IDB WORKING PAPER SERIES Nº IDB-WP-658

Innovation and Productivity in Services and Manufacturing

The Role of ICT Investment

Diego Aboal
Ezequiel Tacsir

Inter-American Development Bank
Institutions for Development Sector
Knowledge and Learning Sector

December 2015

Inter-American Development Bank

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CINVE/ UNU-MERIT

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Aboal, Diego
Innovation and productivity in services and manufacturing: the role of ICT investment / Diego Aboal, Ezequiel Tacsir.
p. cm. — (IDB Working Paper Series ; 658)
Includes bibliographic references.
1. Industrial productivity—Technological innovations—Uruguay. 2. Service industries—Technological innovations—Uruguay. 3. Manufacturing industries—Technological innovations—Uruguay. 4. Investments—Technological innovations—Uruguay. I. Tacsir, Ezequiel. II. Inter-American Development Bank. Competitiveness and Innovation Division. III. Inter-American Development Bank. Knowledge and Learning Sector. IV. Title. V. Series.
IDB-WP-658

http://www.iadb.org

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Contact: Matteo Grazzi, matteog@iadb.org.

Abstract[*]

Several studies have highlighted information and communications technology (ICT) as a driver of firm productivity in developed countries. However, evidence of the impacts of ICT on services and manufacturing, particularly in developing countries, is scarce. This paper analyzes the determinants of investment in ICT at the firm level and how investments in ICT ultimately affect innovation and productivity in Uruguayan service firms compared to manufacturing firms. The results show that investments in ICT are subject to economies of scale to a greater degree than other types of investments. They are also important for product or process innovations in the service sector. The absence of investment in ICT conspires against non-technological (e.g., organizational or marketing) innovations. ICT and other innovation investments are positively associated with productivity in services, but only ICT affects productivity in manufacturing. 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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[*] This paper is part of a research project led by the Competitiveness and Innovation Division (CTI) of the Inter-American Development Bank (IDB), with the financial support of the Public Capacity Building Korea Fund. The project is aimed at promoting knowledge sharing and exchange of national practices between Korea and Latin America and the Caribbean. The paper was presented at "The Knowledge Sharing Forum 2015, Development Experiences: Comparative Experiences of Korea and LAC," one of the events of the IDB-IIC annual meeting in 2015, which took place in Korea. The authors have benefited from comments by Matteo Grazzi, Juan Gallego, and Luis Gutierrez.

1. Introduction

Throughout the world, empirical evidence has shown that innovation is an effective means of improving productivity, spurring economic growth, and raising living standards (Hall, 2011; Hall and Jones, 1999; Rouvinen, 2002;). The earliest analysis of the impact of innovation on productivity (Griliches, 1979) focused mainly on the contributions of investment in research and development (R&D). In recent decades, the literature aimed at understanding the engines of productivity growth has broadened its scope to include other types of investment. Today, information and communications technologies (ICTs) are widely recognized as one of the main drivers of global economic growth. A large body of research highlights the link between ICTs and productivity growth (Jorgenson, 2001; Oliner and Sichel, 1994; Ortega-Argilés, Potters, and Vivarelli, 2014; Wilson; 2009).

ICTs have the potential to affect economic growth and productivity both directly and indirectly. Productivity improvements in sectors that produce ICT goods or services contribute directly to aggregate productivity of the economy proportional to the size of the ICT sector (Gordon, 2000 and 2012; Jorgenson, Ho, and Stiroh, 2002 and 2008; van Ark, O'Mahony, and Timmer, 2008). More importantly, ICT affects the productivity of the sectors that use them. Specifically, ICTs enable faster communication and information processing, ease internal coordination, facilitate decision making, and reduce market failures associated with information asymmetries (Arvanitis and Loukis, 2009; Atrostic et al., 2004; Cardona, Kretschmer, and Strobel, 2013; Gilchrist, Gurbaxani, and Town, 2001). Firm-level research confirms that ICTs operate as an enabling factor for businesses to innovate and improve their performance, serving as a general purpose technology (Bresnahan and Trajtenberg, 1995).

A variety of studies on developed countries find an impact of ICT investment on productivity greater than that for 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; Bugamelli and Pagano, 2004; Castiglione, 2012; Greenan, Topiol-Bensaid, and Mairesse, 2001), but ICT is not enough to affect productivity. Evidence shows that the contribution of ICTs 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 organizational innovation. Hall, Lotti, and Mairesse (2012) state that ignoring these complementarities may lead to an overestimation of the effect of ICT on productivity.

Developing ICT projects requires reorganization of the firm around the new technology, but implementing this reorganization takes time and, more importantly, it implies costs, such as retraining of workers, consultants, and management time. Related research has stressed the possible complementarity between investment in computers and in other forms of allied investment, such as in organizational change (Black and Lynch, 2001; Bresnahan and Trajtenberg, 1995; Brynjolfsson and Hitt, 2000 and 2003; Brynjolfsson, Hitt, and Yang, 2002; Caselli, 1999; Greenwood and Yorokoglu, 1997; Hornstein and Krussell, 1996; Ichniowski, Shaw, and Prennushi, 1997).

To date, the bulk of the literature has focused on developed countries, while evidence from emerging economies is still scarce and dispersed. Most of the contributions from Latin America have centered on the diffusion and adoption determinants of ICT (Basant, et al., 2006; Benavente, Lillo, and Turen, 2011; Charlo, 2011; Calza and Rovira, 2011; Gallego, Gutiérrez, and Lee, 2014; Grazzi and Jung, forthcoming; Gutierrez, 2011), addressing 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. This appears to be related to a productive structure that tends not to produce a great deal of innovation (IDB, 2010a; 2010b; Crespi and Zuñiga, 2012; Crespi, Tacsir, and Vargas, 2014). However, that is not the only reason behind the lack of innovation (Navarro, Llisteri, and Zuñiga, 2010). In many LAC economies, firm innovation consists of incremental changes that have little or no impact on international markets and that are mostly based on imitation and technology transfer (e.g., acquisition of machinery and equipment and disembodied technology) (Anlló and Suarez, 2009; Navarro, Llisterri, and Zuñiga, 2010). R&D is often prohibitively expensive, and it could require long time horizons (Navarro, Llisterri, and Zuñiga, 2010). Crespi and Zuñiga (2012), and Crespi, Tacsir, and Vargas (2014) present specifications of the increase in the Crepón-Duguet-Mairesse (CDM) model by including innovation expenditures (and not only R&D) for a group of LAC countries. These contributions show results with evidence for developed countries. Specifically, firms that invest in knowledge are better able to introduce technological advances, and those that innovate have higher labor productivity than those that do not.

Taking this into account, this paper focuses on understanding the determinants of investments in ICT at the firm level and how the adoption of ICT ultimately affects the productivity of Uruguayan firms. In Uruguay, a combination of increased budgetary allocations and institutional reforms, such as the creation of the National Research and Innovation Agency (Agencia Nacional de Investigación e Innovación, or ANII), have induced higher levels of R&D expenditure at the firm level. However, the evidence shows that Uruguay has fallen behind fast-growing emerging economies and developed economies in terms of productivity and resources devoted to R&D.

This paper contributes to the literature on the interaction between ICT investment, innovation, and productivity. First, it extends the CDM model to highlight the effect of ICT investments on productivity by taking into account all innovation activities, not just R&D. This broader framework is justified and applied to Latin America in Aboal and Garda (2015) and Crespi and Zuñiga (2012), but it has never been applied to underline the importance of ICT. Secondly, it provides evidence of the effect of ICT on productivity for both the manufacturing and the service sectors, using the same specification and data source. This approach illustrates the heterogeneities present in both the adoption of ICT and their effects on productivity between sectors and shows the existing complementarities operating in service sector firms. Third, it jointly models ICT, innovation, and productivity, providing a richer structure than that presented in Hall, Lotti, and Mairesse (2012) and Polder, et al. (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 model independently the decision to engage and the amount invested in innovation activities (ICT and other innovation investments) with a Heckman model for each of these variables. The paper goes 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 way to explain the propensity to undertake innovation activities and the amount spent on them. We also provide robust evidence for a developing country, contributing to closing the knowledge gap in the literature.

2. Literature Review

The existing literature[1] focuses on understanding the link between ICT and productivity. The earliest studies took an aggregate perspective with the intention of disentangling the so-called Solow paradox, according to which increasing investments in information technology do not necessarily lead to higher worker productivity. These contributions described the situation in the United States in the early 1990s. They subsequently looked at other developed regions, such as the European Union, motivated by a need to understand whether, and the extent to which, the U.S.-EU productivity gap was related to different patterns of ICT investment (van Ark, Inklaar, and McGuckin, 2003; Cette, Mairesse, and Kocoglu, 2005).

The initial contributions took the form of growth accounting exercises.[2] Specifically, several studies (Gordon, 1999; Jorgenson, 2001; Jorgenson, Ho, and Stiroh, 2002; Oliner and Sichel, 1994 and 2000; to name a few) find a positive relationship between ICT and productivity in the United States in the 1990s. Several studies find 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 1990s. Similarly, Daveri (2003); Jorgenson, Ho, and Stiroh (2002); and Oliner and Sichel (2002) present results indicating that ICT capital deepening and total factor productivity in ICT-producing sectors together explain between 75 and 100 percent of the increase in labor productivity in the same period. While most of the research focuses on manufacturing, more recent efforts assess the impact on services. Bosworth and Triplett (2007) find a strong contribution of ICT to labor productivity growth in the U.S. service sector.

Several studies (Colecchia and Schreyer, 2002; Crépon and Heckel, 2002; Oulton, 2002) extended the research beyond the United States. Colecchia and Schreyer (2002) extended the approach followed by Jorgenson, Ho, and Stiroh (2000) and Oliner and Sichel (2000) to nine

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[1] Draca, Sadun, and Van Reenen (2007) and Biagi (2013) offer exhaustive reviews of the evolution of the literature.

[2] Various authors note the difficulties involved in measuring ICT at the aggregate level. Biagi (2013) mentions a few of the methodological problems involved. First, aggregate analyses do not prove causation between productivity and its determinants, thus reducing their usefulness in drawing policy implications. Second, growth accounting is normally based on the assumption of constant economies of scale and absence of externalities. These estimates might prove to be higher or lower than the actual effects in the presence of one or the other omitted aspects. Third, the methodology might fail to fully capture the quality improvements.

OECD countries. Their results confirm that other developed countries also experienced higher growth rates due to the benefits arising from investment in ICT. Although the effects have clearly been largest in the United States, they find that ICT contributed between 0.3 and 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 United Kingdom. The contribution of ICT to the growth of gross domestic product (GDP) increased from 13.5 percent in 1979–89 to 20.7 percent in 1989–98. Using data on ICT investments from the tax returns of French firms, Crépon and Heckel (2002) evaluate the contribution of ICTs 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 1987–98, ICTs accounted for 0.7 percentage points of average yearly value added growth, with similar contributions from these complementary channels.

The availability of sectoral and firm-level data led to a second generation of studies that abandoned the growth accounting framework in favor of a more econometric approach (Biagi, 2013). These contributions have the potential to assess the effects of ICT investments on ICT-using sectors (the indirect effect) by looking at the role of complementary assets and their capacity to enable other types of innovation and investment. Thus, ICTs allow for substitution effects, triggering process and organizational innovations (Black and Lynch, 2001; Bresnahan, Brynjolfsson, and Hitt, 2002; Hempell and Zwick, 2008; to name a few). At the same time, there is some evidence that previous innovation performance might help determine the potential use of ICT (Hempell, 2002). In a similar vein, Cerquera and Klein (2008) argue that since adoption rates and capacity to reap the benefits of ICT differ from one firm to the next, ICT might represent a source of firm heterogeneity that generates competitive advantages, affects firm strategies, and/or influences aggregate productivity growth. Specifically, they find that in the case of Germany, ICTs have a robust, positive impact on firm heterogeneity when ICT is used intensively and jointly with specific ICT applications. Moreover, ICT-induced heterogeneity is shown to have a positive, albeit small, impact on the decision to invest in R&D personnel.

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

Hall, Lotti, and Mairesse (2012) use an augmented version of the CDM in which they treat ICT in parallel with R&D as an input to innovation rather than simply an input of the production function. By doing so, they are able to take into account the possible complementarities among different types of innovation activities. Their framework encompasses three groups of relationships. The first is the decision whether and how much to invest in R&D. The second consists of a set of binary innovation outcomes during the previous three years. The investment decisions of firms with respect to R&D and physical capital presumably drive these outcomes. The element of novelty is the inclusion of ICT expenditure at this stage to explain innovation activity. The final equation is a conventional labor productivity regression that includes the innovation outcomes. 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 extend the frameworks proposed by Griliches (1979), Crépon, Duguet, and Mairesse (1998), and Hall, Lotti and Mairesse (2012) for the purpose of adapting them to the specificities of service firms and innovation surveys, particularly those in Latin America. Our framework adds some ingredients taken from Crespi and Zuñiga (2012) and Aboal and Garda (2015).

The original contribution of Griliches (1979) has as a starting point a production function where one of the key inputs is R&D. Crépon, Duguet, and Mairesse (1998) have a production function where the key variable of interest is the innovation output (proxied by patents per employee). In our case, the production function proposed by Crépon, Duguet, and Mairesse (1998) is enriched (in some specifications) to incorporate ICT. The production function[3] will be:

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

where y_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 previously 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 (organizational or marketing) innovations. This is conceptually very relevant since we know that service firms have a greater propensity to introduce non-technological innovations and innovation in services is, for example, less dependent on formal R&D than innovation in manufacturing (Aboal and Garda, 2015). 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:

$$(2)\ INN \equiv \begin{pmatrix} TI_i \\ NTI_i \end{pmatrix} = \mathrm{ICTIp_i}\upgamma_0 + \mathrm{IInictp_i}\upgamma_1 + \mathrm{x_i}\updelta + \mathrm{u_i}$$

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, and 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

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

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 number of employees in the firm (firm size), a dummy indicating if the firm is an exporter, a dummy indicating if more than 10 percent of the firm's capital 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 rather 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 of the other innovation activities, IInict) will be modeled independently with a Heckman model for each variable.

The firm first decides whether or not to invest 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 that decide to invest in innovation activities and 0 for firms that do not (it could be either on ICT of 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 or not the firm decides to invest in innovation. The vector of variables is the same contained in x with the addition of the dummy variable for public financial support, which takes value 1 when the firm receives 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 assume that the variables that affect the process of decision of engaging in certain innovation activities also determine 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:

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

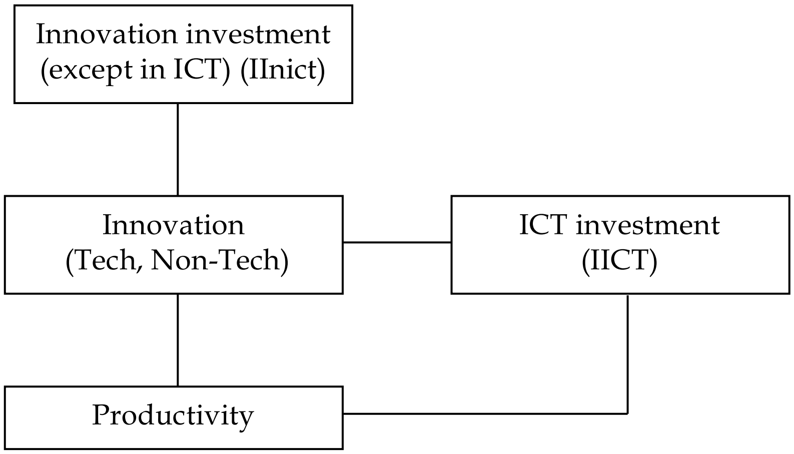
$$I_i = 0 \quad \text{if } ID_i = 0$$

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 whether or not to invest and how much to invest in ICT and other types of innovation activities not related to ICT (R&D, acquisition of capital assets, engineering and industrial design, technology transfer and consulting, organizational 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, particularly ICT. Third, the innovation together with the ICT investment and other production factors affect the level of productivity of firms. We include all innovation expenditures, not only the expenditure on R&D and ICT. One of the reasons to go beyond R&D is that service firms tend to generate innovations without the use of formal R&D. More importantly, there is no reason not to include other innovation investments, since in principle any investment in innovation activities can generate innovations. The second innovation of this paper is the separate treatment of technological and non-technological innovations, albeit in a common framework. This is especially relevant for analyzing innovation in service firms.

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 2004–09, it accounted for approximately 60 percent of GDP and employed more than 70 percent of the total workforce. Both employment and 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 account for 50 percent of total employment in the sector: retail, and professional and household 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 percent of the output and 33 percent of employment in the sector (see Table 1).

Table 1. Contribution of the Service Sector to GDP and Employment in Uruguay

(average, 2005–09)

	GDP	Employment
Subsectors as percent 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 defense	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**

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

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. ANII chose these subsectors based on the following two criteria: first, that knowledge-intensive services should be well represented in the sample, in particular high-technology services (such as informatics and related activities, and research and development); knowledge-intensive market services (air transport; water transport; business services; and rental of machinery equipment, personal effects and household goods), and other knowledge-intensive services (activities related to human health). Second, the selection should include subsectors considered important for the economic development of the country, such as those related to tourism (restaurants and hotels; transport; post and telecommunications; electricity, gas, steam and hot water; and water collection, purification and distribution).

The two waves of SIS available in Uruguay cover the periods 2004–06 and 2007–09. The data are collected in parallel with the Economic Activity Survey (EAS), using the same sample and statistical framework. All firms with more than 49 workers are required to be included. 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 numbers of firms included in the 2004–06 and 2007–09 samples were 900 and 1046, respectively.

We also use the last two available Manufacturing Innovation Surveys (MIS) (2004–06 and 2007–09). The MIS include all manufacturing subsectors. The MIS is also collected simultaneously with the EAS. All firms with more than 49 workers are required to be included. 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 numbers of firms included in the 2004–06 and 2007–09 surveys were 839 and 941, respectively. The final numbers of firms included after cleaning the databases were 1868 service firms and 1727 manufacturing firms.[4]

Both surveys have been matched with the EAS in order to obtain the level of firm's fixed assets 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 survey period. All other variables used in the empirical exercises come from the SIS or the 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 do not find great differences in the innovative behavior of the firms operating in one sector or the other; around one-third of the firms claim to have introduced technological innovation and around a quarter non-technological innovation. Consistent with the existing evidence, manufacturing firms are more likely than service firms to have introduced product or process innovation, while the opposite is true for organizational or marketing innovation. Manufacturing firms are more likely to have engaged in cooperative ventures for the development of R&D projects. Although the average size of firms in the two sectors is similar, the manufacturing sector is more productive.

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

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 labor) (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 labor) (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) organizational or marketing innovation; (3) log of sales per employee at the end of year of survey; (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 do not 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 percent; (10) share of firms that applied for a patent in the survey period; (11) share of firms that cooperated 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 center, or technological institutions as very important or important for innovation projects; (14) share of firms that 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. Year-beginning survey.

With respect to ICT investment and 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 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 show that the proportion of firms that have been involved in some sort of program aimed at promoting innovation is rather small; it is evident that manufacturing firms have received more support than service firms.

5. Results

5.1 Investment in 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 consistent correlation between firm size and the decision to invest in all four regressions. This is one of the most consistent findings in the literature: firm size is relevant for 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), involved in introducing innovations, which larger firms can spread out over more units of output.

Two additional facts related to firm size are worth noting. First, if we compare the point estimates, size seems to be less relevant for services than for manufacturing. This may be because service firms use less formalized 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 larger than those for other innovation activities. This could mean that ICT investment is more subject to economies of scale than other types of investments. This is reasonable, considering that many investments in ICT take the form of fixed costs. For example, once new software is purchased for the production of new goods (services), it can be used for the production of as many units as desired. This means that such costs can be easily diluted in large firms, more easily than other types of investments.

The dummy variables Exporter and Foreign-owned do not seem to be very relevant in the decision whether to invest in innovation activities. The variable Exporter, a 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, which 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 few firms apply for patents (2.3 percent of manufacturing firms and 1.3 percent of service firms), it is correlated with the decision to invest in innovation activities, in both ICT and other activities, and in both manufacturing and services. The point estimates of this variable for other innovation activities is larger than for ICT.

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

The cooperation between firms in R&D activities (the dummy Coop_RD) is one of the variables that is most consistently positively associated with the decision to invest 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 relatively independently 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 investment decision equations for both manufacturing and services, but the coefficients are larger for manufacturing firms. On the other hand, the absence of skilled labor (i.e. h=0) clearly conspires against investment in innovation activities. Only market sources of information (for suppliers, clients, competitors, consulting firms, experts) are consistently positively associated with the decision to invest (except in the case of ICT in manufacturing). Public and scientific sources of information do not seem to be relevant; 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 appears 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.

There are other variables that introduce some differences across sectors or types of innovation activities. Foreign-owned firms (foreign capital greater than 10 percent) invest more in ICT, particularly in services. Manufacturing firms that have 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 analyze the role of ICT in the production of technological and non-technological innovations in manufacturing and services. As discussed in the methodology 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) is 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 introducing the observed ICT investment (ICTI) and a dummy that takes value 1 when there is no investment in ICT (D(No ICTI)) and 0 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 in the case of technological innovation. Therefore, the evidence indicates 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 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 percent 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 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 investments 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 level of investment in both ICT and 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, 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 is 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			
VARIABLES	(1) Tech	(2) Non-Tech	(3) Tech	(4) Non-Tech	(5) Tech	(6) Non-Tech	(7) Tech	(8) 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_owned)	-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 estimate three versions of the labor productivity equation with alternative proxies of innovation and ICT investment. In columns (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 labor productivity both for manufacturing and services. The coefficient is larger for manufacturing firms. The absence of investment in ICT has a negative impact on productivity in manufacturing firms and no effect on productivity in services.

In services, 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 service firms. This result could be related to 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 investments in both ICT and all other innovation activities are positively associated with higher productivity in the case of services, while only investment in ICT is positively associated with higher productivity 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 labor) is positive in the case of manufacturing firms, suggesting economies of scale in the production of these goods. In services, there seem 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 labor productivity in both types of goods. The absence of skilled human capital (i.e., D(h=0)=1) is associated with lower 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 regression 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 a driver of firm productivity in the case of developed countries. However, evidence about the impacts of ICT on services and manufacturing, particularly for developing countries, is scarce. This paper helps close this knowledge gap by highlighting empirically the determinants of investment in ICT at the firm level and how this adoption ultimately affects innovation and productivity in Uruguayan firms.

The paper contributes to the empirical literature in several ways. First, we extend the CDM framework by taking 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, et al., 2009).

In line with the literature, we find a positive and consistent correlation between firm size and the decision to invest 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, different innovation expenditures allow us to find that ICT investment is more subject to economies of scale than other types of investments, which helps explain the higher investments by larger and foreign firms. This finding seems to be related to the fact that many investments in ICT take the form of fixed costs. For 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 desired. Such 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, this appears to be more important for ICT in services than in manufacturing. Finally, the decision to invest in ICT, as distinct from other innovation activities, is less dependent on 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.

Our empirical strategy contemplates different specifications to account for the correlation between the predicted values of investment in 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. The level of investment in ICT has no impact on obtaining non-tech innovations in the case of services, but the reverse is true in manufacturing. 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 labor productivity both for manufacturing and services, with a higher correlation in the case of manufacturing, where the absence of investment in ICT has a negative impact. In fact, we found that both investment in ICT and investment in all other innovation activities are positively associated with higher productivity in the case of service firms, while in manufacturing firms, only investment in ICT is possibly associated with higher productivity. 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 organizational 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_owned)	IS	Dummy=1 if foreign capital greater than 10 percent. 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 for 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 center, 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.