Manag 43(6):740–755
Kung L, Cegielski CG, Kung HJ (2015) An integrated environmental perspective on software as a service adoption in manufacturing and retail firms. J Inf Technol 30(4):352–363
Lacity MC, Khan S, Willcocks L (2009) A review of the IT outsourcing literature: insights for practice. J Strateg Inf Syst 18(3):130–146
Lacity MC, Khan S, Yan A, Willcocks L (2010) A review of the IT outsourcing empirical literature and future research directions. J Inf Technol 25:395–433
Lopez-Garcia P, Montero JM (2012) Spillovers and absorptive capacity in the decision to innovate of Spanish firms: the role of human capital. Econ Innov New Technol 21(7):589–612
Low C, Chen Y (2011) Understanding the determinants of cloud computing adoption. Ind Manag Data Syst 111(7):1006–1023
Mangula IS, Weerd I, Brinkkemper S (2014) The adoption of software-as-service: an Indonesian case study. In: Proceedings in Pacific Asia conference on information systems (PACIS), 2014
Marston S, Li Z, Bandyopadhyay S, Zhang J, Ghalsasi A (2011) Cloud computing—the business perspective. Decis Support Syst 51(1):176–189
McConnell CR, Brue SL, Flynn SM (2011) Economics: principles, problems, and policies, 19th edn. Mc-Graw Hill Education, New York
Mell P, Grance T (2010) The NIST definition of cloud computing. Commun ACM 53(6):50
Müller SD, Holm SR, Søndergaard J (2015) Benefits of cloud computing: literature review in a maturity model perspective. Commun Assoc Inf Syst 37:851–878
Oliveira T, Martins MF (2010) Understanding e-business adoption across industries in European countries. Ind Manag Data Syst 110(9):1337–1354
Oliveira T, Thomas M, Espadanal M (2014) Assessing the determinants of cloud computing adoption: an analysis of the manufacturing and services sectors. Inf Manag 51(5):497–510

Pan MJ, Jang WY (2008) Determinants of the adoption of enterprise resource planning within the technology–organization–environment framework: Taiwan's communications industry. J Comput Inf Syst 48(3):94–102

Rivers D, Vuong Q (1988) Limited information estimators and exogeneity tests for simultaneous probit models. J Econom 39(3):347–366

Rogers E (2003) Diffusion of innovations, 15th edn. The Free Press, New York

Saedi A and Iahad NA (2013) An integrated theoretical framework for cloud computing adoption by small and medium-sized enterprises. In: Proceedings of Pacific Asia conference (PACIS) 2013, Jeju Island

Saya S, Pee L, Kankanhalli A (2010) The impact of institutional influences on perceived technological characteristics and real options in cloud computing adoption. In: Proceedings of international conference on information systems (ICIS) 2010, St. Louis

Scott Long J (1997) Regression models for categorical and limited dependent variables. Sage, Thousand Oaks

Siepermann M, Sutaj A, Lübbecke P, Lackes R (2016) Refuse to walk on clouds—why firms still do not use cloud computing. An empirical study of barriers and enhancers. In: Proceedings of the 49th annual Hawaii international conference on system sciences (HICSS-49), Kauai, Hawai

Sreejesh S, Mohapatra S, Anusree MR (2014) Business research methods—an applied orientation. Springer, New York

Thiesse F, Staake T, Schmitt P, Fleisch E (2011) The rise of the "next-generation bar code": an international RFID adoption study. Supply Chain Manag Int J 16(5):328–345

Tornatzky LG, Fleischer M (1990) The processes of technological innovation. Lexington Books, Lexington

Turner M, Kitchenham B, Brereton P, Charters S, Budgen D (2010) Does the technology acceptance model predict actual use? A systematic literature review. Inf Softw Technol 52(5):463–479

Vandenbussche JP, Aghion P, Meghir C (2006) Growth, distance to frontier and composition of human capital. J Econ Growth 11(2):97–127

Venders W, Whitley E (2012) A critical review of cloud computing: researching desires and reality. J Inf Technol 27:179–197

Vinding AL (2006) Absorptive capacity and innovative performance: a human capital approach. Econ Innov New Technol 15(4–5):507–517

Willcocks L, Venters W, Whitley EA (2013) Cloud sourcing and innovation: Slow train coming? Strateg Outsourc Int J 6(2):184–202

Willcocks L, Venters W, Whitley EA (2014) Moving to the cloud corporation. Palgrave Millan, London

Wu WW (2011a) Developing an explorative model for SaaS adoption. Expert Syst Appl 38(12):15057–15064

Wu WW (2011b) Mining significant factors affecting the adoption of SaaS using the rough set approach. J Syst Softw 84(3):435–441

Yigitbasioglu O (2014) Modelling the intention to adopt cloud computing services: a transaction cost theory perspective. Australas J Inf Syst 18(3):193–210

Zhang Q, Cheng L, Boutaba R (2010) Cloud computing: state-of-the-art and research challenges. J Internet Serv Appl 1(1):7–18

Zhu K, Kraemer K, Xu S (2003) Electronic business adoption by European firms: a cross-country assessment of the facilitators and inhibitors. Eur J Inf Syst 12:251–268

Zhu K, Kraemer K, Xu S, Dedrick J (2004) Information technology payoff in e-business environments: an international perspective on value creation of e-business in the financial services industry. J Manag Inf Syst 21(1):17–54