An Econometric Estimation of ICT Equipment, Usages and depth of adoption in Catalan Firms

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ABSTRACT

The intensity of ICT uses by firms is a growing topic in economic literature, which is becoming in the focus of attention. However, there is a lack of empirical research, particularly in Europe. This paper aims to understand the general forces behind ICT adoption and uses in Catalan firms. Our investigation is based upon a survey conducted in 2003 for 2500 enterprises by the Catalan government. Two econometric models are then tested. The first one is an ordered probit model where we test the probability of equipment in ICT relative to the characteristics of the firms and their environment. Second, we built a general model explaining the usages in function of some specific variables and we explain the specific dynamics of usages in Catalonia. We have tried to test how standard arguments and forces behind usages are working in the Catalan setting. Our aim also is to explain the depth of adoption of the Catalan firms of these new technologies (e.g) the extent of the capabilities of the technologies exploited by these firms.

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1. Introduction

The potential of ICT usages in business is a topic that was well-covered during the last decade. Since ICTs are considered as General Purposes Technologies (Bresnahan et Trajtenberg, 1995), they are shaping the internal organization of the firm, its borders and also its productivity and performance. International literature gives empirical evidence that adopting a new technology influences firms' productivity rates in the short and long term. Short-term productivity losses may affect the decision process of adopting a new technology. In fact, it involves three main decisions: 1) whether to adopt or not, 2) the replacement speed of old technology with new one, and 3) the extent to which the capabilities of the new technology will be exploited by a firm, which is usually known as "depth of adoption" (Astebro, 2004).

The objective of this paper is to verify the standard effects of technology adoption on the extent of ICT depth of adoption. Hence, we focus on Firm's size, organization, its absorptive capacity, location, cooperation and innovation. The main contribution is to verify how standard arguments for ICT adoption behaviour work in the context of Catalan firms in 2003 and highlighting the difference between the patterns of adoption and those of usages.

In order to reach this objective, our paper is divided into five sections. Section one summarizes the main findings in the economic theory. Section two explains how the data was collected and the theoretical model used. Section three identifies the main explanatory variables and the models used. Section four discusses the results and the findings. Section five concludes.

2. Literature review

Through this literature review we aim to identify which are the main variables that theoretically might affect the depth of ICT adoption and use by a firm. In recent years, an extensive literature had tried to understand these main determinants. At least we found five complementary explanations: size of the firm argument, the absorptive capacity argument, the organization argument, the competition argument and the location argument.

Size of the firm: connectivity and scale economies

Firstly, it can be remarked that there are three verified facts related to firms' size. Large firms are more likely to adopt new technology than small firms (Rogers, 1995). Having adopted new technology, large firms will learn how to use a new technology more than small firms (Fichman and Kemerer, 1997). However, the replacement speed of old with newly adopted technology – the intra-firm diffusion speed – is inversely related to firm size. Adjustment costs related to technology adoption can explain these results. As the output to which directly or indirectly the new technology is applied increases, the adjustment costs are spread over a more substantial output volume which in turn, increases the incentive to both adopt and intensify the use of the technology. That is, sunk costs imply firm-level cost-spreading scale economies for these technologies. Adjustment costs also imply that small firms make proportionally larger adjustments to their capital stock than large firms (Doms and Dunne, 1998), which explains the inverse relationship between firm size and replacement speed. Secondly, there are some explanations for the decision about investment and the depth of adoption of a new technology through firms' scale economies. One explanation comes from the classical capital replacement theory. It predicts that larger firms are more likely to adopt new technology because they have a larger capital stock and the capital stock needs

replacement at regular intervals. The larger the stock the larger is the probability of replacement with a new technology at any point of time. Here, it is important to point out that this theory does not determine a prediction on the depth of adoption (Astebro, 2004). Therefore, it is not clear if this prediction is applicable to digital technologies, as they are directly related to labour. An alternative explanation is that firm's output and the size of capital stock are positively correlated. And, finally, another explanation for the positive correlation between scale economies and depth of adoption is scope economies. Larger firms may produce more products (Baldwin and Gorecki, 1986) and ICT use may be an incentive to make the management of business processes more efficient, as they are general-purpose technologies (Bresnahan and Trajtenberg, 1995).

Absorptive capacity: qualification of the workers, research and development and cooperation

The debate on the role of the qualifications of the workers on the use and the adoption of the ICT is not a new topic. Indeed, Nelson and Phelps (1966), Welch (1970), Schultz (1975) described in a detailed way the role of Higher Education graduates in the use of new technologies and the facilitation of their adoption within the firms. This debate takes a new form with the widespread of the ICT. Indeed, since ICT are supposed, partially, to be General Purposes Technologies (Bresnahan and Trjatenberg, 1995), they require complementary adjustments and innovations to in order to be consistent with the firms' needs. Bresnahan, et al. (2002), suggest that ICT uses had lead to more qualified job in the U.S. economy. Thus it is supposed that the human capital accumulated within the firm are a facilitating factor and a driving force for adopting these technologies. Applying the argument of Cohen and Levinthal to ICT means that the more the technological absorptive capacity of the firm is important the more it is able to adopt and to use these technologies for innovation. However, there's a lag between adoption and increase in productivity. The effects of GPT's on productivity increase required about thirty years for electricity (David, 2001). As for ICT, it was estimated between 5 and 15 years for American industry (Basu and alii, 2003). This time lag seems to be more important for the European economy, if we take into account the constraints of qualifications and training (Hempell, 2003).

Organization and ICT

ICT impact the process of coordination and communication (Brousseau and Rallet, 1999). The adoption of the ICT and the new corresponding organisational practices make it possible to involve more and more non-managerial workers in the process of problems resolution and in the identification of new opportunities of innovation and growth (Black and Lynch, 2001). To some extent, the organisational innovations related to the use of ICT make it possible to involve more people in the process of exploration/exploitation. Thus, in the United States, the improvement of the quality of management, the continuous innovation and the modification of the incentives of the employees made it possible to increase the productivity. Black and Lynch (2004) show that out of 1.6% of increase in the Total Factors Productivity over the period 1992-96, the contribution of the changes in the working stations (organisational innovations) accounted for 1.4%! Milgrom and Roberts (1995) affirm from their side, that there is a rationality to use, in this context "a cluster of organisational practices". The adoption of a whole of practices gives better results taking into account the synergic effects. Ichniowski and alii (1997) showed the positive effects of the adoption of the organisational pack on the performance of iron and steel industry in the United States. More generally, many studies in the United States (Ichniowski and alii, 1997; Black and Lynch, 2001 and 2004), in

the United Kingdom (Caroli and Van Reenen, 2001; Forth and Mason, 2004), and in France (Greenan and Mairesse, 2004; Greenan and Walkowiak, 2003) tend to show the link between the generalization of the uses of the TIC and the adoption of a cluster of organisational innovations. For this same case (Kremp and Mairesse, 2004) show that in the modern economies based on knowledge, the companies are conscious that individual and collective knowledge is one of the major factors being able to influence the economic performance. The authors show that in the case of France (1998-2000, CIS3) and in connection with the adoption of these four practical it proves that the management of knowledge contributes to the performances innovating and productive of the companies.
Thus, we expect that firms, which adopt new organizational designs, have more probability to adopt and to use these technologies because they are aware of these complementarities.

Location argument

The relation between ICT and geography was in the heart of an extensive literature. Several studies have tried to show whether those technologies are complement or substitute to cities (NTIA, 2002a, 2002b; Millets and Whitecare, 2003) in the United States, (Dryburgh, 2001) in Canada, (Nunes, 2004) in Portugal, (Balk Curras and Lera Lopez, 2004) in Spain, (Assinform, 2004; Bonaccorsi et al. 2002) in Italy, and (Qingxuan and Mingzhi, 2002; Wensheng, 2002) in China. At least three approaches followed, according to three different optics: substitution, co-evolution and the recombination (Graham, 1998).

According to the substitution view, ICT are supposed to directly induce social and space changes according to a linear and deterministic view. Urban areas are supposed to lose their attraction with the increasing adoption of broadband and ICT. In other words, the rural regions would be revitalized and one would witness a substitution in the establishment of the households and firms between areas. Two spaces are thus regarded as substitutable and the economic agents make their decision of establishment according to various parameters among which the equipments in ICT take a considerable place. The second view is the co-evolution view. It stresses on the process of co-evolution between technology and space. In other words, technologies contribute to the modification of space and the relation between the economic agents and this one. The interaction between technology and space induces the production of new types of space location.

The last view is that of the recombination which gives advantage of importance to the social construction of technology. "Technologies only cuts contingent, and various, effects through the ways they become lined into specific social contexts by linked human and technological agency " (Graham, 1998, p. 178).

After have characterised these effects we will illustrate them in the context of Catalan firms.

3. Hypothesis

From the literature review can be derived that ICT adoption and ICT depth of adoption (understand as intensity of use) by firms have different economic properties, although they share some common traits, such as the influence of firms' organization structure, workers skills, investment in training and willingness to innovate.

ICT adoption or digital investment by a firm can be well explained trough classical assumptions of manufacturing investment behaviour as a mix of availability, price and cost of capital. Under this statement, we want to verify if:

H1: *size, firms' productivity, workers skills and training, new organizational practices, innovation willingness and cooperation policy to innovate are the main variables explaining the probability of ICT adoption by firms.*

Differently, ICT depth of adoption is more influenced by more firm-specific behaviour, focused on economic activity, networking, managers skills and innovation internal capabilities based on ICT uses:

H2: size, economic sector, labour productivity, networking organizational structure, managers skills, workers profile and innovative capabilities based on ICT uses are the main variables on the explaining of a firm's probability of depth of digital adoption.

4. Sample, data description and econometric models

4.1. Data

The analysis is based on the data of a survey carried out between January and May 2003 on the firms developing their activity in Catalonia from. Its general objective is to analyze the transformation of the strategy and the organisation of the companies linked to the use of information and communication technologies (ICT). The survey has been carried out by a questionnaire, consisting of a face-to-face interview of one-hour duration, on a representative sample of 2038 Catalan firms. The interviews, held with entrepreneurs or company directors who have a global vision of the whole activity, were generally well received and the collaboration of the interviewed was high. In addition, the questionnaire information was completed with economic and financial information available to the general public in the Registre Mercantil (Mercantile Register), obtained through the SABI program.

The questionnaire yielded data, for all firms, on the ICT equipments, such as Internet, Mail, Intranet, LAN/WAN/..., the objective pursued by using ICT, such as, Information, Communication, Administration...and many other variables which may also serve as determinants of ICT adoption

The dataset contains information on firm's characteristics such as size, industry affiliation, number of customers, number of providers...its human capital composition, its localisation, its financials characteristics, etc...

4.2. The models

In order to study the factors that influence the intensity of usage and adoption of ICT by the Catalan firms, we use an ordered probit econometric model. The aim of the model is to determine the effect of different factors on the probability of the ICT adoption and use by the firm, such as age, size and networks effects, localisation and geographical dispersion effect, organisation of the firm, its absorptive capacity and human capital effect and the innovation and cooperation effect. Indeed, this method makes it possible to study the exerted influence by a series of factors on a multinomial ordered variable.

The basic variables of our study are binary and qualitative (they take the value 1 if the firm uses an ICT tool and value 0 if not). Firms' answers give us the information on whether they adopt or use a particular technology or a tool of communication or not. For example, a firm indicates if it chooses the use of Intranet or not.

Since we have various types of binary variables, which are gathered, after, in different types of scores, to formulate a total score of adoption and a total score of use of the ICT. This gives us the multinomial character of this distribution (because it is composed of various methods) and the ordered character (because it is deduced starting from other binary variables).

From these particular hypotheses, we use ordered probit models. Indeed, the explained variable is subscripted from 1 to 18 for the adoption score and from 1 to 11 for the usage score. These variables are thus discrete and ordinate. A probit multinomial model would thus neglect the ordinality of the dependent variable while a linear regression, on the contrary, would treat the difference between indices 3 and 4 in the same way that the difference between indices 1 and 2, whereas this corresponds only to one classification. In these two cases, the estimators would be thus biased (Green 2000 & Thomas, 2000).

The models commonly used for this type of variables are thus the ordered logit and probit models. These models are founded on the estimation of a continuous latent variable, subjacent with the subscripted variable of interest. In an ordered probit model, the residue associated with this latent variable is supposed to follow a normal law.

Indeed, this method makes it possible to study the influence exerted by a series of factors on a multinomial ordered variable (Green, 2000& Thomas, 2000). The ordered probit models are generally based on probability. The latent model is similar to that of a binomial probit.

$$y_i^* = \beta x_i + \varepsilon_i$$

Where y_i^* is unobserved, continuous and latent measurement of ICT use, x_i a vector of endogenous variables, β the vector of the parameters and, ε_i the residual error, which follows a normal distribution. In the case of the probit multinomial ordered, one observes:

$$y_i = j \quad if \quad c_j < y_i^* < c_{j+i}$$

Where *j=0, 1, J* represent the various methods of the endogenous variable. The observed coded variable, y_i are determined by the following model:

$$\begin{aligned} y_i &= 0 \quad if \quad -\infty < y_i^* < \mu_1, \\ &= 1 \quad if \quad \mu_1 < y_i^* < \mu_2, \\ &= 2 \quad if \quad \mu_2 < y_i^* < \mu_3, \\ &\vdots \\ &= J \quad if \quad \mu_{J-1} < y_i^* < \mu_J, \end{aligned}$$

Where μ_k is unknown parameter that must be estimated with the vector β.

The estimate of the model enables us to obtain the probabilities of realization of each index of the dependent variable. These probabilities are given by:

$$\Pr ob(y_i = 0) = \phi(-\beta' x_i)$$
$$\Pr ob(y_i = 1) = \phi(\mu_1 - \beta' x_i)$$
$$\Pr ob(y_i = 2) = \phi(\mu_2 - \beta' x_i) - \phi(\mu_1 - \beta' x_i)$$
$$\Pr ob(y_i = 3) = \phi(\mu_3 - \beta' x_i) - \phi(\mu_2 - \beta' x_i)$$
$$\vdots$$
$$\Pr ob(y_i = J) = 1 - \phi(\mu_{J-1} - \beta' x_i)$$

With ϕ represent the normal law function distribution.

The adjustment of the model is done by the Maximum likelihood estimation (Maddala & Flores, 2001), the following latter being written:

$$L = \prod_{i=1}^{N} \prod_{j=0}^{J} F_{ij}(x, \beta)^{y_{ij}}$$

Let us note that the marginal effects of the explanatory variables x_i on the probabilities are not equal to the coefficients. Thus, only the sign of the coefficient will be interpreted here and not its value.
We try to model first the intensity of equipment or adoption of ICT and second the intensity of usage of various ICT tools.

5. The variables

5.1. Dependant variables

In our study we considered four models at four different dependant variables. Our dependent variables are obtained starting from the calculation of a total score of equipment, which is obtained by summing two under-scores (General Equipment and Specific Equipment), and a score of the ICT use.

Variable	Definition
Global intensity of ICT adoption or equipment	
❶ Equipment	Number of ICT elements adopting by the firm in 2003
❷ General equipment	Number of ICT general equipment adopting by the firm in 2003
❸ Specific equipment	Number of ICT general equipment adopting by the firm in 2003
Intensity of ICT usages	
❹ ICT usage	Number of ICT equipment already in use by the firm in 2003

Table 1. Definition of the dependant variables

A - Variables measuring global intensity of ICT adoption

Firstly, we calculate the stock of eighteen ICT tools adopted by the firms: 1-Mobile Phone, 2-Computers, 3-Internet, 4-LAN/WAN, 5-EDI, 6-Web site, 7-CRM … Every firm has a score between 0 and 18. The variable used here is an ordered polytomic variable characterizing the adoption of the ICT (global or total score of adoption), it is obtained by summing two ordered qualitative variables (score of equipment: ***Model1***).

Secondly, this score is divided on two others scores, according to the criteria of the level of adoption. The first score gathers the ICT tools which are generally adopted by all the firms, such as Mobile Phone, PC, Internet ... And the second score gathers the CT tools which are specific to the firm, such as ERP, EIS...

First variable (score of general equipment: ***Model2***) gather the basic or general purpose ICT tools that the firm has, such as: 1- Mobile Phone, 2- Computers, 3- Internet, 4- LAN/WAN, 5- EDI, 6- Web site, 7- E-mail, 8- Intranet, 9- Firewall or antivirus (either nine types of use).

Second variable (score of specific equipment: ***Model3***) gather the specific ICT tools for each firm, such as: 1- Information processing system of production planning, 2- 1- Information processing system of production planning to providers, 3- 1- Information processing system of production planning to distributors, 4- CRM, 5- operational system of accountancy and invoicing, 6- system of payment by ICT tools, 7- system or control program of data or exploitation of information, 8- EIS and 9- ERP (either nine types of use).

Each variable is presented, therefore, as follows:

$$\begin{cases} y_i = 0 \quad if \quad zero\ equipment \\ y_i = 1 \quad if \quad one\ equipment \\ y_i = 2 \quad if \quad two\ equipments \\ \qquad\quad \vdots \\ y_i = n \quad if \quad n \quad equipments \end{cases}$$

With n=9 for variables score General Equipment, n=9 for the variable score Specific Equipment and N = 18 for the Total Score variable (Score of adoption).

y_i represent the dependant variable of the adoption of ICT by the firm *i*. This variable will be estimated by different explanatory variables (X_i).

B –Variables measuring intensity of ICT usages

In this paragraph, we chose to distinguish between the uses of the ICT, not according to the tool used (Internet, Computers, EDI…), but according to the real usage expressed by the firm via their answers concerning usage. In order to obtain this variable we gathered eleven

purposes of ICT use by the firms, such as: Communication, Information, Management, e-commerce, e-mail… Every firm has a score between 0 and 11.

The variable used here (score of ICT usage: ***Model4***) is, also, an ordered polytomic variable characterizing the finality of the ICT usages by the firm. It gathers the uses which meet specific needs for the company, such as: 1- Communication, 2- Communication with costumers and providers, 3- Information via Internet, 4- E-mail, 5- E-banking, 6- Web Page and Online Marketing, 7- Internal communication, 8- Management, administration, Accounting, 9- Basic tool in work/tasks, 10- E-commerce and 11- e-procurement (either eleven types of use).

Therefore this variable is presented as follows:

$$\begin{cases} y_i = 0 \quad if \quad zero\ usage \\ y_i = 1 \quad if \quad one\ usage \\ y_i = 2 \quad if \quad two\ usages \\ \qquad\quad \vdots \\ y_i = 11 \quad if \quad 11\ usages \end{cases}$$

y_i represent the dependant variable which summarizes the intensity of ICT usage by the firm *i*. We test the estimation in function of the same explanatory variables (X_i) of the first model.

5.2. Explanatory variables and expected effects

The aim of our estimation is to characterise the usage of digital technologies among the Catalan firms. In order to do this, we plan to do several estimations by selecting different sub-groups of firms. We want also to understand how different theoretical effects are working in an earlier stage of adoption of these technologies. Five effects are tested: the size and network effect, the absorptive capacity effect, organization effect, location effect, and cooperation and innovation effect.

Size and network effects

The most important effect summarizing the depth of adoption is the size of the firm. Different explanations are giving in order to justify why big firms are more able to adopt and use these technologies. Generally the small firms rather easily adopt the everyday usages of the ICT, but they need to be assisted to reach the uses more innovating. Therefore, more the company is large plus its adoption and use of the ICT is important. In our estimation we took into account the size of the firm by the logarithm of the number of workers establishment.

ICT are network technologies. They fit well with belonging to a group companies and with importer firms. The variable "Belonging to a group", which indicate if the firm belong a group or not, anticipate advantages from improving external relationships and coordination with others firms of its group, which cannot be neglected. This one should tend to increase the probability of integration in a broader network and thus the probability of using the ICT. Even case also for the importer firms which have a more important use of the ICT. We also consider that the number of customers and the number of providers as factors which can influence ICT adoption and use. We try to approximate here the connectivity of the firm by

the number of the relationships (customers, suppliers, importers, plants…). We expect a positive effect between the connectivity of the firm and the adoption process. However the size of the firm gives us the internal dimension of the connectivity, those factors give us the external dimension of the connectivity.

One should not also forget to see the effect of the sector affiliation on the adoption and the use of the ICT. The sector affiliation of the firm should also constitute an important factor of adoption insofar as it reflects productive and organisational logics. Thus, we distinguished, by a dummy variable, in our study between the firms which belongs to the sector of information and the others.

Absorptive capacity effect

Human capital is expected to be correlated with adoption and use of ICT by the firms. We use the only variables referring to this dimension as a proxy of the human capital. The first variables, which all are dummy variables, are higher education degree of the directors and workers; indicate if the director and the worker have a university level. These two last are integrated in the analysis because the educational level is a factor among others which can influence the choices of the manager and the workers and condition his vision towards new technologies which also depends on its own convictions. However, the importance of education is obvious, since new technologies require skilled workers. Also, we try to analyse, whether the worker is implied in training programme, has an effect on the adoption and use of ICT.

The second variable is the average age of the directors and the workers. These two last variables can also give an idea on the effect of the qualified workforce on the ICT adoption and use. The qualification is also summarized in the last variable which it average wages in the firm.

We suppose here that human capital is not depreciating and age summarize experience and learning. Then the stock of "human capital" is approximate by these variables. The absorptive capacity effect refers also to the capability of the firm to develop its own combination and to contextualize the technologies. Since then we use the training inside the firm and the training of the employees and the managers as indicators of the ability to develop and to use these technologies.

Localization and geographical dispersion effects

Thus, according to Antonelli (1999), plus the industrial activity is dense in the zone of localization of the firm, plus its network of relations is dense and thus more the level of received information will be important, which increases the utility of the adoption of the TIC. In this case, we try to explain if the location, in a dense zone like Barcelona, exerts a positive effect on adoption. Our estimation is very simple here and we divide the set of the firms in two sub-sets (Firms located in Barcelona and Firms outside Barcelona). We try to validate the theoretical hypothesis of a positive effect on the use and adoption of ICT led by distance. At the same time we use the geographical dispersion of the customers as an indication of this location effect.

In this study, the dispersion of the firm takes the geographical form: execution of the activity on the local or foreigner market. Indeed, the firms operating on the local and foreigner market

as well as the companies operating on the overseas market strategically manage their communication and the realization of their activities through the ICT. From where the dependence enters the geographical dispersion and the adoption and the use of the ICT. In our study, we approximated this dispersion by a dummy variable indicant if the firm's customers are well dispersed around the world or not.

Organization effect

The relationship between ICT and organizations is all the more strong that the ICT are technologies which, with through circulation and treatment of flows of information, intervene on the mechanisms which coordinate the units of the organizations. There exist thus important relationships between ICT and the organizations. However, the characteristics of the organization appear like a constraint with the introduction of the TIC. The ICT are indeed introduced into the existing organizations to improve the procedures of them: one don't structure the organizations to introduce technologies but one introduces technologies to improve the effectiveness of the organizations (Brousseau & Rallet, 1997).

Organization is an important explanatory factor however it's not well developed in the questionnaire. Theoretical hypothesis suggests that the adoption and use of ICT (depth of technology) depends on the level of hierarchy. Since these technologies are "network" technologies they are more efficient in a decentralized setting. Since then, the level of hierarchy must be positively correlated to the adoption and use. Indeed, more the number of the hierarchical levels increases more the company may find it beneficial to adopt and use the ICT with an aim well of circulating information and of facilitating the internal coordination between all its levels.

Another factor also which connects the organization to the adoption of the ICT is the type of control applied by the company. Thus, the ICT induce new forms of indirect control or supervision (to be reachable constantly) employees who come to replace the traditional forms of direct control by the hierarchically superior (Acemoglu and Newman, 2002). ICT thus tend to replace modes of control of the employees based on the input (attendance time in the company, direct or visual monitoring by a superior) by modes of control based on the output or result (objectives to be filled, times to be respected, answer brought to a request…). The second variable "*control by objective or result*", as an indication of the adoption of new organizational design, is represented by dummy variable referring if the firm admits a control of payment by objective or result within its organization or not.

Concerning the external environment of the firm, we must take into account the importance of the intensity of the informational exchanges of the firm with its environment on the interest of the adoption of the ICT. The ICT are thus used to manage the communication and the coordination inter-firms and the productive relations of the firm with its various partners or its internal relations within its group of membership (Brousseau 1994, Karlson 1995).

ICT are network technologies. They fit well with belonging to a group companies and with importer firms. The third variable "*Belonging to a group*", which indicate if the firm belong a group or not, anticipate advantages from improving external relationships and coordination with others firms of its group, which cannot be neglected. This one should tend to increase the probability of integration in a broader network and thus the probability of using the ICT.

Innovation and cooperation effect

Our data set contains variables describing if the firm is engaged in cooperation with other companies or institutions. Cooperation needs coordination technologies and communication technologies. In this sense, the more the firm is engaged in cooperation and the more it uses ICT. So in our explanatory variables, we take account if the firm is cooperative with others institutions, such as others firms, universities, research and innovation centers, with competitors, with suppliers, with customers… or not.

Also, we try to explain the difference on use and adoption of ICT between innovative and not non-innovative firm and in particular between the firms which use ICT on its Innovation process and the other.

For OECD (2004): a complementary investments in the innovation are essential so that the advantages of the ICT appear, and the use of the ICT influences the performance of the firms only if it is accompanied above all by other changes and investments, or else the economic impact of the ICT will be limited.

A company which innovates gives, through the innovation, of the new possibilities to enter the markets, either because the innovation will have enabled him to reduce its costs, or because new products or new services will answer better at the request of the markets, while making it possible to the customers to profit from more complete services, adapted better to the request or more respectful of the environment. The use and the diffusion of the ICT facilitate and support the innovation for all the companies. Indeed, the innovating firm had more probability of being equipped well on ICT. ICT allows trial and errors without costs (Learning before doing). At the same time, ICT allows the generalization of the exploration-exploitation process and the involvement of non-manager workers (Bellon & al. 2006 & 2007). These facts increase the speed of the innovation. Three variables are used here innovation led by ICT, cooperation with other firms through ICT and if the firm is innovative or not.

Explanatory variables	Definition	Equipment	Usage	References
I. Size and Network effects				
Age	The age of the firm	+/-	+/-	Davies (1997), Dunne (1994)
Size	The logarithm of the number of establishment's workers.	+	+	Roger (1995) Hollenstein (2004) Battisti & Stoneman (2005)
Importer Firm	Dummy variable: equal to 1 if the firm is an importer and 0 if not	+	+	
Number of customers	The logarithm of the number of the customers of the firm	+		Grow (1996)
Number of providers	The logarithm of the number of providers of the firm	+	+	Brynjolfsson & Hitt (2000) Karlsson (1995)
Information industry sector	Dummy variable: equal to 1 if the firm belongs to the sector of information and 0 if not	+	+	Hollenstein (2004)
II. Localization and geographical dispersion effects				
Firm localized inside of Barcelona	Dummy variable: equal to 1 if the firm is localized in the area of Barcelona and 0 if it is localized elsewhere.	+	+	Galiano & Roux (2006) Forman et al. (2005b)
Customers dispersion	Dummy variable: equal to 1 if the firm's customers are well dispersed around the world and 0 if not		+	Forman (2003)
III. Organization effect				
Level of hierarchy	The number of hierarchical level in the firm	+	+	Hollenstein (2004) R. Reix (1990)
Control by objective or result	Dummy variable: equal to 1 if the firm admits a control of payment by objective or result and 0 if not	+	+	Acemoglou & Newman (2002)
Belonging to a group	Dummy variable: equal to 1 if the firm belong a group and 0 if not	+		Bertsckek & Fryges(2002) Windrum & Berranger (2003)
IV. Absorptive Capacity effect				
HE degree of the directors	Dummy variable: equal to 1 if the director has a university level and 0 so not.	+	+	Caroli & Van Reenen (2001)
Average age of the director	The age average of the directors	-	-	
HE degree of the workers	Dummy variable: equal to 1 if the employees have a university degree and 0 if not.		+	Greenan (2002) Glaeser et al (2001)
Training of the workers	Dummy variable: equal to 1 if the employees are implied in training programs	+	+	Lange et al (2000)
Average age of the workers	The average age of the employees	-	-	Leduc (2006-03)
Average wage	The logarithm of the average wage in the firm	+	+	Galliano & Roux (2006)
V. Innovation and cooperation effect				
Innovation process led by ICT use	Dummy variable: equal to 1 if the firm starts its innovation process by the use of ICT and 0 if not.	+	+	Swanson (1994) Raymond Paré (1992)
Innovative Firm	Dummy variable: equal to 1 if the firm is innovating and 0 if not.	+	+	Cohen & Levinthal (1989)
Firm which cooperates with other firms/ institutions	Dummy variable: equal to 1 if the firm has a co-operation with other companies or institutions	+	+	Leduc (2006-02)

Table 2. Description of the explanatory variables and the expected effects

6. Determinants of adoption and of use of ICT by Catalan firms

This section presents the empirical results of a model probit ordered of the determinants of the adoption and the use of the ICT by the Catalans firms. These determinants are gathered according to the five various effects quoted in top. In our empirical study we distinguished between adoption or equipment in ICT and use of the ICT.

This section is divided into two sub-sections. Thus, we present in the first, the results of the determinants of adoption of the ICT, in which we find three different models, and in the second, those of the uses of the ICT in the form of one only model.

6.1. The adoption of ICT

In order to characterize the adoption process we divide our investigation in three different models. Model 1 estimates the adoption of all kind of ICTs. Model 2 estimates the adoption of specific technologies. Model 3 estimates the adoption General Purpose technologies'. Table 3 represents an estimation of the dependence of ICT equipment by the Catalan firms.

		ICT Equipment score		
Explanatory Variables		**Global** ***Model 1***	**General** ***Model 2***	**Specific** ***Model 3***
I. Size and Network effects				
Age		0.0212	-0.0044	0.0432
Size		0.1998***	0.2553***	0.1482***
Importer Firm	*No*	Ref.	Ref.	Ref.
	Yes	0.3636***	0.2932***	0.2927***
Number of customers		0.0294**	0.0575***	0.0009
Number of providers		0.0492**	0.05210**	0.0318
Information industry sector	*No*	Ref.	Ref.	Ref.
	Yes	0.1140	0.1638**	0.0457
II. Localization and geographical dispersion effects				
Firm localized inside of Barcelona	*No*	Ref.	Ref.	Ref.
	Yes	0.0466	0.0836	0.0183
Customers dispersion	*No*	Ref.	Ref.	Ref.
	Yes	0.0875	0.0931	0.0424
III. Organization effect				
Level of hierarchy		0.0495	0.0431	0.0214
Control by objective or result	*No*	Ref.	Ref.	Ref.
	Yes	0.1115 *	0.1361**	0.0949
Belonging to a group	*No*	Ref.	Ref.	Ref.
	Yes	0.0835	0.1739**	0.0201
IV. Absorptive Capacity effect				
HE degree of the directors	*No*	Ref.	Ref.	Ref.
	Yes	0.2081 ***	0.3142***	0.0422
Average age of the director		-0.0089**	-0.0091**	-0.0049
Training of the workers	*No*	Ref.	Ref.	Ref.
	Yes	0.1556 **	0.1982**	0.0629
Average age of the workers		-0.0142***	-0.0134***	-0.0083*
Average wage		0.2133**	0.4093***	0.0536

V. Innovation and cooperation effect				
Innovation process led by ICT use	*No*	Ref.	Ref.	Ref.
	Yes	0.2183***	0.2215***	0.1508**
Innovative Firm	*No*	Ref.	Ref.	Ref.
	Yes	0.3087***	0.3732***	0.0958
Firm which cooperate with other firms/ institutions	*No*	Ref.	Ref.	Ref.
	Yes	0.1525**	0.1299 *	0.1620**

Ref.: reference group
* significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 3. Determinants of ICT Equipments

By observing all the explanatory variables, one notes that practically the totality of the variables (with the exception of localization effect) has a statistically significant effect on the adoption of the ICT and our results confirm most of the theoretical expected effects. Moreover, our results confirm the expected effects stated in H1.

Size and network effects

Firstly, we verify a strong, positive and significant relationship between size and the probability of ICT adoption by a firm. As it was expected, there is a positive correlation between firm's size and ICT capital stock, showing the existence of scale economies for digital investment. Similarly what happens with industrial technologies, large firms have more incentives to adopt ICT, as they have the chance to spread adjustment costs over a more substantial output volume.

Firm' size has a positive and significant effect on the adoption of the three kinds of ICT equipments econometric models (Global, General & Specific). This result is due, from the one hand to the depth of technologies argument and from the other hand to the importance of internal coordination and communication within the firm. Big firms are more able to adopt these technologies because of their financial ability to face financial constraints also.

We also observe that the degree of adoption of the ICT is higher for the importing firms than the other. This is explained by the fact that importation requires the automation of the relationship and perhaps more information processing. This international effect is observed in all studies. We found a significant and positive coefficient of the variable "*importer firm*".
The connectivity effect is also validating in our study. Indeed, a important result appears when analysing external links of a firm. External communication is measured by the number of customers and providers. The pressures by customers and providers to improve communication and to use specific software to manage this kind of relationships contribute to increase the probability of ICT adoption by firms.
The pressure for adopting these technologies can come from the customers and the suppliers. Indeed, to profit fully from the implementation of these technologies, a company strongly encourages its suppliers to adopt the ICT in order to automate their relations, to improve their information processing capacity and to improve their reliability. This is true and was validated for the Catalan firms in our estimate. Thus, it is noticed that the more the number of customers and suppliers increases the higher is the degree of adoption of ICT by the firms.

Another interesting result is the weak link between industry and probability of ICT adoption. Our results show that only in one out of the three ICT equipment models we have specified

(the General model) the coefficient is significant, with $p<0,05$, confirming the idea of the general diffusion of ICT among industries. However, in our General model, we find that ICT industry willingness to increase its digital capital stock is higher than the average probability for the other industries.

Organization effect

As it was expected, we have found a positive and significant effect of new organizational practices, workers' skills and the existence of innovation policies on firms' willingness to invest in digital technologies.

Concerning to organization, we have found that an organizational structure based on flexibility and decentralization on tasks execution and on the assessment of objectives reached lead to a higher probability of ICT adoption.

It is interesting to note that, for the relation between organization and adoption of the ICT, the structure network seems particularly interesting to diffuse knowledge on all the levels of the company. This mode gives the necessary flexibility to adjust the structures and to ensure the fast circulation of the information whose the ICT play a big and important role. Thus, more the hierarchical level increases more the equipment in ICT increases within the company. This is explained by the fact that the automation of the treatment of certain administrative tasks implies a certain level of formalization of information to be introduced into the machines and these through quite precise procedures so that these data are consumable for those.
It is also noticed that the fact that the company carries out its control by objective or result, which required an important coordination, its degrees of adoption of the ICT increases. Which is the case for our sample which one observes a positive and significant coefficient for the variable «Control by objective or result»?
Network effect here is confirmed by the positive sign of the coefficient of the variable "*Belonging to a group*". When a firm is big and multi-plants, the adoption of ICT facilitates the internal coordination and communication, which measured trough the identification of those firms belonging to a group, either with the agents of the same firm or with other members of the group. However, the need of a high coordination between firms within a group contributes to increase the probability of ICT adoption by firms.

Absorptive capacity effect

The managers and their profile (educational level, age, style of command, position to the ICT...) impact strongly the adoption process (Amabile and Gadille, 2003). The manager is the principal actor in the success of the ICT introduction in small and medium firms.
In terms of human capital, our results show different significant effects on the probability of adopting digital technologies by firms. Firstly, higher education attainment by managers has a positive link with the probability of ICT adoption. Firms whom managers has done higher education studies implement more rapidly these technologies since they were used to do it during their studies and are more likely to understand the aims of these technologies. They are more able to impact their collaborators. Since then the degree of adoption of the ICT in their companies is higher on average. Secondly, there is also a positive relation with firm's investment on workers training. And, finally, and a remarkable point, our results show a negative relationship with the age of both, managers (with $p<0,05$) and workers ($p<0,00$).

Therefore, it seems demonstrated that firms with younger workers, younger and highly qualified managers, and with workers following training programmes have a higher willingness to investment in digital technologies.

In addition to those factors, firm's efficiency plays an important role in the explanation of ICT adoption by firms. Consistently with Brynjolfsson and Hitt (2003) findings, our results confirm one direction of the virtuous circle arising from the interaction between firms' efficiency and digitalization. In this sense, we demonstrate that the larger is a firm's labour productivity (measured by average wages) the higher is the probability to invest in digital technologies.
The implementation of ICT requires, mid-term and sometimes short-term, specific competences within the firm especially those of data processing and computer problem solving. We observe that the average wage in firm has a positive effect on ICT equipment or adoption. Since wages are considered as an imperfect measure of competencies and qualifications of the workers, this may allow us to interpret this correlation by a relationship between ICT adoption and qualifications. Therefore, it is important to note that ICT are more adopted by firms with high level of qualification of the employees as table 3 shows.

Cooperation and Innovation effect

Currently, the innovation is the principal engine of the change of the companies and the whole economy. In an environment of globalization, the knowledge and the development of the value of the capital become strongly important factors of competition. Consequently, in this economy based on knowledge, the innovation, which requires coordination and communication intra and inter-firm, plays a specific part in the adoption of the ICT by the firms.
The capability and willingness of a firm to innovate is another significant variable in the explanation of firms' investment in ICT equipment. In this sense, we have found a positive and significant effect from innovative firms (those that have made some innovation in the last two years), from those firms that are used to innovation by using digital technologies, and from cooperation to innovate. This last issue is particularly important in the case of small and medium size enterprises (SIME's) which usually do not have a formal department devoted to Research and Development activities.
In this same context, one of the principal advantages of the innovation is the incentive that it gives to the Catalan companies to establish of new networks of co-operation. Thus, and what is confirmed by the results of table 3, it is noticed that more the degree of co-operation of the firm with other companies or institutions (universities, research centers, public authorities…) increase more the diffusion of the ICT increases. Therefore, it is concluded that the innovation and the co-operation have a positive effect on the diffusion of the ICT by the Catalan companies.

These unidirectional relationships we have found are consistent with the results available in the international literature, which evidence positive complementary effects from ICT investment, organizational change and the demand for skilled labour on the improvement of firms' efficiency (Bresnahan *et al*., 2000; Cristini *et al*., 2003).

The dynamic of uses may not follow the same patterns then the adoption of the technologies. This lag between adoption and use is due to adjustment of the new technologies to the routines of the firms. Our estimate verifies most of the effect for use dynamics.

6.2. The use of ICT

The results of estimations for the intensity of use of ICT, based on the number of ICT elements in use are found in table 4.

		ICT Use score
Explanter Variables		**Usage score** ***Model 4***
I. Size and Network effects		
Age		-0.0620*
Size		0.0613**
Importer Firm	*No*	Ref.
	Yes	0.2026***
Number of customers		0.0335***
Number of providers		0.0087
Information industry sector	*No*	Ref.
	Yes	0.3330 ***
II. Localization and geographical dispersion effects		
Firm localized inside of Barcelona	*No*	Ref.
	Yes	0.1289*
Customers dispersion	*No*	Ref.
	Yes	0.2534 ***
III. Organization effect		
Level of hierarchy		0.0140
Control type	*No*	Ref.
	Yes	-0.0280
Belonging to a group	*No*	Ref.
	Yes	0.0539
IV. Absorptive Capacity effect		
HE degree of the directors	*No*	Ref.
	Yes	0.1491**
Average age of the director		-0.0054 *
HE degree of the workers	*No*	Ref.
	Yes	0.0847
Training of the workers	*No*	Ref.
	Yes	0.1868 **
Average age of the workers		-0.0164***
Average wage		0.1423 **
V. Innovation and cooperation effect		
Innovation process led by ICT use	*No*	Ref.
	Yes	0.1763***
Innovative Firm	*No*	Ref.
	Yes	0.2218***
Firm which cooperate with other firms/ institutions	*No*	Ref.
	Yes	0.1083*

Ref.: reference group

* significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 4. Determinants of ICT Use

Our results also confirm the expected effects stated in H2.

As we have mentioned before, there are some shared variables contributing to explain both the probability of ICT investment and the intensity of digital capital use. But there are relevant differences in terms of significance and coefficient values consistent with their theoretical divergences and particular economic properties.

Size and network effect

The size of the firm exerted a positive and significant effect on the intensity of use of the ICT, like the case of the equipment. Intensity the use of the ICT is positively correlated with its size. Our result confirms most of the well-established literature on this subject (OECD, 2004).

In this sense, it is important to outline that firms' size and productivity levels have also in our ICT usage model a positive and significant effect on the explanation of the probability of digital technologies depth of adoption, but the relationship is weaker than in our ICT Equipment models. This means that the chance to obtain scale economies and firms' economic results seems not to be critical factors to explain the willingness and intensity of ICT use by a firm.

In the opposite side to firm's size and productivity we have found firms' networking structure. Here, it is remarkable the fact that those firms who are more connected with foreign ("importer firms") are those showing a higher probability of depth of ICT adoption. Therefore, it can be said that the promotion of net organizational structures leads has a positive and significant effect on a firm's willingness to show more advanced uses of digital technologies.

Finally, we want to outline that differently to the determinants of ICT investment, the industrial approach plays here and important role. Our results show that ICT and digital content producers are also the firms that have a higher intensity of use of this kind of technologies than the rest of industries in their production processes.

Location and geographical dispersion effects

How distance impacts ICT equipment still a puzzling question in theory. Our estimate shows a negative correlation between distance and ICT use. So, firms located inside Barcelona seem to be more equipped than those outside Barcelona. On the other hand, this factor hasn't a significant effect on the equipment in ICT. Imitation effects, financial constraints and size may play a crucial role in the explanation of this finding.
Geographical dispersion of customers (*Customers dispersion*), which is measured by the degree of dispersion of the customers of the company in the world, exerted also a positive effect. Thus, like in the case of our sample of the firms Catalans, the more the company has dispersed customers, some is in the Union European or the rest of the world, the more it is need to coordinate and to communicate themselves with to send them and him information, and the more it uses the ICT.

Organization effect

Concerning the organization and his connection with the use of the ICT by the Catalan firms, one notices, according to the results of table 4, that the hierarchical level and the application of a control per objective or result by the company do not have an influence on the intensity of use of these tools. On the other hand, these two factors had a positive effect on the equipment in ICT. This may mean that in an earlier stage of adoption, firms have not re-arranged the organization in a way to faster efficient usages. This need more time and may explain why productivity is shortcut in short-run. Further explanations are needed here.

Absorptive capacity effect

From human capital point of view, we have demonstrated in this paper a positive contribution of managers' education attainment and workers profile. In fact, those firms with more qualified managers and younger workers are those showing a higher probability to use digital technologies.

Thus, the intensity of usage is positively correlated with the absorptive capacity of the firm. In our sample of Catalan firms, one notices that the directors (managers) who have a level of academic work have a degree of intensity of use of the more important ICT. The use of the ICT by the directors is far from being uniform and present disparities. However, the use of the ICT increased for all the categories of age, even if the phenomenon seems a little faster in the young people of less than 30 years. The intensity of use of the ICT by the directors decreases with their ages, which is the case in our work. The employees can acquire various qualification levels in ICT. These competences can be acquired, that is to say by the various stages of conventional teaching in the schools or the universities or by a workplace specific training. This result is also confirmed in our estimate. Thus, it is noted that the employees most implied by the training have more intensity of use of ICT. Moreover, the use of ICT is more important for those who have a level of more important average wages. Therefore, as much for the equipment that for the use, one notes that the ICT are adopted and used by the companies with an elevated level of the qualification of the employees.

Confirming Bresnahan *et al*. (2000) virtuous circle between ICT uses and workers' skills, the positive effect of firms' networking structure on the depth of ICT adoption is complemented by the positive and significant contribution of human capital formation as determinants of economic digital uses by firms.

Innovation and Cooperation effect

We can also confirm that those firms that have innovated during the last two years, and specially those whose innovation has been led by ICT uses, show more willingness to have higher levels of depth of digital technologies adoption. So, the results in table 4 indicate that cooperation and innovation has a statistically significant effect on the use of the ICT and especially the innovation which has a significant coefficient at 1% level.

Like example of innovation in the process, we quote a firm which adopts new online shop software. This may allow the firm to deliver its products to customers in a new way or to offer additional services, such as tracking orders online or getting immediate information about availability. This new process thus required an important use of the ICT, because ICT make the innovation process more dynamic, but also more interactive and interdependent. What thus justifies the plus coefficient of the variable "*Innovation process led by ICT use*" in our results.

Three principal reasons describing the positive correlation enters the ICT use and the innovation for Catalan companies. Firstly, because ICT stimulate innovative dynamism in reducing partially the existing obstacles to innovation and making interactions between the agents involved in the innovative process – those both inside and outside the company – more efficient. Secondly, ICT modify the nature of the innovations and allow the development of more sophisticated and interdependent innovative processes. Thirdly, because the complexity of innovative processes induced by ICT means that their use can be considered a sustainable competitive advantage only if these technologies are used in an integrated structure with the available resources and capacities.
With regards to the influence of the cooperation effect, we observe that firm, which cooperate with others institutions or firms, has a probability of ICT use more important than the others. One of the main positive effects of ICT use as an innovation means is the incentive it represents for Catalan firms to build new cooperation networks or to make the existing more efficient.

In this sense, from our results, it can be stated that there is a positive and significant relationship between ICT uses by firms, networking structure, workers' skills and profile, and innovation capabilities and background, as these are the main determinants of the intensity of ICT uses.

7. Concluding Remarks

In this article, we have tried to understand the main forces behind the adoption and usage of ICT in Catalan firms. Our results confirm the well-established literature. Thus, the main conclusion of this paper is that firms' ICT adoption, i.e. investment in digital equipment, and ICT depth of adoption, i.e. intensity of ICT uses, have different determinants, consistent with the theoretical background in international literature, although they share some common traits based on the existence of complementary effects between digital technologies, innovation, organizational structure and workers skills within a firm.

On one hand, ICT investment is influenced by investment theory determinants and, therefore, shows a similar behaviour than investment in previous industrial technologies. In this sense, the chance of obtaining scale economies by a firm and a firm's capability to reach to positive returns to its investment through efficiency levels have a positive and significant effect on the probability of ICT adoption. Thus, the effect of firms' size and productivity levels is confirmed here. However, ICT capital is characterised by representing general purpose technologies and by being complementary to some advanced organizational practices and to analytic, interactive and computing skills. These particular traits can explain why, differently to other industrial technologies, there is an important relationship between ICT equipment in firms and: i) decentralization of decision making processes, ii) human capital formation through the demand of managers with higher education attainment and the investment in workers' training programmes, and iii) firms' willingness to innovate, to use ICT as an innovation tool or mechanism, and to cooperate with other organization for innovating.

On the other hand, intensity of ICT uses is more related to firms' capability to improve their efficiency through the use of digital technologies. This is the reason why the main determinants of the depth of ICT adoption by a firm can be identified in five critical variables: i) firms' networking organizational structure, ii) the demand for high qualified managers, iii) the existence of young workers, iv) the innovation background and v) the belonging to ICT industry.

We found a difference concerning organization effect in term of adoption and usage. The recombination and the modification of the technologies were not optimal at the earlier stage of adoption. The study is based upon a questionnaire concluded in an earlier period of ICT diffusion in Catalonia a new survey may reveal changes in these dynamics. Our study confirms the lag between adoption and usage of these technologies in the earlier stage of adoption.

Finally, it is remarkable that as it was expected following corporate organization theory, the connecting capability of digital technologies explain the fact that, opposite to previous technologies, geographical location is not a significant determinant of firm's investment but significant determinant of use of ICT.

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