IV. Impact of ICT and innovation on industrial productivity in Uruguay

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1. Introduction

Information and Communication Technologies (ICT) refers to technological progress provided by informatics, telecommunications and audiovisual technologies. Basically, these technologies provide information, and serve as tools for its processing and communication channels. This generates innovation defined as a process oriented towards the solution of productive problems (Nelson and Winter, 1982), characterized by matching productive needs and technical capabilities. In short, ICT refer to informatics, Internet and telecommunications. Since we are immersed in an information society, ICT use is increasingly common and unavoidable (Castells, 2001).

When a firm decides to implement ICT innovation projects, two main forces interact. First, the perception of those who take decisions in the firm concerning the opportunity to innovate and the presence of adequate incentives to do it, together with the perception of the capacity to innovate. In other words, it is not only convenient in terms of firm environment, but also that it is sound within the firm. On the other hand, we can identify a set of variables that firms do not control, but which also affect this decision; these are related to industry characteristics, such as market conditions and competition (Romo Murillo and Hill de Titto, 2006). Markets which are intensive in transactions of innovating products are distinguished by organizational forms regulated by institutional agreements which give a stimulus to innovation behavior (Lundvall, 1988). These "organized" markets are part of the systemic dimensions which define firm environment in the context of NIS analysis (Network Information Service) in developed countries. In less developed countries, innovation often faces a great variety of obstacles and there are a few incentives in the way markets are organized, a thing which hinders the trading of new products (Yoguel and Boscherini, 2000).

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Innovation is a productive process which relies on human resources and investment in capital assets procurement, machinery and/or equipments intended for technological development and innovation activities. If the production function at the microeconomic level is the relationship between productive factors and output, capital allocated to ICT can be taken as another productive factor, in the same way as capital, work and human capital. The relative ease of access to ICT, due to their fast price reduction and quality increase, and to the fact that they are considered general purpose technologies, have led various scholars to propose that ICT, due to their effect on cost reductions of coordination among individuals and firms, may produce a change in firm structure. Likewise, innovation also has an effect on productivity, mainly through total factor productivity but also by interacting with other factors such as capital or human capital. This innovation refers to technologically new processes and products, either at firm, local, country or global level. The emphasis on novelty does not mean to make more of the same, but to expand human knowledge frontier, observing that what is novel may also be applied at firm or country level. Therefore, when we speak about innovation, we must understand that what is new for a particular country may not be new at international level.

The characteristics of Uruguayan economy determine that firm innovation behavior has specific features that are different from empirical evidence related to developed countries. The main objective of this paper is to analyze the effects of ICT and innovation on productivity in manufacturing firms in Uruguay. We are also interested in finding out if firm's employees vary in quantity and quality in relation to the level of ICT investment and innovation. This study is organized as follows. Section 2 presents a brief literature review, and Section 3 describes the methodological and empirical approach. Section 4 shows the main features of innovation activities in Uruguay. Finally, Section 5 discusses econometric results and Section 6 concludes.

2. Literature Review

The impact of ICT has been subject to discussion since they began to be investigated three decades ago. Although it is expected that ICT investments lead to cost reductions, higher flexibility and increase in firms' competitiveness, studies undertaken during the eighties and beginning of the nineties did not find a relevant statistical relationship between investment in ICT and productivity at aggregated level. The relative easiness in the access to ICT, due to their fast price reduction and quality increase, and to the fact that they are considered general purpose technologies, have led many scholars in the nineties to propose that ICT may produce a radical change in the firm structure. This phenomenon would be similar to what happened with the steam engine, the locomotive and the telegraph during the Industrial Revolution; therefore, this stage is called the technological or digital revolution.

Nevertheless, there is no consensus on ICT effects. This can be observed in the Solow Paradox, where the Nobel Prize winner said that computers could be seen everywhere, except in productivity statistics. Indeed, several studies investigated the correlation between ICT investment and firm outcomes such as benefits or improvement in productivity. As no relevant relationship was found between these variables, these studies concluded that ICT investment did not increase productivity (see Brynjolfsson, 1993). The evidence were considered paradoxical by most authors, who explained the results through the limitations of using simple bivariate relationships (Lehr and Lichtemberg, 1999), the potential negative effect of the variety increase in productivity (Barua et al., 1991), and the lagged effect of ICT investment and its dependence on labor networks externalities, and the changes in complementary infrastructure (Becchetti *et al*., 2003).

In the second half of the nineties, with new databases and new econometric methods, a positive relationship was established between ICT investment, productivity and economic growth (Brynjolfsson and Hitt, 1996). There were several improvements in empirical studies leading to these results. First, these studies disentangled the effect on productivity by different ICT technologies (communications, software, hardware, etc.). Second, special attention was given to ICT as part of the innovation process, which has to go along with other changes so that it may evidence an important improvement in productivity. Some of these changes are investments in human capital, specially qualified labor force, and employee-oriented organizational practices. Thus, ICT investment by itself does not imply productivity gains unless it is complemented by other practices (Milgrom and Roberts, 1995). Third, a wide range of econometric methods was used, giving special attention to avoid selectivity (only a small number of firms implement innovations) and simultaneity biases (innovation may involve productivity outcomes, but a high productivity may also stimulate innovation).

In this perspective, Crepon *et al.* (1998) developed a more integral framework that considers all innovation factors, starting with the firm decision to invest in R&D, results of these efforts, and their impact on productivity. This model was used later in developing countries; the study of Benavente (2004), for the Chilean case, was the first one of this kind. The results did not find that sales resulting from innovation had an effect on productivity. In Latin America, in addition to Benavente (2004), Chudnovsky *et al.* (2006) deal with manufacturing firms in Argentina in the nineties, revealing the particular features of an economy with a very pronounced economic cycle. Sanguinetti (2004) also studies the determinants of firm innovation in Argentina, and the results suggest a positive impact of size, market share and foreign capital. Sanguinetti (2004) also identifies the effects of variables at sectoral level such as market concentration or tax rate with negative effects, and qualified labor force participation with positive effect.

Innovation is a process aiming at the solution of productive problems and it is at firm level that knowledge is generated, adapted and applied to productive purposes (Nelson and

Winter, 1982). According to this approach, innovation is a specific process for each firm and it is characterized by a high degree of uncertainty (Dosi, 1988). During the process, firm generates knowledge and applies it to the creation of new products or processes, undergoing a sequence of cumulative learning. The fact that the innovating process is specific and accumulative does not mean that there is an autarchic learning by the firm; on the contrary, the development of the innovation process depends on firm capabilities to identify their needs, opportunities and incentives offered by the environment. Thus, innovation process is seen as a systemic and interactive phenomenon which takes place among the different individuals within the organization and, at the same time, between the firm and its environment (Lundvall, 1992).

In our investigation we differentiate between product and process innovations. Product innovation refers to the production of goods or services which are technologically different or improved, that is, innovation occurs when features of a product improve. Instead, process innovation occurs when there is a significant change in the technology or production methods, or when there are significant changes in the management or organization system, process reengineering, strategic planning, quality control, etc.

3. Methodological and Empirical Approach

The National Institute of Statistics (INE, in Spanish) in cooperation with the National Agency of Research and Innovation (ANNI, in Spanish) carried out Surveys on Innovation Activities (EAI, in Spanish) to manufacturing firms in Uruguay with reference years 1998-2000, 2001-2003 and 2004-2006. In the service sector, the survey was implemented only for the period 2004-2006. Furthermore, INE carried out Structural Economic Activity Surveys (EAE, in Spanish) as an updating of the Economic Census of 1997, with annual periodicity for all the following years; and its last publication was in 2007. Using the microdata derived from both surveys (EAI and EAE), this paper studies the effects of spending in ICT and innovation on productivity and personnel employed in Uruguayan manufacturing firms. We intend to quantify the ICT effects on productivity, its relationships with innovation, either in product or process, and its effects on the quantity and qualification of firm employees. Specifically, we seek to answer the question if ICT investment replaces workers or if it displaces unskilled workers in favor of skilled workers.

This study follows the methodology proposed by Leeuwen and van der Wiel (2003), who analyzed the case of Dutch firms. These authors estimate a production function in order to estimate ICT elasticity. In the case of Uruguay, we include an additional variable to identify human capital effects on productivity. As usual in the literature, we start with a Cobb-Douglas production function at firm level, where the inputs for the production of value added (Y) are capital in ICT (KTIC), other or non-ICT capital (K), workers (L) and workers with university or technical education as an approximation of human capital (LC):

$$Y_{it} = A^* K^{\alpha}_{it} * KTIC^{\beta}_{it} * LC^{\delta}_{it} * L^{ø}_{it} \qquad (1)$$

The sub-indexes i and t refers to firm and year, respectively. If we divide both sides of the equation by the number of workers L and taking logarithms, the equation for the production per worker is expressed as follows:

$$y_{it} – l_{it} = a + \alpha (k_{it} – l_{it}) + \beta (ktic_{it} - l_{it}) + \delta (lc_{it} – l_{it}) + øl_{it} \qquad (2)$$

This equation is estimated econometrically by taking the cross products of innovation with the factors corresponding to ICT capital, non-ICT capital and human capital as follows:

$$y_{it} – l_{it} = \beta_0 + \beta_1 (k_{it} – l_{it}) + \beta_2 N_i (k_{it} – l_{it}) + \beta_3 (ktic_{it} – l_{it}) + \beta_4 N_i (ktic_{it} – l_{it}) + \beta_5 (lc_{it} – l_{it}) + \beta_6 N_i (lc_{it} – l_{it}) + \beta_7 l_{it} + \beta_8 N_i + \varepsilon_{it} \qquad (3)$$

In this case, N represents a variable which takes the value 2 if the firm does innovation in both EAI surveys (2001-2003 and 2004-2006), 1 if the firm implement innovations in only one period and zero if it does no innovation, and ε is the error term of the model. In equation (3), the coefficients may be interpreted as elasticities.

The objective of the empirical section is to test two main hypotheses: i) greater ICT investment is associated to greater productivity at firm level, and ii) ICT investment implies an employed personnel reduction or a reduction of non-qualified workers. To test the first hypothesis, equation (3) is estimated in first differences. In order to evaluate the second hypothesis, the following equation is estimated:

$$l_{it} – l_{it-1} = \alpha + \beta_1 \Delta ktic_{it} + \beta_2 \Delta k_{it} \qquad (4)$$

Equation (4) estimates effects of capital and ICT investments on the variation of employment. Thus, the sign of the estimated coefficient will suggest the complementarity or substitution hypothesis between capital and workers. We also estimate equation (5) to find the effects of investment in the unskilled worker variations and to identify if there are significant differences between the effect on total workers and unskilled workers (lnc_{it}).

$$lnc_{it} – lnc_{it-1} = \alpha + \beta_1 \Delta ktic_{it} + \beta_2 \Delta k_{it} \qquad (5)$$

The data used come from the EAE 2003-2007 and from the EAI 2001-2003 and 2004-2006. We constructed a panel data formed by 738 manufacturing firms which responded at least three EAE between 2003 and 2007 and EAI between 2001-2003 and 2004-2006.

The EAE collects data at firm level concerning gross value of production, value added, workers, intermediate consumption, fixed capital, gross fixed capital formation, industrial sector (4-digit ISIC Rev. 3), among others[2]. The EAE is a stratified sampling survey, where some of the frame units are mandatory (forced stratum) and a random sample is designed for the other units.

The Innovation Survey was divided in two main parts. The first part collects information concerning firms' characteristics, such as type of activity, juridical nature, capital source, number and qualification of employees and sales, among others. The second part collects information related to innovation activities, identifying type of activity and its purpose, resources involved to perform them, their financing source, results obtained, factors that hinder innovation and links with other agents of the National System of Innovation, among other factors. The firm sample includes firms with 5 or more workers. The data on ICT capital, capital source and exports were obtained from the Annual Survey 2003-2007, while the data on product and process innovation were obtained from the Annual Survey 2001-2003 and 2004-2006.

4. Main innovation patterns

The Uruguayan economy has been historically based on livestock production, although in recent years agriculture and services such as tourism, financial services and software, have gained more relevance. The breeding of bovine and ovine livestock are identified as two of the most important activities, and the main exportable products have always been meat, wool and leather. In recent years, there is a trend to increase the participation of agricultural products such as soya, rice and wheat.

Uruguay has shown a strong economic growth since the financial crisis of 2002, and concerning its structure it should be highlighted that the agricultural production is close to 10% of GDP, the manufacturing industry, 16%, trade, restaurants and hotels, 14%, and services 50%, with special mention of real estate and business activities which includes software with 15% and financial services representing 6% of GDP. The growth rate of Uruguay was close to 6% in the period of five years considered in this work, and manufacturing GDP growth was even higher. Thus, its GDP proportion increased from 13.6% in 2003 to 15.2% in 2007. It should be emphasized that this increase follows a strong regional and domestic crisis whose climax occurred in 2002.

[2] See Table A.1 in the appendix for a description of the variables.

In the study undertaken by Bianchi and Gras (2006), using multivariate analysis techniques for analyzing the Survey on Innovation Activities 2001-2003, the innovating process was typified through firm internal capabilities, relationships kept by the firm with the environment in order to develop innovation activities (with agents of the National System of Innovation or others) and innovation experience. This work showed, according to the cognitive base sustained by innovation, that there are three types of firms: those which are less or not innovating (75% of firms considered), those that are based on the incorporation of exogenous knowledge (14%), and those which develop the innovation process by themselves (4.7%).

In the Survey on Innovation Activities, specifically concerning obstacles for innovation, we find that firms responded in the highest proportion to the “small market size” option. The second option was “difficult access to financing”, and in the third place, “macroeconomic instability”. With regard to results of innovating firms in relation to the question about the importance of economic impacts of innovation in a scale from 1 to 4 (being 1 high and 4 not relevant), the response with the highest importance percentage was the option “it maintain firm market share”. The second option was “it improves product quality”, and in the third place, the option “it increase productive capacity”. Additionally, the overall Uruguayan situation is characterized by the following characteristics: i) increasingly demanding customers; ii) pressure on the efficiency to reduce costs and adapt the supply to its particular features; iii) technological progress which generates changes in economic relations; iv) strong competition in international markets; v) certain “aversion to risk” which figures as a negative behavior concerning innovation activities of manufacturing firms. This idea comes from the analysis of section G of EAI, which details some possible obstacles when it comes to developing innovation activities.

The following two tables, with data from the EAE 2006 and 2007, refer to the proportion of firms using ICT and those having Internet and what they use it for. We observe that a very high percentage of firms have computers, use the Internet and have presence in the Web (see Table IX.1 and IX.2). This is so, because the sample is composed by manufacturing firms with more than 50 employees (forced inclusion stratum). The random firms were not a study subject in EAE 2006, so if we considered them, the results would not have been comparable.

Table IX.1
Uruguay: proportion of firms using ICT
(Percentages)

Variable / Year	2006	2007
Proportion of firm with computers	94.7	96.8
Proportion of firms using the Internet	95.1	98.0
Proportion of firms with presence in the Web	68.6	70.3

Source: Author’s own elaboration based on EAE 2006 and 2007.

Table IX.2
Uruguay: ICT use in firms
(Percentages)

Internet Use	2006	2007
Sending or receiving e-Mail	99.3	99.5
Internet banking or access to other financial services	85.1	86.0
Interacting with general government organizations	66.7	67.4
Providing customer service	65.6	64.4
Delivering products online	18.3	18.7
Publicity and marketing	46.2	44.8
Virtual meetings and forums	22.0	22.1
Decision-taking support and/or definition of business operations	42.3	45.1
Getting information about goods and services	90.4	91.8
Getting information from general government organizations	89.0	87.9
Other information search or research activities	70.9	70.9
Receiving orders via Internet	58.0	58.1
Making orders via Internet	59.0	60.0

Source: Author's own elaboration based on EAE 2006 and 2007.

In relation to innovation capabilities of the firms and their effort in this matter, Table IX.3 presents the percentage of firms that innovated by size. As expected, the percentage of firms which innovated increases with the number of personnel employed, in all years. Also, the innovation reduction is evident from one period to another in all segments, even in those firms with more than 200 workers. The possible explanation lies in the fact that the period 2001-2003 included the crisis which affected the Uruguayan economy in 2002. In spite of this situation, manufacturing firms had to make innovations in nearly all areas in order to remain operative. During the crisis, the exchange rate doubled, therefore the external market seemed more attractive to Uruguayan industry. Thus, in 2002 and 2003 many firms were obliged to introduce changes in order to readjust their manufacturing production, remain operative and make their products competitive at both the domestic and international levels. We do not mean that the crisis stimulated innovation, but a certain need was created for firms to innovate so that their products could remain in the market. This competitiveness is based on the ability to produce innovating products and processes, where knowledge and innovation contribute to improve productivity. Precisely for this reason, the percentage of innovating manufacturing firms was lower in the period 2004-2006, because most firms had made innovations in the precedent period, and three years is a relatively short time for local firms to make new innovations.

Similarly, firms with mostly foreign capital are on average more innovative than those whose capital is mostly national. Although both groups showed a reduction of innovation activities in 2004-2006, the difference in favor of foreign firms remains (see Table IX.4). According to the data, we also observed a positive relationship between capital source, size and exports with innovation activity. Indeed, firms with foreign source capital are larger, have the highest exports propensity and a higher innovation rate. Table IX.4 also shows how firms with foreign capital innovated more than those with national capital.

Table IX.3
Uruguay: percentage of innovating firms by size
(Percentages)

Size	Did not innovate	Innovated in 2003	Innovated in 2006	Innovated in both periods
Less than 49 workers	0.36	0.50	0.44	0.30
Between 50 and 99 workers	0.28	0.53	0.55	0.36
Between 100 and 199 workers	0.15	0.72	0.67	0.54
Over 200 workers	0.11	0.82	0.71	0.64

Source: Author's own elaboration based on EAE and EIA, several years.

Table IX.4
Uruguay: percentage of innovating firms by export range and ownership
(Percentages)

Exports (% of sales)	Did not innovate	Innovated in 2003	Innovated in 2006	Innovated in both periods
Exports less than 10%	0.29	0.55	0.56	0.39
Exports between 10% and 50%	0.19	0.70	0.58	0.47
Exports over 50%	0.17	0.70	0.63	0.50
Mostly foreign capital	0.08	0.76	0.76	0.61
Mostly national capital	0.27	0.59	0.54	0.40

Source: Author's own elaboration based on EAE and EIA, several years.

5. Econometric results

This section displays the econometric results by using an unbalanced panel database of 738 firms in 5 years.[3] The dependent variable used is a proxy of productivity (value added per worker), and it has a positive correlation with all interaction factors and terms except one, the interaction between innovation and the proxy of human capital (see Table A.3 in the Appendix). Besides productive factors specified in the model, there are other variables which may explain productivity and productivity differences among firms, like administrative skills, firm culture or ability to obtain intangible resources. The panel structure of the data allows correcting this unobservable heterogeneity when considering the presence of firm specific effects. If these effects are correlated with explanatory variables, fixed effects (FE) methodology must be used; instead, if they are not, random effects (RE) methodology is more accurate.

[3] See table A.2 and A.3 in the Appendix to see variables definitions and Pearson correlation matrix. Additionally, Table A.4 presents a statistical description of variables.

The econometric estimation is implemented by using generalized least squares, because ordinary least squares would be inefficient. We also estimate by weighted least squares for panel data (GWLS), which estimates weighting factors based on the estimations of specific error variances for the respective sample units. This proceeding is an iterative process, and in each round residuals are recalculated using estimated parameters, obtaining a new set of estimators of the specific error variances for each unit, and from there a new set of weighting factors is derived. Overall, the empirical model is estimated by FE, RE and GWLS. See Table IX.5 for GWLS estimation and Tables A.5 and A.6 in the Appendix for fixed and random effects.

The estimation by GWLS shows that all the factors and interactions affected the value added worker. Indeed, ICT capital and innovation interaction with all other production inputs are significant. Nevertheless, in the case of the interaction with ICT capital, the coefficient was negative. With regard to innovation, the model identified that innovation by itself has a negative effect on productivity, although this effect becomes positive when we consider the joint effect with investment both in capital and ICT. One of the reasons that may explains this is the reduced sample and that many firms declared to have implemented innovations when maybe it was not so. The estimation of production functions per worker in first differences shows that capital per worker, ICT capital per worker and employees had positive effects on output growth per worker. Also, innovation was not relevant by itself and had a negative effect on productivity growth when considered together with capital and human capital (see Table IX.6). Jointly, these variables generate an increase in firms' productivity, but they do not increase its growth.

Table IX.5

Estimation Results for the Production Function

Variables	*Coefficient (GWLS) (t-test)*
Constant	10.645 (73.12) ***
k-l	0.152 (14.88) ***
kICT-l	0.030 (3.79) ***
lc-l	0.212 (15.99)***
l	0.038 (3.73)***
N(k-l)	0.118 (11.76)***
N(kict-l)	0.015 (2.21)***
N(lc-l)	-0.064 (-5.307)***
N	-1.510 (-10.69)***
Obs.	1 004
Firms	397
F (8.995)	490.33
Adjusted R-square	0.796

Source: Author's own elaboration.
*Note: * Significant at 10%; ** Significant at 5%, *** Significant at 1%.*

Table IX.6
Estimation results for the production function in differences

Variables	*Coefficient (GWLS) (t-test)*
Constant	0.093 (8.410)***
dk-l	0.035 (2.278)**
dkICT-l	0.030 (3.404)***
dlc-l	0.032 (1.503)
dl	-0.939 (-19.98)***
dN(k-l)	-0.044 (-2.562)**
dN(kict-l)	-0.009 (-1.523)
N(lc-l)	-0.037 (-2.060)**
N	-0.006 (-0.6561)
Obs.	548
Firms	266
F (8.539)	60.54
Adjusted R-square	0.47

Source: Author's own elaboration.
*Note: * Significant at 10%; ** Significant at 5%, *** Significant at 1%.*

In order to test the hypothesis that ICT investments affect the employment level negatively, we estimate equation (4). The results suggest that the increase in ICT capital investment has a positive effect in employment growth, in the same way as the increase in non-ICT capital. For the effects on unskilled workers, we estimate equation (5). The evidence shows that non-ICT capital investment has a higher effect than ICT capital, although both have positive effects on labor demand. These results support the ICT complementarity hypothesis, in the sense that they act as general purpose technologies that stimulate the incorporation of new workers to the firm.

Table IX.7
Estimation results for employment growth

Variables	*Coefficient (t-test)*
Constant	0.065 (77.42)***
dk	0.013 (7.347)***
dkTIC	0.010 (8.322)***
F (2.712)	1 012.2
Adjusted R-square	0.73

Source: Author's own elaboration.
*Note: * Significant at 10%; ** Significant at 5%, *** Significant at 1%.*

Table IX.8
Estimation results for employment growth of unskilled workers

Variables	*Coefficient (t-test)*
Constant	0.064 (32.09)***
dk	0.015 (5.17)***
dkTIC	0.0108 (9.07)***
Adjusted R-square	0.18
F (2.712)	82.68

Source: Author's own elaboration.
*Note: * Significant at 10%; ** Significant at 5%, *** Significant at 1%.*

6. Concluding remarks

This study analyzes the impact of ICT and innovation on productivity in a sample of Uruguayan manufacturing firms. This represents a first attempt to measure the effect of ICT and innovation investment both on productivity and its growth, and on the demand for skilled and unskilled workers. The econometric estimations show that an increase of ICT capital produces an increase in productivity when we consider the isolated effect of this variable. The opposite happens with innovation, which by itself does not have the expected effects on productivity. Indeed, results show that innovation has a negative effect by itself, but this is reverted when it interacts with capital or ICT capital investments. With regard to the effect on productivity growth, ICT investment does have a positive effect, in the same way as the other factors, except human capital. Again, innovation did not have a positive effect. On the other hand, increases in ICT capital investments have a positive impact on labor demand variations. This effect is also maintained on the demand for unskilled employees, although with a somewhat lower coefficient than for other capital.

In Uruguay, there is no research on the effects of ICT or innovation on productivity at firm level. The main obstacle is that there are no surveys exclusively on ICT; questions are included in only one chapter of the Structural Survey of Economic Activity since 2005. Moreover, in the Surveys on Innovation Activities there are no ICT questions either. In our empirical exercise, we relied on a reduced number of firms having detailed data for several periods so as to make a panel analysis. This limitation is expected to disappear when the quantity and quality of data are improved through successive Surveys on Innovation Activities and Structural Surveys of Economic Activity. Another limitation is that the empirical model does not disentangle among product, process or organizational innovations, nor does it consider variables like organization culture or new practices of labor organization and its complementarities with ICT.

Additionally, it also seems necessary to study the sampling method in the Innovation Surveys, both for the manufacturing industry and for services. We perceive that employed personnel are not adequate for stratifying. It should be discussed if other variables, like sales, investments or activity class are more adequate for this purpose. There continue to be many doubts on this matter. Other important gaps in the survey are related to the fact that there is no information about how much the firms invest in ICT, and if they actually give it the right use. We propose to work in a base questionnaire, with a shared purpose, shared, research unit, activity classification and shared definitions. In addition, the questionnaire must last several years in order to have a consistent and comparable series.

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8. Appendix

Table A.1
Variables Definitions

Variable	Definition
Gross fixed capital formation	Investments in buildings, machinery or facilities of any kind, which in collaboration with other factors, are intended for the production of consumer goods. It is captured in current values by the Structural Survey of Economic Activity and transformed to constant values by using the Price Index of National Products (IPPN – Índice de Precios de Productos Nacionales) elaborated by INE.
Gross fixed capital formation in ICT	Investments in informatics and telecommunications. These technologies provide innovation to the firm, and tools for its process and communication channels. It is captured in standard values by the Structural Survey of Economic Activity and carried to constant values by using the Import Price Index of Capital Assets (Índice de Precios de Importación de Bienes de Capital), elaborated by the Central Bank of Uruguay.
Human capital	Set of human resources owned by a firm or economic institution. We speak of improvement in human capital when the degree of skill, know-how or education background of the employees increases.
Personnel employed	Total number of employees in the firm.
Professionals and technicians	Number of employees with university degree or who have a major in the task they develop.
Capital source	Foreign capital participation in the firm's total capital. The Annual Survey of Economic Activity establishes three categories: no share, less than 50% of the capital, 50% or more.
Value added	Difference between production value of goods and services produced and the intermediate consumption used in their production, carried to constant prices by using the corresponding Pasche Price Index of the Survey of the Physical Volume Index for each 4-digit activity class of ISIC Rev.3.
Product innovation	Introduction of technological or other changes in a product. Innovation is produced when the characteristics of a product change.
Process innovation	Introduction of significant changes in production technology. It also happens when there are changes in management system or organizational methods, process reengineering, strategic planning, quality control, etc.
Organizational innovation	Introduction of changes in organizational and management aspects of the firm; changes in the organization and administration of productive process, incorporation of significantly modified organizational structures and implementation of new or substantially modified strategic guidelines.

Source: Author's own elaboration.

Table A.2
Variables used in econometric analysis

Variable	Definition
y-l	Logarithm of value added by employee in constant pesos.
l	Logarithm of number of employees.
kict-l	Logarithm of ICT capital per employee in constant pesos.
k-l	Logarithm of capital per employee in constant pesos.
lc-l	Logarithm of the proportion of professionals and technicians per employee.
N	Variable which takes the value zero if the firm declares to have made no innovation in any of the two innovation surveys, 1 if it introduced any innovation in only one of the surveys and 2 if it implemented it in both surveys.

Source: Author's own elaboration based on EAE and EIA, several years.

Table A.3
Pearson correlations

y-l	l	kict-l	k-l	lc-l	N(kict-l)	N(k-l)	N(lc-l)	N	
1	0.26	0.26	0.52	0.10	0.44	0.40	-0.29	0.34	y-l
	1	-0.03	0.32	-0.48	0.44	0.41	-0.52	0.38	l
		1	0.29	0.11	0.35	0.14	-0.04	0.10	kict-l
			1	-0.02	0.38	0.41	-0.29	0.29	k-l
				1	0.00	-0.03	0.46	-0.03	lc-l
					1	0.97	-0.85	0.97	N(kict-l)
						1	-0.87	0.99	N(k-l)
							1	-0.87	N(lc-l)
								1	N

Source: Author's own elaboration based on EAE and EIA, several years.

Table A.4
Basic statistics

Variable	Mean	Median	Min.	Max.	Standard Dev.
l	4.01	3.98	0.69	8.50	1.16
y-l	12.45	12.42	5.94	18.08	1.06
kTIC -l	8.78	8.93	-1.41	19.38	1.99
k-l	12.15	12.30	-4.34	16.62	1.61
Lc-l	-2.88	-2.80	-7.02	0.01	1.02
N(kTIC-l)	6.17	0.00	-1.41	27.49	7.30
N(k-l)	11.04	11.96	-4.34	33.06	9.58
N(lc-l)	-2.45	-2.27	-14.04	0.00	2.52
N	0.89	1.00	0.00	2.00	0.73

Source: Author's own elaboration based on EAE and EIA, several years.

Table A.5
Estimation results of the production function

Variable	Fixed effects	Random effects	GWLS
Constant	15.408 (23.01)***	10.95 (22.70)***	10.646 (73.12)***
k-l	0.038 (0.61)	0.167 (4.747)***	0.152 (14.88)***
kTIC-l	-0.001 (-0.0775)	0.006 (0.3353)	0.030 (3.793)***
lc-l	-0.010 (-0.15)	0.100 (1.879)*	0.212 (15.99)***
l	-0.68 (-9.73)***	-0.141 (-3.626)***	0.038 (3.734)***
Innova(k-l)	-0.010 (-0.2293)	0.071 (2.302)**	0.118 (11.76)***
Innova (ktic-l)	0.002 (0.1587)	0.009 (0.595)	0.015 (2.211)**
Innova (lc-l)	-0.017 (-0.4081)	-0.058 (-1.626)	-0.064 (-5.307)***
Innova		-0.738 (-1.805)*	-1.510 (-10.69)***

Source: Author's own elaboration.
*Note: * Significant at 10%; ** Significant at 5%, *** Significant at 1%.*
Fixed effects model
Contrast of different intercepts per groups – Null Hypothesis: the groups have a common intercept. Contrast statistics: F(396.6) = 11.2364 with p value = P(F(396,6) > 11.2364) = 1.55586e-145.
Random effects model
- Breusch-Pagan contrast - Null Hypothesis: Variance of error specific to unit = 0. Asymptotic Contrast Statistics: Chi-square (1) = 490.194 with p value = 1.29312e-108
- Hausman Contrast – Null Hypothesis: the estimators of GLS are consistent. Asymptotic Contrast Statistics: Chi-square (7) = 122.045 with p value = 2.87296e-023

Table A.6
Estimations results: fixed effects, random effects and weighted least squares

Variable	Fixed effects	Random effects	GWLS
Constant	0.084 (4.12)***	0.120 (2.85)***	0.093 (8.41)***
dk-l	0.088 (1.12)	0.037 (0.718)	0.035 (2.27)**
dkTIC-l	0.024 (0.83)	0.026 (1.17)	0.030 (3.40)***
dlc-l	0.033 (0.38)	0.025 (0.37)	0.032 (1.50)
dl	-0.911 (-8.06)***	-0.879 (-10.02)***	-0.939 (-19.98)***
dN(k-l)	-0.096 (-0.11)	-0.058 (-1.29)	-0.044 (-2.56)**
dN(ktic-l)	-0.004 (-0.19)	-0.009 (-0.55)	-0.009 (-1.52)
dN(lc-l)	-0.054 (-0.99)	-0.037 (-0.84)	-0.037 (-2.06)**
N		-0.026 (-0.86)	-0.006 (-0.65)

Source: Author's own elaboration.
*Note: * Significant at 10%; ** Significant at 5%, *** Significant at 1%.*
Fixed effects model
Contrast of different intercepts per groups – Null Hypothesis: groups have a common intercept. Contrast statistics: F(265.275) = 1.1066 with p value = P(F(265.275) > 1.1066) = 0.202673.
Random effects model
- Breusch-Pagan contrast - Null Hypothesis: Variance of error specific to unit = 0. Asymptotic Contrast Statistics: Chi-square (1) = 7.23672 with p value = 0.00714274.
- Hausman Constrast – Null Hypothesis: the estimators of GLS are consistent
Asymptotic Contrast Statistics: Chi-square (7) = 2.72639 with p value = 0.909108.