Drivers of information and communication technologies adoption in Colombian services firms

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Abstract: This paper analyses the determinants of ICT adoption in Colombian services firms using micro-level data. It contributes to the scant literature on the determinants of ICT adoption at firm level in emerging economies. Due to ICT heterogeneity, different econometric models are estimated to identify the drivers of ICT adoption. The results show that the factors that positively influence ICT adoption are the proportion of foreign capital, firm age, employees' education and the ICT spillovers from the corresponding service industry. Information spillovers from the service industry adopters to non-adopters are taken into account as determinants of ICT adoption. An extended version of the model explores the determinants of ICT adoption comparing large firms and SME. For some variables, such as proportion of foreign capital, firm age and employees' education, the results differ by firm size.

Keywords: ICT adoption; services; new information and communication technologies; developing countries; Columbia.

Reference to this paper should be made as follows: Alderete, M.V. and Gutiérrez, L.H. (2014) 'Drivers of information and communication technologies adoption in Colombian services firms', *Int. J. Business Information Systems*, Vol. 17, No. 4, pp.373–397.

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1 Introduction

Nowadays, information and communication technologies (ICT) are one of the main success factors, especially in service firms characterised by interactivity and intensity of information. ICT have played a key role in the transition to a service economy.

The recent academic debate in the field of service research (Bitner et al., 2010; Breidbach et al., 2013; Chesbrough and Spohrer, 2006; Rust and Miu, 2006), recognises the need to advance the understanding of the role of ICT in service. Some authors postulate that ICT in service should be considered as one of the key research priorities within the service science research agenda, as well as in the information systems (IS) field (Raj and Vallabh, 2006).

The adoption of information technology across many service industries is rapidly changing the nature of services. Technology, in particular information technology, has influenced the nature of services themselves, how they are delivered (Jong et al., 2003) and the practice of service innovation and service management (Bitner et al., 2010).

ICT adoption promotes complementary organisational innovations (both in business processes and work practices) that increase productivity, reducing costs and increasing the firms 'products quality and its competitive position (Alderete and Gutierrez, 2012; Brynjolfsson and Hitt, 2000; Dholakia and Kshetri, 2004; Han et al., 2011; Simmons et al., 2008; Sapprasert, 2010). It has also been argued that the use of IT enhances the performance of service employees, both in terms of efficiency and effectiveness, by enabling customisation and flexibility in their encounters with customers (Bitner et al., 2000). Bitner et al. (2010) illustrates the impact of information technology on strategies associated with closing the gaps of service quality focusing on the customer.

ICT drivers for organisational changes in services firms are: the use of more sophisticated and faster information; the reorganisation of business models (how firms organise to create value) and routines associated with e-business software; and the modern business processes usually followed by the supply chain transformations (global sourcing, changes between clients and suppliers interactions). As a result of this evidence suggesting an existent positive relationship between ICT adoption and firms' value creation; it becomes relevant analysing the explanatory factors of ICT adoption among firms. Even though computers are practically everywhere today, the degree of ICT adoption varies substantially between countries and even within sectors (Hempell et al., 2006; Oliveira and Martins, 2010; Tan et al., 2010).

Although there is now a wide and growing literature on the determinants of ICT adoption, yet most of the literature is concerned with the manufacturing industry and only a few studies with developing countries. Among the possible reasons are: the lack of appropriate data for services, the academic preferences on industrial studies but also the notion that services are not productive (Baumol, 1967; Baumol et al., 1985). For many years, the manufacturing sector has been considered the main engine of economies. However, the service sector becomes a key player in the economic growth of developed economies, which as a whole have shown a progressive intensification of the service sector reaching nearly 75% of the economy (Maroto and Rubalcaba, 2008).

High income countries show a digitalisation pattern that highlights the relative weight of more advanced technologies (Billon et al., 2009). Dedrick et al. (2013) find that the effect of IT on productivity is expanding from richest countries into a large group of developing countries. The effect of ICT in developing countries is a more interesting issue due to its potential to become larger. Based on the Rogers' (1995) diffusion curve, developing countries are located in the first steps of the ICT diffusion curve. On the other side, most small firms are lagged behind large firms in ICT adoption. Therefore, building an ICT diffusion policy is becoming a strong attempt in many Latin-American countries. In Latin-America, Rivas and Stumpo (2011) summarise some of the direct programmes for ICT implementation at firm level. Colombia represents a remarkable example of ICT programmes in the region striving for constant progress in ICT.

In Colombia, the service sector is one of the main engines of regional economic development. According to DANE (Colombia Bureau of Statistics), it represents nearly 70% of GDP and 74% of employment. Growth sources have migrated towards new sectors and services and have displaced traditional sectors like agriculture, commerce and industry. The tertiary sector (mainly services) has grown from 38% to 59% during the last decades (Cámara de Comercio de Medellín para Antioquía, 2009). In particular, the health services have an increase of 4.9%. The three main new and emergent sectors are business process outsourcing (BPO&O), IT software and services, and health tourism.

This research looks for finding out what the explanatory factors of ICT adoption in Colombian service are. Much of the research focuses on the barriers to adoption, identifying external and internal factors likely to cause ICT adoption. However, only limited research has included the role of ICT spillovers in its adoption. Although there is a vast literature that emphasises how ICT enables the creation and use of network externalities and spillovers., there are only a few examples in the empirical studies (Brynjolfsson and Hitt, 2000; Han et al., 2011; Tallon, 2012; van Leeuwen and van der Wiel, 2003), probably because of the difficulty in measuring spillover effects. Kotelnikov (2007) stresses the importance of implementing an ICT diffusion policy focused on the innovators and early adopters firms. These firms are key actors to tempt ICT adoption among non-adopters. One of the contributions of this paper is to provide some evidence of the influence of ICT spillovers from the service industry. An attempt of the paper consists of giving empirical evidence on the determinants of ICT adoption in services firms from Colombia. In spite of the increasing implementation of IT in services, there has been little research about the critical success factors in adoption. As Rivas and Stumpo (2011) state, the knowledge and the analysis of the factors that enhance and hinder ICT adoption in firms are of relevance for public policy. The paper is organised as follows. First, an analytical framework on the main determinants of ICT adoption is provided. Following, a descriptive analysis of the services firms in terms of ICT adoption is made. Afterwards, some econometric models are estimated to capture the significant

explanatory variables of ICT adoption. An extended version of the model explores the determinants of ICT adoption comparing large firms and SME. Lastly, the paper finishes with some final remarks.

2 Theoretical framework

ICT play a main role in changing drastically the way traditional services are produced, exchanged and distributed. The old vision that services industries are technologically lagged can be rejected. Empirical evidence shows that ICT embrace an important place in the service industry (Bitner et al., 2010; Breidbach et al., 2013; Davis et al., 2011; Tan et al., 2010).

The characteristics of services and the intangibility of their operations can be changed or reinvented on behalf of the new economy and ICT adoption. The advancement of ICT has changed and continues to change the characteristics of the exchanges between firms and customers (Davis et al., 2011), enabling interpersonal interactions between a customer and a firm (Makarem et al., 2009). ICT already helped to "diminish personal interaction in service" [Walker and Johnson, (2004), p.564], thereby resulting in technology-generated self-service (Breidbach et al., 2013).

ICT advances, that allow more information to be codified, and the increasing move into knowledge technologies such as expert systems, have expanded the scope for ICT use in many services (Pilat, 2001). Little empirical literature on ICT adoption has investigated the relative importance of the explanatory factors of ICT adoption in services (Alam and Noor, 2009; Bhadouria et al., 2011; Elbeltagi et al., 2013; Haller and Siedschlag, 2008; Oliveira and Martins, 2010; Sar and Garg, 2012; van Huy et al., 2013; Tan et al., 2010; Youssef et al., 2012). Knowing the motivations and factors that promote ICT adoption constitutes an objective of researchers and business men (Chow, 1967; Taylor and Todd, 1995).

ICT adoption is a complex process that involves a multiplicity of dimensions at firm level. It is an evolutionary process that requires a minimum threshold of technological infrastructure for achieving higher levels of maturity (Kotelnikov, 2007; Rivas and Stumpo, 2011; Peirano and Suárez, 2004). Besides, organisational ICT adoption is recognised as a learning process consisting of several steps (Marchese and Jones, 2010). At the initial steps, ICT are used for digitalisation of simple tasks and processes. At the intermediate steps, firms use ICT for communication and IS sharing (intranet, extranet). Once the firms achieved a maturity level, they use more complex ICT [such as enterprise resource planning (ERP), client relation management (CRM)].

Similar to any innovation, an information technology must possess a relative advantage over existing alternatives. According to Rogers (1995), when a new technology emerges, individuals evaluate both its economic profitability and other variables such as degree of risk, convenience, time and effort saving, and immediacy of rewards.

In order to understand the main factors that drive firms to the adoption of ICT, Lucchetti and Sterlacchini (2004) divide the available technologies according to a taxonomy based on their typical function. The authors identify three types of ICT: general purpose ICT; production integrated ICT (basically intranet, EDI) and ICT market oriented (identified by a firm's website ownership and contents).

Table 1 Studies on the determinants of ICT adoption

Type of dependent variable		*Scope*	*Reference*
Dicothomous	LAN	Determinants of the perception of the objectives and promoters of a LAN network adoption in SME from Italy	Corrocher and Fontana (2008)
Nominal	Website	Factors incidence on internet adoption in SME	Dholakia and Kshetri (2004)
	Website	Determinants of a website adoption in SME	Simmons et al. (2008)
	CAD/CAM, internet	Determinants of different ICT uses, emphasis on learning	Oyelaran-Oyeyinka and Lal (2006)
	Internet-web; LAN-intranet-EDI	Determinant of internet use	Lucchetti and Sterlaccini (2004)
Continuous	E-commerce	Determinants of EC level of deployment (mixes different applications, number of links with partners and proportion of on line businesses), measured by a ratio	Chong (2006)
	PC, e-commerce, index of on line services,% of employees using PC, % internet sales	Determinants of ICT use in Irish firms	Haller and Siedschlag (2008)
	ICT adoption (numerical)	ICT adoption in services firms from Malaysia	Alam and Noor (2009)
		ICT adoption in the Swiss business sector	Hollestein (2004)
Ordinal	Ordinal ICT	Characterisation of ICT adoption in firms from tunes	Youssef et al. (2009)
	Ordinal ICT (order by number of applications)	Determinants of ICT adoption in transport and logistics firms	Hidalgo and López (2009)
	Ordinal	Determinants of ICT intensity use	OCDE (2004)
	–3 (7–9 TIC)		
	–2 (5–6 TIC)		
	–1(3–4)		
	–0 (less than 3)		
Mix types	Continues: PC/ICT expenditures per employee, time of adoption.	ICT adoption in Italian industrial firms	Fabiani (2005)
	Discrete: organisational software, website updating, network technologies use		
Qualitative	E-business; SCM	Qualitative study of the determinants	Wagner et al. (2003)
	B2B EC	Adoption paths in SME	Lefebvre et al. (2005)

Source: The authors

In Table 1, a summarising data on the recent studies about the determinants of ICT adoption classified by the type of the dependent variable used (continuous, dichotomous, and nominal) is presented.

Besides, factors for IT adoption can be distinguished between internal and external factors in empirical studies. The main reason for separating internal from external influences is to distinguish between organisation-derived factors and other motivations that may arise from the overall business environment (or outside the organisation). There are many inhibitors of ICT adoption, such as the cost of technology, a lack of managerial and technological skills, a lack of system integration and a lack of financial resources (Cragg and King, 1993; McCole and Ramsey, 2005). These inhibitors play a key role especially in SMEs where resources and the level of computer sophistication are limited.

Opportunities provided by ICT are not limited and accessible only by large firm but also to SME. An awareness of the critical success factors of ICT adoption becomes especially essential for SME (Alam and Noor, 2009; Arendt, 2008; Bhadouria et al., 2011; Chong, 2006; Dibrell et al., 2008; Dholakia and Kshetri, 2004; Elbeltagi et al., 2013; Fillis and Wagner, 2005; Meyer, 2011; Tan et al., 2010; van Huy et al., 2013) to appropriately address the relevant issues and avoid the potential failures from an inappropriate resources allocation. By using ICT, SME can reinforce their competitive position and improve their productivity.

Firm size stands for firm-specific effects not explicitly modelled such as capacity to absorb risks related to future ICT developments, economies of scale in ICT adoption, access to capital markets, among others. Firm size constitutes a relevant factor for explaining ICT adoption at business level (Fabiani et al., 2005; Hollenstein, 2004; Lugones et al., 2004; Morgan et al., 2006; Teo and Tan, 1998; Thong, 1999). Hollenstein (2004) finds that firm size is a significant explanatory factor of ICT use. This result is opposite to the assertion that ICT have reconfigured the economic structure in such a way that firm size is not already a key element for competitiveness. Some authors (European Commission, 2001; Lefebvre et al., 2005; Love et al., 2005; Teo et al., 1997; Vilaseca et al., 2002) show the lack of a significant correlation between firm size and ICT adoption. Lefebvre et al. (2005) find that some SME do not follow a linear ICT adoption pattern, since they skip some phases.

Literature on ICT adoption also includes the *ICT investment costs* as an independent variable. ICT costs represent the investment in computers and ICT equipment. Investment costs are highly important to the adoption of ICT (Alam and Noor, 2009; Chong, 2006; Dholakia and Kshetri, 2004; Rivas and Stumpo, 2011). However, they are usually ignored in the empirical analysis (Karshenas and Stoneman, 1995). Hollenstein (2004) found that ICT costs are one of the obstacles to introduce these technologies.

It has been argued that firms exposed to *international competition* are more prone to innovate and adopt new technologies. Some studies show that firms with an international orientation are more likely to adopt ICT and electronic commerce through website portals than firms without external contacts (Bayo-Moriones and Lera-López, 2007; Daniel and Grimshaw, 2002; Haller and Siedschlag, 2008; Hollenstein, 2004; Wagner et al., 2003). Hollenstein (2004) and Bayo-Moriones and Lera-López (2007) find evidence showing that firms that export are more likely to use the internet.

Moreover, patterns of ICT adoption differ between domestic and foreign owned firms meaning that the *source of capital* matters (Haller and Siedschlag, 2008). With regard to the role of networks for ICT adoption, being a *subsidiary company* increases the probability of ICT adoption due to the increasing need of coordination. Some authors

argue there exist factors of extrinsic character influencing ICT adoption such as the environmental pressure (Davis et al., 1992; Steinfield et al., 2012). Steinfield et al. (2012) show a positive relation between ICT adoption and benefits derived from cluster membership. Arendt (2008) argues that one of the main barriers of ICT adoption in SMEs is that managers and employees lack the skills, education and knowledge. *Qualification of employees* encourages innovation and makes ICT adoption easier at firm level (Arvanitis, 2005; Black and Lynch, 2004; Bresnahan et al., 2002; Fabiani et al., 2005; Meyer, 2011; Parente and Prescott, 1994). Oyelaran-Oyeyinka and Lal (2006) establish that climbing the technological ladder requires skills upgrading through explicit learning of new ICT. Many authors have employed the expenditure in salaries per employee as a proxy of human capital at firm level (Davis and Haltiwanger, 1991; Dunne et al., 2004; Franklin et al., 2008; Haller and Siedschlag, 2008; Siedschlag et al., 2011; Teitel, 1981; Wignaraja, 2008) although there are some limitations in this proxy, (salaries reflect not just differences in labour abilities, but also differences in the market structure, level of unions pressure, and the like).

Given the uncertainty about the profitability of a new technology, observing the adoption decision of other firms might play an important role in the decision to adopt new technologies (Haller and Siedschlag, 2008). ICT presents *network externalities* (Church and Gandal, 1992). Network externalities mean that the usefulness of adoption increases with the number of other adopters (direct effect) and usefulness depends on the compatibility with other components, such as compatibility between hardware and software (indirect effect).

Atrostic and Nguyen (2005) find evidence for this network externality that arises when the efficiency of products or services increases as products or services are adopted by more users. Han et al. (2011) find that industries receive significant *IT spillover* benefits in terms of total factor productivity growth through economic transactions with their respective supplier industries. It follows that information spillover effects from interactions among firms might be important for ICT adoption. Proximity to early adopters of new technology is positively related to learning effects that fostered the adoption of new technology. Information spillovers from ICT adopters to non-adopters are determinants of ICT adoption levels (Bertschek and Fryges, 2002; Canepa and Stoneman, 2003; Guiso and Schivardi, 2000; Haller and Siedschlag, 2008; Hollenstein, 2004; Karshenas and Stoneman, 1995).

Rincon and Vecchi (2010) analyse the impact of ICT spillovers on companies' performance. The authors use ICT at the industry level under the assumption that the productivity of a single company is affected by other firms' investment in ICT in its own industry. For example, the output of a pharmaceutical company is affected by the ICT undertaken in the whole chemical industry. Aggregate ICT at the industry level can only account for spillovers within the industry.

Finally, some authors believe *that firm's age* can foster (Haller and Siedschlag, 2008; Karshenas and Stoneman, 1995) as well as hamper technology adoption in terms of resistance to change and experience on advanced technology adoption (Dunne, 1994). According to Haller and Siedschlag (2008), the positive relationship is associated with reputation building. However, the theoretical arguments with respect to the role of firm age are not conclusive (Hollenstein, 2004): positive impact on adoption in case of older firms reflecting specific (technological) experience vs. a negative effect for this category of firms due to lower adjustment costs in younger companies with a more up-to-date capital stock (Dunne, 1994).

The way firms combines business activities with ICT use conveys different business paths that turns firms into single specificities (Peirano and Suárez, 2004). Due to these specificities, differentiation among services firms is needed. Their own peculiarities can impact on the determinants of ICT adoption. Among *services subsectors*, OECD (2005) argues that business services and financial services are ICT pioneers, while health and retail commerce are laggards. Similar to the manufacture industry, where the product features limit or extend the marketing possibilities through internet, web, B2C (Poon and Swatman, 1999), some services are more likely to adopt ICT for marketing (like telemarketing, travel agencies which differ from health or education services). Besides, the probability of ICT adoption in some firms (high tech industries, modern services and wholesale commerce) is higher than in others. Oliveira and Martins (2010) investigate the factors that affect the adoption of e-business by firms belonging to European Union (EU) countries, by comparing the effect across two different industries: telecommunications and tourism. Electronic and telecommunications environment as well as the business environment in which a specific firm operates influence the level of involvement of the firm in the internet (Dholakia and Kshetri, 2004). Businesses located in new and high bandwidth telecommunications regions can expect to obtain better technological services. On the other side, some authors argue that industrial norms can affect ICTs adoption by SMEs, like websites (Fillis and Wagner, 2005; Sadowski et al., 2002).

Based on the theoretical framework above, we observe several drivers of ICT adoption. The following research questions, however remain to be answered: Are the internal and external ICT adoption factors also applicable to Colombian services firms? Are there any differences in the drivers according to the ICT type? Are larger firms more likely to adopt ICT than small firms when controlling for age, human capital and industry, regardless the type of ICT? What is the impact of ICT spillovers since there have not been enough studies?

In order to address these questions, the following hypotheses were examined in the study:

Hypothesis 1	Larger firms are more likely to adopt ICT than small firms when controlling for age, human capital and industry, regardless the type of ICT.
Hypothesis 2	Firms with greater ICT investments costs are more likely to adopt more advanced ICT.
Hypothesis 3	Exporter firms are more likely to adopt ICT than firms just selling to the domestic market.
Hypothesis 4	Older firms are more likely to adopt ICT (due to reputation, technological experience) than younger companies.
Hypothesis 5	Firms with a large proportion of foreign capital or being subsidiaries of other companies are more likely to adopt ICT.
Hypothesis 6	Firms with qualified employees or intensive in human capital are more likely to ICT adoption.
Hypothesis 7	The larger the ICT spillover from the firm's service industry the more likely to adopt ICT the firm is.

3 Database source and methodology

Empirical testing of the model mainly uses a sample of Colombian services firms for the year 2008. This database was obtained through the Annual Services Survey (EAS) carried out by DANE (Colombian Bureau of Statistics). The EAS contains a special format that capture information about firm's adoption of ICT like whether a firm has internet, a web page, and the like which allows the construction of main ICT variables used in the study. The EAS also provides key information on value added, number of employees, service sector where the firm belongs, and salaries paid, among other. Then, a database merging the EDIT (Colombian Innovation Survey) 2006 and the EAS 2006 is built to achieve information about the employees' skills and other variables related to innovation activities in the services industries. Both databases include information from different services industries and different regional states. In 2006, the DANE introduced some important changes in the services data collection. The most important one was including new service activities to the sample, going from eight to 16 services activities. Therefore, the merging of these database allow us, first to test our main working hypothesis and provide results that can be useful to compare with similar research done in management information science.

Firm size is defined by the number of employees. Classification according to the number of employees (micro-firm: 1–10 employees; small: 11–50 employees; medium: 51–200 employees; large: more than 200 employees) result in:

Table 2 Size distribution of services firms

Firm size	*Frequency*	*Percentage*	*Accumulated*
Micro-firm	411	10.53	10.53
Small	1,311	33.59	44.12
Medium	1,392	35.66	79.78
Large	789	20.22	100
Total	3,903	100	

Source: The authors based on EAS (2008), DANE

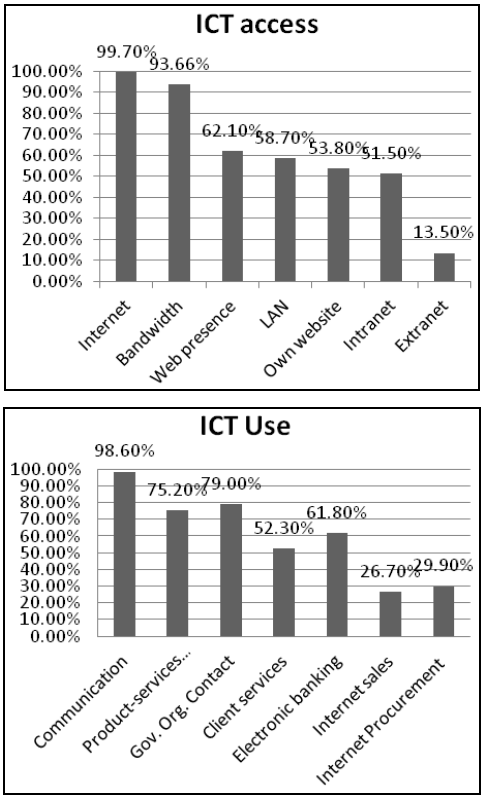
Nearly 36% of the sample is composed of medium firms, 34% of small, 20% of large and 11% of micro-firms, respectively (Table 2). In summary, 56% of the firms have more than 50 employees. The descriptive analysis links the dependent variable (ICT adoption) with some control variables.

Most of the firms use internet, website (neither own or external domain) and LAN (Figure 2). On the other side, 93.66% of the services firms have access to a bandwidth greater than 256 kbps. Among the ICT uses, communication prevails (98.06%), followed by contacting with government institutions (79%) and electronic banking (61.80%). Internet sales and internet procurement respectively rank the lowest in ICT use.

Firm size is related to significant differences in ICT adoption. The higher the firm size, the higher the percentage of firms adopting ICT. An exception is internet that is widely spread among the different sizes. On the other hand, the more complex the technology, the lower the proportion of firms using it is. At regional level, the largest proportion of firms is located in Bogotá, followed by Medellín and Barranquilla. In Bogotá, the use of an extranet prevails, while in Barranquilla, Medellín and Cali LAN use

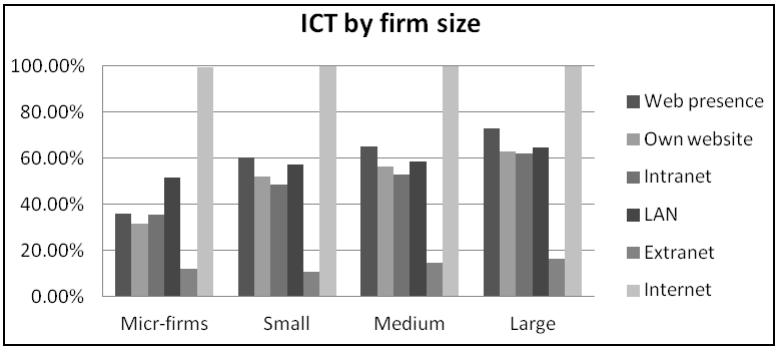
prevails. From these examinations, it is evident that the sample covers a wide amount of firms of different sizes and from different sectors and regions.

Figure 1 ICT access and ICT use



Source: The authors

Figure 2 ICT adoption by firm size



Source: The authors

4 The model

In this paper, given the richness of the ICT indicators that will be used allows that different types of models can be estimated assuming ICT heterogeneity and the nature of the dependent variable. Most of the research revised in earlier section has been limited by the availability of ICT indicators. In our case, we try to exploit that richness and run various models with the aim to see whether some general patterns prevails regardless the type of ICT indicator. The general specification is as follows:

$$y = \beta_1 \text{firmsize}_i + \beta_2 \text{ICTK}_i + \beta_3 \text{export}_i + \beta_4 \text{firmage}_i + \beta_5 \text{foreignK}_i + \beta_6 \text{education}_i + \beta_7 \text{subsidiary}_i + \beta_8 \text{serviceindustryspillover}_i + \alpha \text{Dummies}_i + \varepsilon_i$$

The dependent variable ICT adoption, y_i, can adopt different measures. It can be continuous or dichotomous. It is continuous if the variable is measured by the percentage of employees using PC or internet, dichotomous, taking a value of one if the variable is website use and zero otherwise and categorical if the variables is measured by the level of ICT use, or ICT adoption.

Based on the ICT module of EAS that brings rich information about adoption and use of different technologies (internet, website, intranet, and extranet), some ICT indicators are built: ICTSum, wICTSum, ICTUse, Website, InternetL and PCL. First, the number of ICT adopted for each firm are added giving each technology the same weighting (ICTSum). This indicator just depends on the number (quantity) of ICT adopted by each firm. It can take values from 0 to 4. Besides, an ordinal dependent variable (wICTsum) is built that differs from the ICTsum in that it weights each ICT differently according to the level of sophistication or complexity: 1 if the firm uses internet, 2 if the firm has a website and 3 if the firm has adopted other applications (intranet, extranet). Although arguably the weights are ad-hoc, they are based on the specialised literature.

Secondly, the ICTUse indicator sums up information on the several options of ICT use of each firm: communication, searching information on products and services; transactions with government; client services, electronic banking, internet selling or buying. The indicator can takes values from 0 to 7, corresponding to the number of uses.

Order logit models are estimated using these ordinal variables as dependent variables.

Thirdly, an alternative dependent variable is built: the availability of a website (Website), a dichotomous variable that takes value 1 if the firm has a website, and 0 otherwise. In this case, a logistic regression model is estimated. Lastly, the percentage of employees using internet (InternetL) and the percentage of employees using PC (PCL), both continuous variables, are estimated using a linear regression model. From the literature review, ICT adoption depends on the following group of variables: firm size (firmsize), ICT investment costs (ICTK), export conduct (export), age of the firm (firmage), percentage of foreign capital (foreignK), if the firm is a subsidiary company (subsidiary), employees' level of education (education), the ICT spillovers from the service industry (serviceindustryspillover), and service industries (dummies). The ICT spillovers from the service industry is included as an independent variable under the assumption that the ICT adoption decision of each firm is influenced by the ICT adoption level of their corresponding service industry. These spillover effects are proxied by the variables: intra-service ICT; serviceICThigh, serviceICTlow and serviceICTconstant. Table 3 summarises the basic statistics for the main explanatory variables and their meanings.

Table 3 Descriptive statistics

Variable		*Description*	*Expected sign*	*Mean*	*St dev*
wICTsum		Sum of weighted ICT		2.205136	.8934784
ICTsum		Sum of unweighted ICT		1.623918	.6574817
ICTuse		Number of ICT uses		4.139269	1.746358
Internet		Natural log of percentage of employees using internet		3.249045	1.315357
PC		Natural log of percentage of employees using PC		3.564122	1.229684
Firmsize		Natural log of number of employees, firm size	+	4.26690	1.6150
ICTK		Investment in computers equipments.	+	926995.9	9876267
Export		1 if the firm exports	+	0.10612	0.30804
Firmage		Age of the firm	+	20.4350	12.592
foreignK		1 if the firm posses foreign capital	+	0.08303	0.27598
Education	salaries	Natural log of salaries per worker	+	9.814377	.5771904
	serviceProf	Mean of professional employees' percentage of the firm's service industry	+	33.16757	13.61293
	serviceTec	Mean of technicians employees' percentage of the firm's service industry	+	9.261566	2.471018
Subsidiary		1if the firm is a subsidiary company	+	0.9455	.22701

Source: The authors

Table 3 Descriptive statistics (continued)

Variable		*Description*	*Expected sign*	*Mean*	*St dev*
Service industry spillover	intra-serviceICT	1 if the firm's ICT adoption is higher than its service industry average ICT adoption.	+	0.616207	.4863872
	serviceICThigh	1 if ICT adoption of the firm's service industry improved between 2006 and 2008 compare to the total service industries.	+	.1826484	.386441
	serviceICTlow	1 if ICT adoption of the firm's service industry worsened between 2006 and 2008 compare to the total service industries.	–	.7729941	.4189647
	serviceICTconstant	1 if the firm's service industry does not change its ICT adoption level from 2006 to 2008.	?		
Services industries	sectorR&H	Sectorial dummy: 1 if restaurant and hotels service industry (12.9%)			
	sectori	Sectorial dummy: 1 if transport, storage and marketing service industry (12.7%)			
	sectork	Sectorial dummy: 1 if real estate service industry (50.1%)			
	sectorl	Sectorial dummy: 1 public administration (3.6%)			
	sectorn	Sectorial dummy: 1 if teaching and health (15.8%)			
	sectoro	Sectorial dummy: 1 if other sector (4.8%)			
Firm size	Micro	Size dummy: 1 if the firm employs <10 employees			
	Small	Size dummy: 1 if the firm employs 11–50 employees			
	Med	Size dummy: 1 if the firm employs 51–200 employees.			
	Large	Size dummy: 1 if the firm employs >200 employees.			

Source: The authors

5 Findings

Table 5 presents the overall findings. Each column is numbered and represents the estimation output for each of the several dependent variables and the econometric technique used.

Firm size (firmsize) presents a significant and negative sign in the linear regression models (percentage of employees using internet). According to Lucchetti and Sterlaccini (2004), the negative sign could be explained by the taxonomy of the ICT.

> "Since PC and Internet are ICTs of general use, rates of adoption are very high and do not depend on size. When the rate of effective use is measured by the share of total employees with access to these ICTs, the percentage of educated workers exerts a positive effect, and in the case of Internet, a negative impact of size emerges." (Lucchetti and Sterlaccini, 2004)

The negative effect of size is strongly influenced by the functional distribution of the firm's employees. In particular, the negative relationship between size and the percentages of employees with access to these ICT could depend on the fact that the share of non-production workers decreases with size. However, this difference could be difficult to address in services firms and data about the functional distribution of the employees is missing.

In the ordinal dependent variable models, the influence of firm size is significant and positive. This result is similar to some authors (Hollenstein, 2004; Elbeltagi et al., 2013). Thus, empirical evidence show the inconclusive effect of firm size on ICT adoption (Bengtsson et al., 2007; Dholakia and Kshetri, 2004; Sadowski et al., 2002).

Besides, the ICT investment (ICTK) shows a positive and significant effect on the ICT adoption. Literature on ICT and productivity stress the existence of a positive relationship between ICT investment and productivity at firm level (Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000). This suggests, following Haller and Siedschlag (2008) that ICT adoption may be more likely in ICT intensive industries relative to the rest of industries Some authors (Love et al., 2005) show that the level of investment in information technology differs across industries.

Besides, export service firms (export) are more likely to adopt ICT as was stressed in the theoretical framework. The international penetration of these firms enhances ICT adoption for communication and coordination purposes, among others. These results confirm Hollenstein (2004) and Bayo-Moriones and Lera-López (2007) findings. Besides, they are robust to the inclusion of some control variables and to changes in the dependent variable.

In the case of firm age (firmage), the older the firm, the higher the probability of ICT adoption is. This positive effect reflects specific technological experience of older firms and confirms Haller and Siedschlag (2008) and Karshenas and Stoneman's (1995) findings.

The proportion of foreign capital, foreignK, is only significant in the order logistic models. The difference in the probability of accepting/receiving orders online between the domestic and the foreign owned firms is stress in Haller and Schiedslag (2008). One explanation is that the adoption of more advanced technologies requires a higher amount of capital and confronts greater risks. Foreign firms can mitigate both effects since they can afford the capital needed and they have the experience in ICT use from other

countries. On the other hand, the positive sign of the condition 'if subsidiary' was expected: a subsidiary firm is more likely to adopt ICT than the others due to the ICT spillovers effects.

Similar to previous empirical studies (Tan et al., 2010; Haller and Schiedslag, 2008) and contrary to Dholakia and Kshetri (2004), the employees' level of capabilities and skills, education, (proxied by salaries per employee) is a significant and positive variable. Those firms with qualified workers are more likely to adopt ICT. Therefore, a lack of ICT expertise has been highlighted as one of the barriers to ICT adoption (Elbeltagi et al., 2013) and it is consistent with the results of this study. For instance, intranet and extranet are more complex technologies and demand higher absorptive capacities from employees. The variable appears insignificant when using website and ICTUse as the dependent variables.

Following Lucchetti and Sterlaccini (2004), this study does not consider there is a correlation problem between human capital and investment in computer equipments (ICTK). However, one way to take account of this problem is adding the variables serviceProf and serviceTec which represent the service industry human capital, not the firm's (see Table 6).

The variable Intra-ServiceICT level shows a significant and positive incidence on ICT adoption, meaning that the ICT adoption level of a service industry can influence the propensity to adopt ICT of its firms. The spillovers or externalities from the service industry to the individual firm are significant. This result is consistent with Han et al., (2011), Haller and Siedschlag (2008); Hollenstein (2004); Canepa and Stoneman (2003) and Bertschek and Fryges (2002). For instance, the more ICT dependent a service industry becomes, the more likely that a firm belonging to that service will adopt ICT.

Furthermore, a variable that captures if a firm's service industry has improved (increase) its ICT adoption between 2006 and 2008 is included (see Table 6). It pretends to capture the ICT adoption variation of a specific service industry compare to the whole services industries'. The ICT adoption worsening (decrease) of a service industry reduces the likelihood of ICT adoption of a firm belonging to that service industry. However, the results show that an ICT adoption improvement at industry level does not induce ICT adoption at firm level. This is an interesting result but more research has to be done to better explain it, perhaps in a longer span of time. One can forward that the level of adoption at industry level is still low and spillover has not been produced. But it also can be explained by the sample of firms. The EAS includes some firms randomly and a small set is mandatorily included, in particular larger firms.

The independent variables show a good fit of adjustment both in the OLOGIT model (wICTsum) and the OLS models. Although the study does not focused on a particular kind of service, the transport, storage and distribution (including travel agencies) and the public administration industries are significant in the model.

5.1 Estimation comparison between large and SME firms

In this section, the weighted ICT sum model is estimated segmenting the sample by firm size. The ICT adoption decision differs between large firms and SME (ICT adoption is supposed to be a size-dependent decision). Table 6 shows the findings.

Table 4 Correlation matrix

Variable	*Firmsize*	*ICTK*	*Export*	*Firmage*	*ForeignK*	*Education*	*Subsidiary*	*Intra-serviceICT*
Firmsize	1							
ICTK	0.079*							
Export	0.0073	–0.0289	1					
Firmage	0.0306	0.1838	0.0047	1				
ForeignK	–0.0172	–0.0442	0.0397	–0.0172	1			
Education (salaries)	0.048*	–0.1145*	0.3157*	0.1014*	0.0823*	1		
Subsidiary	0.02*	0.0345*	0.1329*	–0.0041	–0.0056	0.2664*	1	
Intra-serviceICT	0.047*	–0.001	0.1741*	0.0707*	0.0540*	0.2956*	–0.1000*	1

Note: *Significant at 5%.

Source: The authors

Table 5 Estimation outputs

	LOGIT		*OLOGIT*						*OLS*			
	Website		*ICTSum*		*wICTSum*		*ICTUse*		*InternetL*		*PCL*	
	Coef	*z*	*Coef*	*z*	*Coef*	*z*	*Coef*	*z*	*Coef*	*t*	*Coef*	*t*
Firmsize	–.00001	–0.28	.3836***	6.17	.3036***	5.09	.05254*	1.80	–.8089*	–2.02	–.0207	–0.14
ICTK			4.49e-09**	2.49	3.64e-09**	2.25			1.08e-07***	7.07	2.12e-09 ***	4.63
Export	.2338***	2.27	.7533***	10.46	.6466***	7.42	.3869***	9,28	4.103**	2.56	.054**	3.41
Firmage	.0048***	1.97	.1624	1.83	.0031	1.06	.0044***	3,04	–.1729***	–14.82	.0009	1.40
foreignK	.1464	1.43	.207***	3.48	.2666***	3.62	.02591	0,31	11519	0.69	–.0376	–0.19
Subsidiary	–.365***	–3.01	–.1178	–1.17	–.409***	–5.87	.0154	0,68	–3.626**	–2.70	.6234	6.63
Education	9.66e-06	7.64	.3912***	3.98	.3883***	3.34	9.52e-07	0,82	8.842***	7.97	.2448***	5.05
Intra-serviceict					1.121***	9.24	1.377***	12.9	46.73***	23.31	1.1624***	15.84
SectorrR&H	.1860		.27870**		.0209		–.0546		–15.6***		–.2689***	
SectorI	.4420 *		.60566**		.3217		.1314		9.028**		.6586***	
SectorK	–.1137		–.1714**		–.2146**		–.0279		6.575**		.00474	
SectorL	1.592***		.9911***		.8089***		.0696		28.32***		.5307***	
SectorN	–.553***		–.486***		–.446***		–.0977		–6.329*		.3116***	
Micro							–.2556*					
Small			.2023		.3052**		.1138		–23519		.16452	
Médium			–.0692		.1940		–.0130		–.1300		.07121	
Large			–.5154		.0396				–10.75**		–.2979*	
Constant									–99.7***		–1.545**	
N	3267		3084		3085		3408		3035		3061	
Wald chi2/F			255.29		163.59		248,09					
Prob>chi2/F			0.00		0		0		0.00		0.00	
PseudoR2/R2	0.0404		0.1177		0.082		0.0123		0.5723		0.5675	

Notes: ***, **, * significant at 1%, 5% and 10% respectively. Standard errors are robust to heterocedasticity

Source: The authors

Table 6 Estimation output *wICTSum* (large versus SME)

	Complete sample		*Large*		*SME*	
	Coef	*z*	*Coef*	*z*	*Coef*	*Z*
Firmsize	.2856***	6.17	.2609***	2.74	.3315***	12.82
ICTK	5.08e-09***	2.19	4.24e-09***	2.54	3.60e-09	1.46
Export	.8359***	13.60	.9650***	3.30	.7631***	13.54
Firmage	.0049		.0177***	3.67	–.0005	–0.14
ForeignK	.3192***	3.51	–.1289	–0.68	.4116***	3.37
Subsidiary	–.402***	–4.79	–.5811***	–4.09	–.4051***	–3.20
Education (salaries)	.3883268 ***	3.34	8.29e-06		.00001***	
serviceProf	.0060***	6.22	.0294***	4.67	.0161***	5.17
ServiceTec	–.0679***	–4.62	–.0248	–0.68	–.0158	–1.38
ServiceICThigh	–.0555	–0.21				
ServiceICTlow	–.6524***	–3.31				
Intra-ServiceICT	1.2085***	12.56	.9665***	8.22	1.24***	12.64
Small	.3188**	2.13				
Medium	.2235	1.33				
Large	.0799	0.25				
sectori			.6592		.3780*	
sectork			–.5115***		–.4226***	
sectorn			–.5708***		–1.155***	
N	3120		645		2475	
Wald chi2	905.28		79.10		948.21	
Prob>chi2	0.0000		0.0000		0.0000	
Pseudo R2	0,0769		0.088		0.0717	

Notes: ***, **, * significant at 1%, 5% and 10% respectively. Standard errors are robust to heterocedasticity

Source: The authors

The number of employees is statistically significant for all firm sizes. An increase in the number of employees increases the probability of ICT adoption. This result is consistent with the general model from the previous section. On the other hand, Table 6 also shows that the export indicator is robust to firm size changes. If a firm exports, the probability of ICT adoption is higher regardless of firm size. The proportion of foreign capital is a significant variable for SMEs while for large firms, surprisingly, this variable does not affect ICT adoption. This relationship between firm size and foreign owned is documented in Haller and Siedslag (2008).

Firm age is significant for large firms, but not for SMEs. The older a large firm is the higher its ICT adoption propensity is. Furthermore, the condition of subsidiary affects in a significant and positive way the ICT adoption between SMEs and large firms.

The Education variable (salaries per employee), shows a significant and positive effect in SME ICT adoption. The higher the education (the ICT readiness of employees), the higher the propensity to adopt ICT is. However, this variable is not significant in

large firms. This result suggests that qualification of employees is a necessary condition in SME to adopt ICT and for large firms they nay have adopted for some time and then the human capital might be not so important.

The model includes the mean percentage of professional employees of the service industry (serviceProf) to which the firms belong. This variable is built based on data from EDIT-EAS 2006 and pretends to proxy the learning process of the firms. Interestingly, it positively influences ICT adoption for all firm sizes, meaning that the educated employees can absorb better the new technologies. On the other hand, in the case of technicians (serviceTec), the variable is not significant and negatively related to ICT adoption.

Lastly, the Intra-service ICT variable is significant and positive in both sizes. Thus, if a service industry's ICT level is lower than its corresponding firm's, the firm's probability to adopt ICT will be lower.

6 Final remarks

ICTs play a key role in businesses and in service firms in particular. Service firms, now engaged in a knowledge-based economy, have changed and developed due to advances in technologies.

This paper examines factors driving the adoption of ICT at firm level using data from about 3,400 services firms in Colombian services industries. Although the study uses data from Colombia, this paper contributes to the understanding of the determinants of ICT adoption in developing economies using micro level data. Achieving this goal is a complementary step to understanding the impact of ICT on service firms. A future research objective would be comparing the results between manufacturing and services. Since a large number of manufacturing firms provides services, it would be interesting to compare the results.

A further contribution of the paper is assuming ICT heterogeneity. Therefore, the adoption decision model can be different according to the ICT type. Most of the variables included as drivers of ICT adoption, such as firm size, firm age, export conduct, percentage of foreign capital, whether the firm is a subsidiary company, the employees' level of education, the ICT spillovers from the service industry, among others, are significant and present the expected signs, regardless the ICT indicator. The estimated models have a good fit adjustment.

Besides, the paper deals with the assumption that ICT adoption differs between large and SMEs. Results revealed that the adoption of ICT by SME is explained by different factors than for some variables, such as proportion of foreign capital, firm age and employees' education, the results differ. For instance, a higher education level (proxied by the amount of salaries per employee) increases the probability of ICT adoption in SMEs but not in large firms. Also the experience of a firm (proxied by firm age) only impacts positively in large firms.

On the other hand, the marginal effects of the variables in the OLOGIT models were not estimated since there is interest on the direction of the relationships between the explanatory factors and ICT adoption, not on their magnitude.

ICT adoption is recognised as a learning process. The ordinal nature of the dependent variable pretends to capture that once the firms achieved a maturity level, they use more complex ICT. However, it would be interesting to add data about the first year of

adoption of the technologies to capture the firm's experience in ICT use (learning effects).

Moreover, the estimated model can be improved, for example, introducing variables of organisational change. These organisational change variables are usually perceived as a barrier to large firms. Contact with third parties, such as universities, business partners, government support, was not included in the model due to lack of information. However, these institutional sources could explain the incentives to adopt ICT. Besides, there is no information about the perceived benefits and risks associated to ICT adoption in the survey.

This paper, by identifying the factors that influence ICT adoption in services firms from Colombia, provides further information that may help service industries and government from developing countries in designing policies for enhancing ICT adoption and use. The results offer valuable insight to managerial and policy makers; they should promote information technology training programs to employees, and information technology infrastructure in each industry.

Acknowledgements

María Verónica Alderete is very grateful for the financial support of DIRSI (*Diálogo Regional sobre la Sociedad de la Información*). DIRSI financed a research internship of six months in Universidad del Rosario, Colombia in 2011. The project used funds from the IDRC-CRDI International Development Research Centre and the Canada's International Development Research Centre.

The authors thank DANE and its officers who kindly collaborated with the provision of main data. All data processing of both EAS and EDIT took place in DANE's facilities. The errors and omissions are all authors' responsibility.

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