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Innovation and Productivity in Services and Manufacturing: The Role of ICT Investment[1]

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Abstract

Several studies have highlighted ICT as a driver of firm productivity in developed countries. However, the evidence about the impacts of ICT on services and manufacturing and particularly for developing countries is scarce. This paper focuses on understanding the determinants of investments in ICT at firm level and how this adoption ultimately affects innovation and productivity of Uruguayan services firms *vis a vis* manufacturing. Results show that ICT investments are more subject to economies of scale than other types of investments, are important for obtaining product or process innovations in services and its absence conspires against non-technological (organisational or marketing) innovations. Both ICT and other innovation investments are positively associated with productivity in services but only ICT affect productivity in manufacturing. Interestingly, the absence of investment in ICT is associated with lower levels of productivity.

JEL Codes: O31, O32, D22, O38.
Keywords: ICT, Innovation, Productivity, Uruguay.

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1. Introduction

Throughout the world, the empirical evidence highlights that innovation is an effective means of improving productivity, spurring economic growth and raising living standards (Hall and Jones, 1999; Rouvinen, 2002; Hall, 2011). The first contributions to analyse the impact of innovation on productivity (Grilliches, 1979) focused mainly on the contributions of investments on research and development (R&D). Over recent decades, literature aimed at understanding the engines of productivity growth has broadened its view to include other types of investment. Nowadays, Information and Communications Technologies (ICT) have been widely recognised as one of the main engines of the world's economy. A large body of research highlighted the link between ICT and productivity growth (Oliner and Sichel, 1994; Jorgenson, 2001).

Conceptually, ICT have the potential to affect growth and productivity of the economy by two different channels, directly and indirectly. First, productivity improvements in the sectors producing ICT goods or services contribute directly to aggregate productivity of the economy proportional to the size of the ICT sector (see Jorgenson, Ho and Stiroh, 2002 and 2008, Gordon, 2000 and 2012; van Ark, O'Mahony and Timmer, 2008). Second, and more importantly, ICT affect the productivity of sectors using them. Specifically, ICT enable faster communications and information processing, contribute to ease internal coordination and facilitate the process of decision making, and in the reduction of market failures related to information asymmetries (Cardona et al, 2013; Arvanitis and Loukis, 2009; Atrostic et al, 2004; Gilchrist et al, 2001). In particular, research at the firm level confirms that ICT operate as an "enabling factor" for businesses to innovate and improve their performance, serving as a General Purpose Technology (GPT) (Bresnahan and Trajtenberg, 1995).

In fact, a variety of studies for developed countries find an impact on the productivity that is greater than that for ordinary non-ICT investment (Brynjolfsson and Hitt, 1995, 2000; Brynjolfsson and Yang, 1998; Brynjolfsson, Hitt, and Yang, 2002;Greenan and

Mairesse, 2000). Similarly, the relationship between ICT and productivity at the firm level is generally positive (Black and Lynch, 2001; Bresnahan, Brynjolfsson, and Hitt, 2002; Greenan, Topiol-Bensaid, and Mairesse, 2001; Bugamelli and Pagano, 2004; Castiglione, 2009) but ICT alone are not enough to affect productivity. Evidence shows that the contribution of ICT to productivity varies widely by country and industry, suggesting that simple diffusion is not sufficient to fully profit from this potential. For example, Black and Lynch (2001) and Bresnahan, Brynjolfsson, and Hitt (2002) focus on the interaction between ICT, human capital, and organisational innovation. Hall, Lotti and Mairesse (2012) state that ignoring these complementarities may lead to overestimating the effect of ICT on productivity.

In fact, development of ICT projects requires reorganisation of the firm around the new technology, but this reorganisation needs time to be implemented and, more importantly, it implies costs, such as retraining of workers, consultants, and management time. On a related vein, research has stressed the possible complementarity between computer investment and other forms of allied investment, such as in organisational change (Bresnahan and Trajtenberg, 1995;Brynjolfsson et al, 2002; Ichniowski et al, 1997; Brynjolfsson and Hitt 2000 and 2003; Brynjolfsson Hitt and Yang, 2002; Greenwood and Yorokoglu, 1997; Hornstein and Krussell, 1996;Caselli, 1999; and Black and Lynch, 2001).

Still to this day, the bulk of the literature has focused on developed countries, while evidence from emerging economies is still scarce and dispersed. Most of the contributions for Latin America have dealt with the diffusion and adoption determinants of ICT (Basant, 2006; Benavente, Lillo and Turen, 2011; Charlo, 2011; Calza and Rovira, 2011; Gutierrez, 2011; Gallego, Gutiérrez and Lee, 2014; Grazzi and Jung, 2015) dealing with the link between innovation and productivity without a robust identification strategy.

Firms in developing countries, in general, and in Latin America and the Caribbean (LAC) in particular, are less productive and this seems to be related with an innovation shortage (IDB, 2010a and 2010b; Crespi and Zuñiga, 2012; Crespi, Tacsir and Vargas, 2014) that exceeds the limitations accounted for their productive structure (Navarro et al, 2010). In many LAC economies, firms' innovations consist in incremental changes with few or no impacts on international markets, and mostly based on imitation and technology transfer, - e.g. acquisition of machinery and equipment and disembodied technology (Anlló and Suarez, 2009; Navarro et al, 2010). R&D is in many cases prohibitive and it could demand perhaps longer time horizons to be manifested (Navarro et al, 2010). Crespi and Zuñiga (2012), and Crespi, Tacsir and Vargas (2014) present specifications of the augment the CDM by including innovation expenditures (and not only R&D) for a group of LAC countries. These contributions show results with the evidence for developed countries. Specifically, firms that invest in knowledge are more able to introduce technological advances and those that innovate exhibit superior labour productivity than those that don't. In line with the literature, firms that invest in knowledge are more able to introduce new technological advances and those who innovate have superior labour productivity than other firms.

Taking this into account, this paper will focus on understanding the determinants of investments in ICT at the firm level and how this adoption ultimately affects the productivity of Uruguayan firms. Although a combination of increased budgetary allocations and institutional reforms (such as the creation of an agency devoted to the promotion of research and innovation activities -ANII) have induced higher levels of R&D expenditure at the firm level in Uruguay, evidence shows that the country has fallen behind fast-growing economies and developed economies in terms of resources devoted to R&D and productivity.

This paper provides several contributions to the literature on the interaction between ICT investment, innovation and productivity. First, we extend the CDM model to highlight the effect of ICT investments on productivity by taking into account all innovation activities and not only R&D. This broader framework is justified and applied to Latin America in Crespi and Zuñiga (2012) and Aboal and Garda (2012) but has never been applied to underline the importance of ICT. Secondly, we are capable of providing evidence on the effect of ICT on productivity for both manufacturing and service sectors, using the same specification and data source. This allows us to highlight the heterogeneities present in both the adoption of ICT and their effects on productivity between sectors, and to show the existing complementarities operating in the service sector firms. Third, we jointly model ICT, innovation and productivity -- providing a richer structure than in the case of Hall, Lotti and Mairesse (2012) and Polder, van Leeuwen, Mohnen and Raymond (2009). While in Hall, Lotti and Mairesse (2012) there is no analysis of the factors behind the decision to invest in ICT and their intensity (first two equations of the CDM model), treating ICT in parallel with R&D as an input to innovation, we independently model the decision to engage and the amount invested in innovation activities (in ICT and other innovation investments) with a Heckman model for each of these variables. We also go beyond Polder et al (2009), who only added the decision to invest in ICT and the amount per worker invested in the first stage of the model as a means to explain the propensity to undertake innovation activities and its expenditure. Our final contribution consists in providing robust evidence for a developing country, contributing to closing the knowledge gap currently existing in the literature.

The remainder of the paper is organised as follows. Section 2 provides a literature review. Section 3 describes the conceptual framework and presents the empirical strategy. Section 4 describes the data. Section 5 presents the results and Section 6 concludes.

2. Literature review

The existing literature[2] focused on understanding the link between ICT and productivity initiated with studies that took an aggregate perspective, motivated to disentangle the so-called Solow paradox. In particular, these contributions were initially concerned with the U.S. in early 1990s and later on expanded to other developed regions such as the UE, motivated by need to understand whether the US-EU productivity gap was related (and to what extent) to different patterns of ICT investment (as in Ark, Inklaar, and McGuckin, 2003; Cette, Mairesse and Kocoglu, 2005). The initial contributions took the form of growth accounting exercises.[3]

Specifically, different studies (Oliner and Sichel, 1994 and 2000; Jorgenson, 2001, Jorgenson et al. 2002; Gordon, 1999, to name a few) have found a positive relationship between ICT and productivity in the US in the 1990s. In fact, several contributions found quite sizeable effects of ICT. For example, Oliner and Sichel (2000) find that the capital deepening in ICT and the efficiency gains in the production of computers accounted for about two thirds of the 1 percentage point step-up in productivity growth between the first and second halves of the last decade of the twentieth century. Similarly, Jorgenson, Ho and Stiroh (2002), Oliner and Sichel (2002) and Daveri (2003) all presents results indicating that ICT capital deepening and TFP in ICT-producing sectors together explain between 75% and 100% of the increase in labour productivity in the same period. While most of the research focused on manufacturing, there have been more recent efforts to assess the impact in services. Bosworth and Triplett (2007) found

[2]Draca et al (2007), Biagi (2013) offers quite exhaustive reviews of the evolution of the literature.

[3]Different authors warn us about the difficulties involved in measuring ICT at the aggregate level. Biagi (2013) mentions a few methodological problems involved. First, aggregate analyses are not capable of highlighting the causation mechanism between productivity and its determinants, reducing the capability to draw policy implications. Second, growth accounting is normally based on the assumption of constant economies of scale and absence of externalities. These estimates might result higher or lower than actual effects in the presence of one or the other omitted aspects. Third, the methodology might fail to fully capture the quality improvements.

for the US a strong contribution from ICT to labour productivity growth in the service sector.

Several studies (Colecchia and Schreyer, 2002; Oulton, 2002; Crepon and Heckel, 2002) extended the research beyond the US. Colecchia and Schreyer (2002) extended the approach followed by Jorgenson and Stiroh (2000) and Oliner and Sichel (2000) to nine OECD countries. They results confirm that other developed experiences higher growth rates due to the benefits arising from ICT investment. Although, the effects have clearly been largest in the United States, they found that ICT contributed to 0.3 to 0.9 percentage points per year to economic growth during the second half of the 1990s. Oulton (2002) applies a modified growth accounting approach to the UK. ICT contribution to GDP growth increased from 13.5% in 1979-89 to 20.7% in 1989-98. Using data on ICT investments from the tax declarations of French firms, Crepon and Heckel (2002) evaluate the contribution of ICT to the growth of value added via the accumulation of IT capital across all industries and the productivity gains in ICT-producing industries. They find that, over the period 1987-1998, ICT accounted for 0.7 percentage points of the yearly value added growth, with almost similar contributions from these complementary channels.

The availability of sectoral and firm-level data motivated a second generation of studies that abandoned the growth accounting framework in favour of a more econometric approach (Biagi, 2013). These contributions have the potential to assess the effects of ICT investments on ICT-using sectors (so-called "indirect effect") and for this they look at the role of complementary assets and their capacity to enable other forms of innovation and investments. In this line, ICT allow for substitution effects, trigger process and organisational innovations (Black and Lynch, 2000; Bresnahan, Brynjolfsson, and Hitt, 2002; Hempell and Zwick, 2008, to name a few). At the same time, there is some evidence that the previous innovation performance might help determine the potential use of ICT (Hempell, 2002). In a similar line, Cerquera and

Klein (2008) argue that that since the adoption rates and capacity to reap the benefits from ICT differs among firms, ICT might represent a source of firm heterogeneity that might generate competitive advantages, affect firm strategies and/or influence aggregate productivity growth. Specifically, they found that in the case of Germany, ICT have a robust, positive impact on firm heterogeneity when ICT are used intensively and jointly with specific ICT applications. Moreover, ICT induced heterogeneity is shown to have a positive impact, albeit small, on the decision to invest in R&D personnel.

Another strand of research, treat ICT as an input, both of the production function and, more importantly, of the knowledge production function. Based on the CDM model, these contributions allow accounting for potential biases dues to simultaneity and selectivity. Polder et al (2009), using Dutch data, extend the CDM model to include an equation for ICT as an enabler of innovation and organisational innovation as an indicator of innovation output. Specifically, they distinguish two types of innovation inputs: R&D expenditures and ICT investment that feed into a knowledge production function consisting of a system of three innovation output equations (product innovation, process innovation and organisational innovation), which ultimately feeds into a productivity equation. By doing so, they found that ICT are an important driver of innovation in both manufacturing and services.

Hall, Lotti and Mairesse (2012) use an augmented version of the Crépon–Duguet–Mairesse (CDM) in which they treat ICT in parallel with R&D as an input to innovation rather than simply as an input of the production function. By doing this, they are capable of taking into account the possible complementarities among different types of innovation activities. Their framework encompasses three groups of relations. The first consists of the decision whether to invest in R&D or not and how much to invest. The second consists of a set of binary innovation outcomes during the previous three years. These outcomes are presumed to be driven by the investment decisions of the firms with respect to R&D and physical capital. The element of novelty is the inclusion of ICT expenditure at this stage to explain innovation activity. The final equation is a conventional labour productivity regression that includes the innovation outcomes as well. Their contribution is based on a large unbalanced panel data sample of Italian manufacturing firms in the 1995–2006 period, constructed from the four consecutive waves of the 'Survey on Manufacturing Firms' conducted by Unicredit. This extension of the model specification leads to augmented difficulties in estimation owing to the increased number of equations with qualitative-dependent variables: we bypass some of these difficulties by estimating the different blocks of the model sequentially, while still correcting for endogeneity and selectivity in firm R&D investment.

3. Conceptual framework and empirical strategy

We will extend the framework proposed by Griliches (1979), Crepon, Duguet and Mairesse (1998) (CDM from now on) and Hall, Lotti and Mairesse (2012) (HLM from now on) with the purpose of adapting them to the specificities of service firms and innovation surveys, particularly innovation surveys in Latin America. Our framework is very close to the one proposed by Hall, Lotti and Mairesse (2012) but with the addition of some ingredients taken from Crespi and Zuniga (2012) and Aboal and Garda (2012).

The original contribution of Griliches (1979) has as a starting point a production function where one of the key inputs is R&D. CDM have a production function where the key variable of interest is the innovation output (proxied by patents per employee). In the case of HLM the production function proposed by CDM is enriched (in some specifications) to incorporate ICT. Our approach will be very similar to HLM, the production function[4] will be:

$$(1) y_i = c + \pi_1 k_i + \pi_2 l_i + \pi_3 h_i + \pi_4 ICT_i + \pi_5 INNp_i + v_i$$

wherey_i is sales per worker–labor productivity-, k_i is physical capital per worker, l_i is the number of workers (our firm size variable), h is a measure of human capital (number of professionals and technicians per worker), ICT is the investment in software and hardware per worker and INNp is the predicted innovation output that results from equation (2) (and sometimes (3)) below, c is a constant, π_1 to π_5 are parameters and v_i is a disturbance term. All the variables are expressed in logarithms with the exception of INNp. In addition, ISIC two-digit dummies are included in all regressions.

Following the approach of the previous cited works we will model explicitly the innovation outcome, or the "production function" of innovations. We will distinguish between technological (product and process) and non-technological (organisational or marketing) innovations. This is conceptually very relevant since we know that service firms have a bigger propensity of introducing non-technological innovations and innovation in services are, for example, less dependent on formal R&D than manufacturing (Aboal and Garda, 2012). In other words, service firms innovate differently and the innovation production function is different across sectors.

The *innovation output* equation, sometimes also-called *knowledge production function*, is:

$$(2) \qquad INN \equiv \begin{pmatrix} TI_i \\ NTI_i \end{pmatrix} = \mathrm{ICTIp_i}\gamma_0 + \mathrm{IInictp_i}\gamma_1 + \mathrm{x_i}\delta + \mathrm{u_i}$$

where TI is a dummy indicating technological innovation and NTI is a dummy for non-technological innovation, ICTIp is the predicted investment in software and hardware,

[4]This formulation can be obtained from a Cobb-Douglas production function with capital, labour, human capital, innovation output and ICT as inputs, and dividing both sides by labour and taking logs.

IInictp is the predicted investment in all other innovation activities. These last two variables will be predicted from a Heckman regression (see next equations). γ_0 and γ_1 are diagonal matrices of parameters and δ is a block diagonal matrix of parameters, x is a block diagonal matrix of determinants of innovation production, and u is the error vector. As additional control variables (in the x matrix) we are including the logarithm of firm's number of employees (firm size), a dummy indicating if the firm is an exporter, a dummy indicating if more than 10% of the capital of the firm is foreign owned, a dummy indicating if the firm has obtained patent protection, dummy variables indicating if the firm received public financial support for innovation activities, if the firm cooperates with other firms to carry out R&D activities, if the firm considers market, scientific or public sources of information important for the innovation activities and finally the log of the ratio of professionals and technicians in the workforce. Industry dummies are also included in all regressions. We are assuming that public financial support does not affect innovation output directly, but only indirectly through the level of investment in ICT and other innovation activities. This is why this variable will appear in the next equations, but not in this one. A Biprobit model will be estimated at this stage.

The decision to engage and the amount invested in innovation activities (on ICT, IICT, or in all the other innovation activities, IInict) will be modelled independently with a Heckman model for each of these variables.

The firm first decides whether to invest or not in innovation activities and then it decides how much to invest. The *innovation decision* equation could be expressed as follows:

$$(3) ID_i = 1 \text{ if } w_i\alpha + \varepsilon_i > c$$
$$ID_i = 0 \text{ if } w_i\alpha + \varepsilon_i \leq \text{c}$$

where ID_i is the innovation decision binary variable which is 1 for firms who decide to invest in innovation activities and 0 for firms who do not (it could be either on ICT or in all other activities), w is the vector of explanatory variables that determine the decision,

α is the vector of parameters, ε is the error term, and c is the threshold level that determines whether the firms decides to invest in innovation or not. The vector of variables is the same contained in x with the addition of the dummy variable public financial support that takes value 1 when the firm gets public support and zero in other case.

A second equation will model the magnitude or intensity of innovation activities carried out by firms (on ICT or on all the other activities). The dependent variable in this case is the logarithm of the actual innovation investment per employee (in IICT or IInict). As for the explanatory variables we make the assumption that the variables that affect the process of decision of engaging in certain innovation activity determine also the magnitude of that activity, but because we are using innovation expenditure per employee, the variable size (number of employees) is not included in this equation (this exclusion will also allow the identification of the first equation). Implicitly, since our dependent variable is (log of) innovation expenditure per employee, we are assuming that innovation expenditure is strictly proportional to size.

Accordingly, the equation for *innovation effort (or investment)*would be:

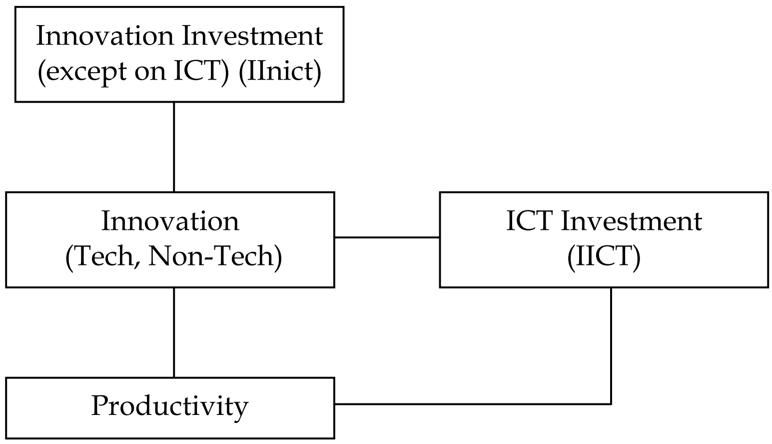
$$(4) \quad I_i = z_i\beta + e_i \quad \text{if } ID_i = 1$$
$$I_i = 0 \qquad\qquad \text{if } ID_i = 0$$

where I is the magnitude of the investment (or the log innovation investment per employee), z is the vector of explanatory variables, β is the vector of parameters and e is the disturbance term.

For the second variable –innovation investment- to be observable the first one –innovation decision- has to surpass the stated threshold. Otherwise, no research would occur and there would be no magnitude or intensity to measure.

Figure 1 illustrates the sequential structure of the model. First, firms decide to invest or not and how much to invest in ICT and also on other types of innovation activities not related to ICT (R&D, Acquisition of Capital Assets, Engineering and Industrial Design, Transfer of Technology and Consulting, Organisational Design and Management and Training). Second, firms produce innovations. One of the key factors in this production function is the level of investment in innovation activities, particularly on ICT. Third, the innovation together with the ICT investment and other production factors affect the level of productivity of firms. This structure of the model is very similar to the one employed by HLM, the main extension is the inclusion of all the innovation expenditures and not only the expenditure on R&D and ICT. One of reasons to go beyond R&D is that service firms tend to generate innovations without the use of formal R&D. But more importantly, there is no reason to not include other innovation investments, since in principle any investment in innovation activities can generate innovations. The second "innovation" of this paper with respect to HLM is the separate treatment of technological and non-technological innovations albeit in a common framework. As explained before this is especially relevant for analysing service firms' innovation.

Figure 1. ICT investment, Innovation and Productivity



4. Data and Descriptive Statistics

The service sector is one of the major contributors to output and employment in Uruguay. In the period 2004-2009 it has represented approximately 60% of the GDP of the economy and employed more than 70% of the total workforce. Both, the employment and the output of the service sector are concentrated in a few subsectors. Half the GDP of the sector is explained by three subsectors: “Retail”, “Communications”, and “Real Estate, Renting and Business Services”. Two subsectors accounts for 50% of total employment of the sector: “Retail” and “Professional Services and Household's Services”.

Service innovation surveys (SIS) in Uruguay do not cover the universe of services. However, the weight of the subsectors considered here is significant in terms of output and employment, representing more than 50% of the output and 33% of the employment of the sector (see Table 1).

Table 1. Contribution of the service sector to GDP and employment in Uruguay (average, years 2005-2009)

	GDP	Employment
Subsectors as % of service sector		
Electricity, gas and water *	3.5	1.2
Retail	18.7	27.6
Hotels and restaurants *	4.6	3.9
Transport and Communication *	12.9	8.1
Financial intermediation	7.9	2.4
Real estate, renting and business *	23.4	9.7
Public administration and defence	8.5	9.7
Education	6.3	8.1
Activities related to human health *	8.1	10
Professional services and domestic household services	6.1	19.2
Sectors covered by SIS**	52.5	33
Service sector/total economy	**59.2**	**73.5**

Notes: * Included in innovation surveys; ** Including real state.
Source: National Bureau of Statistics, Central Bank of Uruguay.

The subsectors covered by the SIS in Uruguay are the following (ISIC Rev.3): “Electricity, Gas, Steam and Hot Water”; “Collection, Purification and Distribution of

Water", "Hotels and Restaurants", "Land Transport", "Water Transport", "Air Transport", "Auxiliary Transport Activities and Travel Agencies", "Post and Telecommunications", "Rental of Machinery Equipment, Personal Effects and Household Goods", "Informatics and Related Activities", "Research and Development", "Business Services", and "Activities Related to Human Health".

These subsectors were chosen by the National Agency for Research and Innovation following two criteria. First, that knowledge-intensive services were well represented in the sample, in particular the high technology ones (such as "Informatics and Related Activities", and "Research and Development"), the knowledge-intensive market services ("Air Transport", "Water Transport"; "Business Services"; and "Rental of Machinery Equipment, Personal Effects and Household Goods"), and the other knowledge-intensive services ("Activities Related to Human Health"). Second, the selection sought to include subsectors considered important for the economic development of the country, such as the tourism-related ones ("Restaurants and Hotels", "Transport", "Post and Telecommunications", "Electricity, Gas, Steam and Hot Water" and "Water Collection, Purification and Distribution").

There are two waves of Services Innovation Surveys (SIS) available in Uruguay at the moment: 2004-2006 and 2007-2009. The data is collected in parallel with the Economic Activity Survey (EAS) (same sample and statistical framework). All the firms with more than 49 workers are of mandatory inclusion. Units with 20 to 49 employees and with fewer than 19 workers are selected using simple random sampling within each economic sector at the ISIC 2-digit level up to 2005. Since then, random strata are defined for units with fewer than 50 workers within each economic sector at the ISIC 4-digit level. The number of firms included in the 2004-2006 and 2007-2009 samples are 900 and 1046, respectively.

We will also use the last two Manufacturing Innovation Surveys (MIS) available (2004-2006 and 2007-2009). The MIS include all the manufacturing subsectors. The MIS is also collected by INE in parallel with the EAS. All firms with more than 49 workers are of mandatory inclusion. Units with 20 to 49 employees and with fewer than 19 workers are selected using simple random sampling within each economic sector at ISIC 2-digit level up to 2005. Since then, random strata are defined for those units with fewer than 50 workers within each economic sector at the ISIC 4-digit level. The number of firms included in the surveys 2004-2006 and 2007-2009 were 839, and 941 respectively.

The final number of firms after cleaning the databases is 1868 services firms and 1727 manufacturing firms.[5] Both surveys have been matched with the EAS in order to obtain the level of firm's fixed assets that is needed for the productivity equation. In order to avoid endogeneity problems associated with the capital variable, we use this variable at the beginning of the period of the survey. All the other variables used in the empirical exercises come from the SIS or MIS. The matching with the EAS was not without loss. Due to sampling frame changes, and registration problems we lose a significant number of firms. When using the capital per worker variable (i.e. after matching with the EAS) the sample is reduced to 1093 service firms and 1209 manufacturing firms.

Table 2 presents some descriptive statistics of the sample, both for manufacturing and service sector firms. Overall, we don´t find great differences in the innovative behaviour of the firms operating in one sector or the other where around one third of the firms declare the introduction of technological innovation and around a quarter non-technological innovation. Consistent with the existing evidence, manufacturing firms are more likely that service sector firms to have introduced product or process innovation while the opposite is true for organisation or marketing innovation. Consistent with this fact, manufacturing firms are more likely to have been engaged in cooperation ventures for the development of R&D projects. Although the average size

[5]Firms with missing information on sales or employment were excluded, also were excluded the percentile 1 and 99 of productivity and the percentile 99 of innovation investment per employee.

in the two different sectors is similar, the manufacturing sector presents higher productivity levels.

In what refers to ICT investment, and related to the prevalence of non-technological innovation, we observe that a higher proportion of service sector firms report some expenditure on ICT items (software, hardware or computer services), allowing for an ICT intensity expenditure that more than double that for manufacturing. Similarly, service firms are endowed with a higher proportion of skilled personnel.

From the point of view of policy intervention, the data shows that the proportion of firms that have been involved in some sort of program aimed at promoting innovation is rather small; it becomes evident that manufacturing firms have received more support than service sector firms.

Table 2. Descriptive statistics of variables included in regressions

	mean	sd	min	max
Manufacturing				
Tech innovation (1)	0.38	0.49	0.00	1.00
Non-technological Innovation (2)	0.20	0.40	0.00	1.00
Productivity(3)	1648.91	2491.05	56.33	25712.73
Non-ICT innovation expenditure (4)	21.77	59.48	0.00	534.11
ICT Innovation expenditure (5)	1.47	7.31	0.00	153.05
No investment in ICT (6)	0.81	0.39	0.00	1.00
Firm size (7)	3.63	1.23	0.00	7.75
Exporter (8)	0.38	0.48	0.00	1.00
Foreign ownership (9)	0.11	0.32	0.00	1.00
Patent (10)	0.02	0.15	0.00	1.00
Cooperation in R&D (11)	0.07	0.25	0.00	1.00
Market sources of information (12)	0.85	0.36	0.00	1.00
Scientific sources (13)	0.26	0.44	0.00	1.00
Public sources (14)	0.73	0.44	0.00	1.00
Public support (15)	0.04	0.20	0.00	1.00
h (Share skilled labour) (16)	0.11	0.15	0.00	1.00
h=0 (17)	0.25	0.43	0.00	1.00
k (18)	0.64	1.55	0.00	21.00
Services				
Tech innovation(1)	0.31	0.46	0.00	1.00
Non-technological Innovation (2)	0.24	0.43	0.00	1.00

Productivity (3)	1118.78	2191.69	18.00	31936.16
Non-ICT Innovation expenditure (4)	11.69	45.04	0.00	536.07
ICT Innovation expenditure (5)	3.17	20.28	0.00	368.75
No investment in ICT (6)	0.79	0.40	0.00	1.00
Firm size (7)	3.71	1.40	0.00	9.21
Exporter (8)	0.14	0.35	0.00	1.00
Foreign ownership (9)	0.10	0.30	0.00	1.00
Patent (10)	0.02	0.13	0.00	1.00
Cooperation in R&D (11)	0.03	0.17	0.00	1.00
Market information sources (12)	0.87	0.34	0.00	1.00
Scientific sources (13)	0.32	0.47	0.00	1.00
Public sources (14)	0.71	0.46	0.00	1.00
Public support (15)	0.02	0.14	0.00	1.00
h (Share skilled labour) (16)	0.23	0.28	0.00	1.00
h=0 (17)	0.25	0.43	0.00	1.00
k (18)	0.85	3.24	0.00	62.04

Notes: (1) Product or process innovation, (2) Organisation or marketing innovation, (3) Log of sales per employee. (4) R&D expenditures and other innovation expenditures such as design, installation of machinery, industrial engineering and embodied and disembodied technology (capital and machinery, patents, patent and trademark licensing, disclosures of know-how, and other technological services) with the exception of ICT investment, and design, marketing, and training, per employee, (5) Expenditures on Software, Hardware and Computer Services, (6) Share of firms that don´t report investment in ICT (7) Log of the number of employees, (8) Share of firms that export,(9) Share of firms with foreign capital greater than 10%, (10) Share of firms that applied for patent in the survey period (11) Share of firms that co-operated in R&D on innovation activities, (12) Share of firms that indicated market sources (suppliers, clients, competitors, consulting firms, experts) as very important or important for innovation projects, (13) Share of firms that indicated scientific sources (universities, public research centres, technological institutions as very important or important for innovation projects, (14) Share of firms that public indicated public sources (journals, patents, magazines, expositions, associations, databases, internet) were very important or important for innovation projects (15) Share of firms that received public financial support for innovation, (15) Share of firms that applied for one or more patents, (16) Log of share of skilled employment (professional and technicians over total employees), (17) Share of firms with no skilled employment (18) Log of total fixed assets over employees.

5. Results

5.1 Investment on ICT and other innovation activities

In columns (2), (4), (6) and (8) we can see the results from the probit estimation for the investment decision in ICT and other innovation activities for manufacturing and services.

The first thing to note is the positive and very consistent correlation between size and the decision of investing in innovation in all the 4 regressions. This is one of the most consistent findings in the literature; size is relevant for the investment in innovation. One way of interpreting this finding is that there are some fixed costs, particularly related to R&D and fixed assets investments (e.g. labs), in the production of innovations and therefore larger firms can spread them on more units of output.

Two additional facts related to size are worth noting. First, if we compare the point estimates, size seems to be less relevant for services than for manufacturing, this is probably because service firms use less formalised processes to produce innovations and therefore are less subject to economies of scale and scope in their production. Second, the point estimates for ICT are bigger than those for other innovation activities, this could mean that ICT investment is more subject to economies of scale than the other type of investments. This is reasonable, if one takes into account that many investments in ICT take the form of fixed cost, for the example, once new software is bought for the production of new goods (services) it can be used for the production of as many units as it is wished. This means that this kind of costs can be easily diluted in large firms, and more easily than other types of investments.

The dummy variables Exporter and Foreign_own do not seem to be very relevant in the decision of investing in innovation activities. The variable Exporter, that is proxy for the intensity of the links with external markets, is only significant for the investment in other innovation activities in the case of service firms.

The dummy Patent that takes value 1 when the firm applied for a patent, is a measure of past innovation efforts of firms. Even though this is an imperfect proxy, since only few firms applied for patents (2.3% of manufacturing firms, and 1.3% of service firms), it is correlated with the decision of investing in innovation activities, both in ICT and in other activities and also both in manufacturing and services. The point estimates of this variable for other innovation activities are bigger than for ICT.

The dummy PubSupport, that takes value 1 when the firms receives public financial support for innovation activities, is a variable that is positively correlated with decision of investing in other innovation activities, but seems to be less relevant for the decision of investing on ICT. However, it seems to be more important for ICT in services than in manufacturing. Probably public support has been directed more to other innovation activities than to ICT, but this is just a hypothesis.

The cooperation between firms in R&D activities (the dummy Coop_RD) is one of the variables most consistently positively associated with the decision of investing in innovation activities. The coefficients are similar across sectors, but not across innovation activities. They are smaller in the case of ICT, indicating that ICT activities can be done with relative independence of the cooperation of other firms in R&D activities.

The variable human capital (share of professionals and technicians in the workforce) is important in the investment decision equations for both manufacturing and services, but the coefficients are larger for manufacturing firms. On the other hand the absence of qualified workforce (i.e. h=0) clearly conspires against the investment in innovation activities.

Only market sources of information (for suppliers, clients, competitors, consulting firms, experts) are consistently positively associated with the decision of investment (except in the case of ICT in manufacturing). Public and scientific sources of information do not seem to be relevant, in fact in some cases significant negative signs are found.

In columns (1), (3), (5) and (7) the results for the innovation effort (or innovation investment) are shown. Four are the variables that are usually associated with greater investment in innovation activities across sectors and across types of investment: Coop_RD, h, D(h=0) and D(Market info). When comparing the point estimates, human capital, appear to be more important for the level ICT investment than for the level of investment in other innovation activities. Something similar happens with the variables cooperation in R&D and market sources of information.

In addition we have other variables that introduce some differences across sectors or types of innovation activities. Foreign owned firms (foreign capital greater than 10%) invest more on ICT, and particularly in services. The manufacturing firms that applied for patents invest more in ICT.

Table 3. Investment decision and level of investment equations (Heckman selection model)

	Manufacturing				Services			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	IInict	P(IInict>0)	ICTI	P(ICTI>0)	IInict	P(IInict>0)	ICTI	P(ICTI>0)
L (=Size)		0.362***		0.462***		0.251***		0.367***
		(0.0314)		(0.0230)		(0.0160)		(0.0156)
D(Exporter)	0.119	0.0655	-0.105	-0.0263	0.294	0.300***	0.155	0.0852
	(0.131)	(0.0601)	(0.216)	(0.0752)	(0.226)	(0.103)	(0.313)	(0.0912)
D(Foreign_own)	-0.193	0.0551	0.393*	-0.157	0.0401	0.0556	0.914***	0.0551
	(0.186)	(0.111)	(0.202)	(0.119)	(0.227)	(0.124)	(0.299)	(0.172)
D(Patent)	-0.274	1.081***	1.154***	0.783***	0.503*	1.357***	0.725	0.390*
	(0.320)	(0.362)	(0.338)	(0.136)	(0.260)	(0.424)	(0.573)	(0.212)
D(PubSupport)	0.490	1.878***	0.738*	0.218	0.943	2.089***	0.612	0.466**
	(0.326)	(0.410)	(0.410)	(0.155)	(0.689)	(0.423)	(0.831)	(0.233)
D(Coop_RD)	0.467**	1.314***	0.835***	0.316***	0.937**	1.152***	1.493***	0.404**
	(0.187)	(0.155)	(0.277)	(0.112)	(0.373)	(0.209)	(0.516)	(0.159)
h	1.791**	0.975**	4.334***	1.202***	1.955***	0.613***	3.072***	0.662***
	(0.713)	(0.394)	(1.080)	(0.276)	(0.446)	(0.235)	(0.919)	(0.185)
D(h=0)	0.604***	-0.354***	-0.126	-0.177*	-0.683**	-0.302**	-0.866**	-0.211**
	(0.198)	(0.115)	(0.311)	(0.0959)	(0.280)	(0.138)	(0.430)	(0.0958)
D(Market info)	0.0238	0.352***	0.599*	0.123	0.489**	0.446***	0.894**	0.423**
	(0.191)	(0.128)	(0.342)	(0.116)	(0.222)	(0.149)	(0.376)	(0.209)
D(Scientific info)	-0.0556	-0.251**	-0.445**	-0.230***	-0.138	-0.170*	-0.208	-0.0529
	(0.240)	(0.100)	(0.185)	(0.0845)	(0.128)	(0.0936)	(0.424)	(0.101)
D(Public info)	-0.0269	0.101	0.493	0.304**	0.183**	0.0682	-0.00547	-0.0145
	(0.140)	(0.0961)	(0.433)	(0.149)	(0.0903)	(0.107)	(0.198)	(0.0470)
Constant	2.155***	-2.043***	-7.060***	-3.176***	-1.237**	-2.087***	-11.92***	-3.284***
	(0.611)	(0.199)	(0.576)	(0.153)	(0.534)	(0.117)	(0.928)	(0.307)
athrho	-0.243		1.542***		0.595***		2.132***	
	(0.214)		(0.185)		(0.174)		(0.0981)	
lnsigma	0.515***		0.909***		0.648***		1.311***	
	(0.0385)		(0.0762)		(0.0671)		(0.0532)	
Observations	1,727	1,727	1,727	1,727	1,868	1,868	1,868	1,868
Log likelihood	-2211	-2211	-1282	-1282	-2268	-2268	-1584	-1584

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All regressions include 2-digit ISIC dummies.

5.2 Technological and non-technological innovation

The main objective of this subsection is to understand the role that ICT has in the production of technological and non-technological innovations in manufacturing and services. As discussed in the methodological section, the idea is to introduce the prediction of the investment in ICT and other innovation activities as an input of the innovation production function. The prediction of these variables (i.e. IInict_pred and ICTI_pred) are highly correlated (corr. = 0.77 for services and 0.36 for manufacturing) and this could be a problem, especially in services. Therefore we will also run alternative regressions (following closely the strategy of HLM) introducing the observed ICT investment (ICTI) and a dummy that takes value 1 when there is no investment in ICT (D(No ICTI)) and zero in other case instead of ICTI_pred. The correlation between IInict_pred and ICTI is 0.39 for services and 0.23 for manufacturing.

Columns (1)-(2) and (5)-(6) show the results using IInict_pred and ICTI_pred, and columns (3)-(4) and (7)-(8) using ICTI and D(No ICTI) instead of ICTI_pred.

Columns (1) and (2) show that for manufacturing (where the problem of correlation is less severe) both IInict_pred and ICTI_pred are highly significant in the tech and non-tech innovation equations. The coefficients are bigger for the case of technological innovation. Therefore, the evidence indicates then that ICT is very relevant for innovation in manufacturing, especially for technological innovation.

When we estimate again the biprobit for manufacturing using the variables ICTI and D(No ICTI) instead of ICTI_pred we see that the level of investment in ICT is only statistically significant for non-tech innovations, but the fact of having zero investment is negatively correlated with both tech and non-tech innovations. The level of investment in other types of innovation activities is highly significant in the case of tech innovation, and significant only at 10% in the case of non-tech.

As noted before the correlation between IInict_pred and ICTI_pred is very high in the case of services, this means that these two variables contain very similar information. When introduced together in the Biprobit, the investment in ICT is positive only for non-tech innovations (columns (5) and (6)). The other types of investment are more relevant for tech innovations. The alternative strategy that is less prone to the problems coming from the high correlation of variables (columns (7) and (8)), shows that the levels of investment in ICT and in other innovation activities are important for obtaining tech innovations in services (but not for non-tech innovations). The absence of ICT investment conspires against both tech and non-tech innovations.

With respect to the other control variables, it can be seen that size continues to be a very relevant variable. The additional contribution of the other variables to the increase in the probability of introducing tech and non-tech innovations are not clear across industries and types of innovations. Note that the variables IInict_pred, ICTI_pred already contain the indirect effect of these variables coming from the previous stage or equations, this could explain the negative sign of some of these variables.

Table 4. Technological and non-technological innovation equations

	Manufacturing				Services			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Tech	Non-Tech	Tech	Non-Tech	Tech	Non-Tech	Tech	Non-Tech
IInict_pred	1.151***	0.245**	3.137***	0.603*	1.501***	0.324*	1.245***	0.105
	(0.198)	(0.124)	(0.537)	(0.351)	(0.362)	(0.184)	(0.470)	(0.168)
ICTI_pred	1.262***	0.352***			-0.132**	0.0969***		
	(0.182)	(0.119)			(0.0522)	(0.0262)		
ICTI			-0.0548	0.0852***			0.103***	-0.000608
			(0.0640)	(0.0289)			(0.0371)	(0.0496)
D(No ICTI)			-1.104***	-1.609***			-1.765***	-1.335***
			(0.225)	(0.242)			(0.179)	(0.236)
L (=Size)	0.333***	0.296***	0.249***	0.248***	0.178***	0.213***	0.157***	0.157***
	(0.0424)	(0.0303)	(0.0416)	(0.0350)	(0.0184)	(0.0182)	(0.0134)	(0.0172)
D(Exporter)	0.0835	-0.157*	-0.313***	-0.328***	-0.145	0.152*	-0.130	0.184
	(0.0744)	(0.0851)	(0.105)	(0.107)	(0.165)	(0.0820)	(0.183)	(0.113)
D(Foreign_own)	-0.351***	-0.164	0.542***	0.00705	-0.103	0.180**	-0.406***	0.238**
	(0.134)	(0.120)	(0.127)	(0.100)	(0.0973)	(0.0768)	(0.127)	(0.116)
D(Patent)	-0.00232	0.397*	1.623***	0.546**	0.547***	0.371	0.581	0.351
	(0.354)	(0.225)	(0.372)	(0.247)	(0.203)	(0.399)	(0.376)	(0.535)
D(Coop_RD)	-0.217	0.0557	-0.0852	0.0501	0.0240	0.307*	-0.0566	0.455**
	(0.282)	(0.178)	(0.299)	(0.239)	(0.290)	(0.170)	(0.475)	(0.212)
h	-6.855***	-1.216	-5.165***	-0.666	-2.063***	-0.637***	-2.155**	-0.105
	(1.189)	(0.865)	(0.999)	(0.825)	(0.708)	(0.224)	(1.091)	(0.285)
D(h=0)	-0.842***	-0.486***	-2.166***	-0.709***	0.559**	0.0332	0.607*	-0.106
	(0.145)	(0.134)	(0.315)	(0.238)	(0.266)	(0.179)	(0.357)	(0.129)
D(Market info)	-0.373**	-0.00746	0.334***	0.174	-0.110	0.402***	-0.199	0.502**
	(0.168)	(0.148)	(0.120)	(0.161)	(0.121)	(0.130)	(0.171)	(0.205)
D(Scientific info)	0.320***	0.0786	-0.101	0.0360	-0.00301	0.0114	-0.0360	-0.0140
	(0.117)	(0.0786)	(0.130)	(0.0711)	(0.0789)	(0.0768)	(0.0906)	(0.0755)
D(Public info)	-0.396***	0.113	0.221***	0.221**	-0.266**	-0.0474	-0.188	0.0238
	(0.135)	(0.137)	(0.0822)	(0.0888)	(0.131)	(0.0968)	(0.144)	(0.114)
Constant	4.162***	-0.358	-7.778***	-1.992**	-1.557***	-0.886**	1.428**	-0.958***
	(0.865)	(0.588)	(1.199)	(0.782)	(0.296)	(0.350)	(0.573)	(0.194)
athrho		0.512***		0.297***		0.547***		0.267***
		(0.0404)		(0.0348)		(0.0242)		(0.0327)
Observations	1,727	1,727	1,727	1,727	1,868	1,868	1,868	1,868

Log likelihood	-1568	-1568	-1398	-1398	-1791	-1791	-1551	-1551

5.3 Productivity

In this section we will estimate three versions of the labour productivity equation with alternative proxies of innovation and ICT investment.

In column (3) and (6) we estimate the equation proposed in the methodological section. In these regressions we are using the predicted probability of introducing tech, non-tech and both (from the biprobit estimation in the versions presented in columns (3)-(4) and (7)-(8) of table 5). The first thing to notice is that the level of investment in ICT is positively correlated with the labour productivity both for manufacturing and services. The coefficient is larger for manufacturing firms. The absence of investment in ICT has a negative impact on manufacturing firms and no effect in the case of services.

In services the non-technological innovation and the combined strategy of tech and non-tech innovation have a positive impact on productivity. Technological innovation has no impact. For manufacturing only technological innovation has a positive impact on innovation, the other configurations have a negative impact.

When we use only the predicted investment in innovation activities in the regressions (columns (1) and (4)) we find that ICT investment only increases productivity in the case of services firms. As mentioned in previous section this result could have to do with the positive correlation between IInict_pred and ICTI_pred. Therefore, in columns (2) and (5) we use the observed ICT investment and a dummy capturing those firms that do not invest in ICT in replacement of ICTI_pred. From this exercise we can see that both the investment in ICT and the investment in all other innovation activities are positively associated with higher productivity in the case of services and only ICT in the case of manufacturing firms. The impact of ICT on productivity is similar across sectors. Interestingly, the absence of investment in ICT is associated with lower levels of productivity in both sectors.

The variable size (or labour) is positive in the case of manufacturing firms, suggesting economies of scale in the production of these goods. In services, there seems to be constant returns to scale. The coefficients of the variables k and h are significant and positive for both manufacturing and services firms, indicating that physical and human capital are relevant for labour productivity in both types of goods. The absence of qualified human capital (i.e. D(h=0)=1) is associated with lower levels of productivity in both services and manufacturing.

Table 5. Productivity Equation

	Manufacturing			Services		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Productivity	Productivity	Productivity	Productivity	Productivity	Productivity
IInict_pred	0.101	0.137		-0.141	0.130*	
	(0.112)	(0.114)		(0.110)	(0.0670)	
ICTI_pred	0.0429			0.219***		
	(0.0493)			(0.0777)		
ICTI		0.0811***	0.184***		0.0940***	0.116***
		(0.0275)	(0.0235)		(0.0245)	(0.0244)
D(No ICTI)		-0.400***	-1.670***		-0.528***	0.122
		(0.103)	(0.249)		(0.137)	(0.243)
P(Tech and Non-Tech)			-1.924***			1.545***
			(0.411)			(0.411)
P(Tech)			0.589***			-0.486
			(0.209)			(0.377)
P(Non-Tech)			-6.329***			2.443***
			(0.921)			(0.664)
L (=size)	0.226***	0.234***	0.313***	-0.0121	0.0238	-0.0421
	(0.0284)	(0.0311)	(0.0411)	(0.0233)	(0.0260)	(0.0332)
k	0.196***	0.196***	0.186***	0.0684**	0.0651*	0.0606**
	(0.0539)	(0.0578)	(0.0561)	(0.0301)	(0.0333)	(0.0266)
h	0.124***	0.120***	0.150***	0.238***	0.244***	0.280***
	(0.0409)	(0.0341)	(0.0360)	(0.0386)	(0.0372)	(0.0221)
D(h=0)	-0.615***	-0.628***	-0.808***	-0.884***	-0.879***	-1.006***
	(0.140)	(0.103)	(0.130)	(0.157)	(0.148)	(0.109)
Constant	12.81***	12.79***	14.65***	15.28***	13.46***	13.00***
	(0.509)	(0.354)	(0.326)	(0.789)	(0.174)	(0.247)
Observations	1,209	1,209	1,209	1,093	1,093	1,093
R-squared	0.311	0.317	0.343	0.435	0.446	0.453

Bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All regressions include 2-digit ISIC dummies. The predicted probabilities P(Tech and Non-Tech), P(Tech), and P(Non-Tech) come from the Biprobit models expressed in columns 3-4 and 7-8 of previous table.

6. Conclusions

Several studies have highlighted ICT as driver of firm productivity in the case of developed countries. However, the evidence about the different impacts of ICT on services and manufacturing and particularly for developing countries is scarce. This paper contributes to close this knowledge gap by highlighting empirically the determinants of investments on ICT at firm level and how this adoption ultimately affects innovation and productivity of Uruguayan firms.

In addition, we contribute to the empirical literature in several ways. First, by extending the CDM to take into account all innovation activities and not only R&D in the context of understanding the link between ICT and productivity. Secondly, we provide robust and comparable evidence on the effect of ICT on productivity for both manufacturing and service sectors, using the same specification and data source. This allows us to highlight the heterogeneities present in both the adoption of ICT and their effects on productivity between sectors and show the existing complementarities operating in the service sector firms. Third, we jointly model ICT, innovation and productivity providing a richer structure than in the received literature (Hall, Lotti and Mairesse, 2012; and Polder, van Leeuwen, Mohnen and Raymond, 2009).

In this setting, and in line with the literature, we found a positive and consistent correlation between size and the decision of investing in innovation. Despite this overall picture, sectoral heterogeneities emerged showing that service sector firms are less subject to economies of scale and scope in the production of innovation. At the same time, considering the different innovation expenditures allow us to find that ICT investment is more subject to economies of scale than the other type of investments, contributing to explain the higher investments by larger and foreign firms. This finding seems to be related to the fact that many investments on ICT take the form of fixed cost, for the example, once new software is bought for the production of new goods (services) it can be used for the production of as many units as it is wished. This means that this kind of costs can be easily diluted in large firms. In this sense, ICT investment seems to be less influenced by public financial support than other innovation expenditures. However, it seems to be more important for ICT in services than in manufacturing. Finally, the decision to engage on ICT investment –different from other innovation activities- is not that dependent of cooperation with other agents. Interestingly, the level of ICT investment tends to be more sensitive to human capital endowments than other forms of innovation activities.

In what refers to the impact on obtaining different types of innovations, our empirical strategy contemplates different specifications to account for the correlation between the predicted values of investment of ICT and other innovation activities. By doing so, we are able to show that ICT is very relevant for obtaining technological innovation in both services and manufacturing. However, the level of investment in ICT show no impact on obtaining non-tech innovations in the case of services but the reverse happens in manufacturing. It should be noted that the absence of ICT investment conspires against both tech and non-tech innovations in every sector considered.

Finally, our results indicate that the level of investment in ICT is positively correlated with the labour productivity both for manufacturing and services, with higher importance in the case of manufacturing where the absence of investment in ICT has a negative impact. In fact, we found that both the investment in ICT and the investment in all other innovation activities are positively associated with higher productivity in the case of services and only ICT in the case of manufacturing firms. The impact of ICT on productivity is similar across sectors. Interestingly, the absence of investment in ICT is associated with lower levels of productivity in both sectors.

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Appendix A.

Table A.1. Definition of variables

Variable	Source	Description
Technological innovation	IS	Dummy=1 if firm introduced product or process innovation in the period of the survey
Non-technological Innovation	IS	Dummy=1 if firm introduced organisational or marketing innovation in the period of the survey
Productivity	IS	log(sales per employee). End of year of survey.
ICTI		Log of Investment in ICT innovation activities per employee. Year-end survey.
D (No ICTI)	IS	Dummy=1 if ICTI=0.
IInict	IS	Log of innovation investment in all other innovation activities (except ICT). Year-end survey.
L (=size)	IS	log number of employees. Year-end survey
D(Foreign_own)	IS	Dummy=1 if foreign capital greater than 10%. Year-end survey
D(Patent)	IS	Dummy=1 if firm applied for patent in the survey period
D(Exporter)	IS	Dummy=1 if firms exports. Year-end survey
D(Public support)	IS	Dummy=1 if firm obtained financial support from government in the period of the survey
D(Cooperation_R&D)	IS	Dummy=1 if firm was linked to some institution or design or R&D in the period of the survey
D(Market info)	IS	Dummy=1 if importance of market sources (suppliers, clients, competitors, consulting firms, experts) was very important or important in the period of the survey
D(Scientific info)	IS	Dummy=1 if importance of scientific sources (universities, public research centre, technological institutions) was very important or important in the period of the survey
D(Public info)	IS	Dummy=1 if importance of public sources (journals, patents, magazines, expositions, associations, databases, internet) was very important or important in the period of the survey
h	IS	Log of share of skilled employment (professional and technicians over total employees). End of year
D(h=0)	IS	Dummy=1 when h=0.
k	EAS	Log of total fixed assets over employees. Year-beginning survey.

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