

ICT effects on firm's export decisions: evidence for Colombian manufacturing

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Abstract. The objective of this work is to explore the impact of ICT (using several indicators) on the firm's export decision for Colombian manufacturing. To study this decision, we specify a model that accounts for sunk costs, firm previous experience in exporting and the impact of importing on exporting, and we estimate a dynamic (panel data) discrete model for the decision to export. To undertake this study, we merge three data bases at the firm level for Colombia: the Annual Manufacturing Survey (EAM), the Technological Development and Innovation Survey (EDIT) and the Annual ICT Manufacturing Survey (EAM-TIC), for the period 2013-2016. The results we obtain, show that ICT has a significant and positive impact on firm's propensity to export, regardless the ICT category examined. Our work also confirms the existence of persistence on firm's exports, self-selection, and depreciation of export experience. This evidence contributes to the scarce empirical literature on this topic for emerging economies, such as Colombia.

Keywords: ICT, Exports, Self-Selection, Panel Data, Emerging Economies.

JEL Classification: L16, L96, F14, C23, D22.

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Acknowledgements. We are grateful to the editor and two anonymous referees for their comments and suggestions. We also thanks to Jovanna Correa (DANE, Cali-Colombia) for the constant support to obtain the database.

1. Introduction.

Information and Communication Technologies (ICT) are those technological tools used to improve communications within institutions and firms, as these facilitate to transmit, store, create, share or exchange internal and/or external information. Thus, these technologies might have crucial effects on firms as they would help to boost productivity, gain efficiency, increase market share and profitability, improve organizational changes, and develop new forms of access to knowledge. Further, they might also be used to store, process and transmit information that generates new knowledge and improves coordination and communication across production lines and customers (Pita, 2018; DeStefano et al., 2018). As a direct consequence, these positive effects would strengthen firms competitiveness in local and international markets (Li et. al., 2022), what would enhance firms to participate in international markets.

The literature that studies the effects of ICT on firms internationalization activities is quite new both for developed and developing economies. In the particular case of the ICT-export link for developed economies, for example, Hagsten and Kotnik (2017) analyse it for the United Kingdom, Italy and France, and Añon and Bonvin (2019) carried out the analysis for Spain. In both studies, the results point to a positive effect of ICT on exports. In emerging countries, such as those in Latin America, this issue is scarcely explored. Among the scant studies, Mathews and Bianchi (2010), that study the case of Chile, find that ICT play a relevant role on firms exports. In the case of Colombia, as many other emerging countries, this topic remains unexplored.

In relation to ICT, the creation of the Ministry of ICT in 2009 fostered the ICT adoption in Colombia, especially among SMEs. And, there is evidence of an increasing use of ICT for exporting activity in Colombian manufacturing, especially among SMEs (that represent the 91% of the industry).¹ In addition, the manufacturing exporting activity has increased in the last two decades after trade liberalization. These facts indicate the relevance of exploring the link between the use of ICT and exporting activity in Colombia. And this is the main objective of this work.

¹ https://www.dane.gov.co/files/investigaciones/boletines/tic/pres_tic_empresas_2016.pdf

To examine whether ICT adoption affects the firm's exporting decision in Colombian manufacturing, we use firm level data obtained by merging three data sets: the Annual Manufacturing Survey (EAM), the Technological Development and Innovation Survey (EDIT), and the Annual ICT Manufacturing Survey (EAM-TIC) published by the National Administrative Department of Statistics (DANE) from 2013 to 2016.² The empirical model we specify to study this decision, would account for sunk costs, firm previous experience in exporting and the impact of importing on exporting. We estimate this model we use a dynamic random effects discrete model.

Our contribution to the empirical literature is threefold. First, we contribute to the scarce empirical literature on this topic for developing economies, such as Colombia. Second, we consider some key novel aspects on the firm's export decision: the effects of import experience on export propensity; besides we explore the impact of sunk costs and the initial conditions problem to capture the possible correlation between unobserved individual heterogeneity and past export decisions. Moreover, we include the depreciation pattern of export experience to capture the depreciation pattern on initial export sunk costs. Third, we uncover that all the ICT categories considered have a positive and significant impact on the firms' decision to export. Specifically, the strongest impacts are obtained by those ICT that ease the external communication of the firms and by those related to internal firm's communication.

The rest of the paper is organized as follows. In section 2 we provide a review of the empirical studies for Latin America and Colombia. In section 3 we present the data and some descriptive statistics. The empirical modelling and results are presented in section 4. Finally, section 5 concludes.

2. Literature review.

The ICT-export link can be explained through two channels. A direct channel, that suggests that firms use basic ICT (such as the Internet and/or website) to establish commercial relationships with their clients. And an indirect channel, that operates through the import-export linkage: firms that use ICT related to their importing activity (to find or

² We are unable to consider a longer period of analysis given that the information in EAM-TIC starts in 2013.

contact suppliers, to share information or buy abroad) gain experience in international markets that would facilitate their future exports. (Gómez, Máñez and Sanchis, 2022).

There are two main approaches in the empirical literature on the ICT-export link: the macroeconomics evidence and the microeconomics one. As regards the macroeconomic studies, many of the works aim at testing the “productivity paradox” (that hypothesises that ICT have no impact on countries’ productivity; Solow, 1987). The studies that analyse this paradox include Brynjolfsson (1993), Loveman (1994), Oliner et al. (1994), Berndt and Morrison (1995); Gordon (1999), Jorgenson et al. (2008) or Acemoglu et al. (2014), among others. All of these works find supporting evidence on the existence of the paradox. Other macroeconomic studies use international trade gravity models to explore the effect of ICT on countries international trade (Rodríguez-Crespo and Martínez-Zarzoso, 2019; Xing, 2018; Wang and Li, 2017; Yushkova, 2014; among others). And the results of this group of studies uncover the existence of positive impacts of ICT on international trade.

Wang and Li (2017) research whether the different levels of ICT (internet and broadband), for the countries analysed, enhance a comparative advantage in international trade. Yushkova (2014) estimates the impact of the use of internet for commercial purposes on exports for 40 countries (including Brazil). Clarke and Wallsten (2006), investigate the effect of internet penetration on exports going from developing countries to developed ones (including some Latin American countries as Colombia). In the case of emerging economies, Ahmad et al. (2011) study the influence of ICT (telephone subscribers, personal computers and internet users) on the international trade of Malaysia with 36 countries. As before, all the studies show significant effects of ICT on international trade. In the same vein, and for Latin American countries, Rodríguez-Crespo and Martínez-Zarzoso (2019), Vemuri and Siddiqi (2009), uncover that the ICT elements (such as internet, telephones or PCs) have a positive effect on international trade.

The empirical literature that analyses the relation between ICT and exports at the firm level is scarce and basically focuses on developed economies. Hagsten (2015) explored the impact of website, broadband and e-sales on the propensity to export for manufacturing and services firms in 11 European countries. The results show that all the ICT components considered had a positive effect on firm’s export decision for most of the countries

analysed. In a similar study, Hagsten and Kotnik (2017) explore the linkages between website, e-sales, broadband internet and ICT human capital and the propensity to export and export intensity for SMEs belonging to 12 European countries. The results they obtain reveal positive effects for most of the countries analysed. Finally, Añon and Bonvin (2019) explore the relationship between website and online trade, and the decision to export (and export intensity) for Spanish manufacturing firms. Their results suggest that firm's ICT usage increases the likelihood to export but not the export intensity. However, they further analyse the impact of ICT using a break down by the level of digitalization among sectors. Their analysis reveals that in high-digitalized sectors ICT boost export intensity, a result not confirmed for the low-digitalized sectors.

As far as we know, there are only a couple studies for Latin America countries. Mathews and Bianchi (2010) examine the relationship between internet usage and internet marketing with exports in Chilean manufacturing and service firms. Their results suggest a positive effect between ICT and exports. Further, the Economic Commission for Latin America and the Caribbean (CEPAL) compiles a set of descriptive studies that explores if information technologies applications used by SMEs fostered trade promotion. For Brazil (Botelho and Tigre, 2005) find positive results, meanwhile Ueki (2005) for Chile and Rodríguez Rodríguez (2005) for Argentina do not find evidence of this relationship.

3. Data and descriptive statistics.

To determine the impact of ICT on international trade, we merge three Colombian databases, from 2013 to 2016. We use four waves of the Annual Manufacturing Survey (EAM) and the Annual ICT Manufacturing Survey (EAM-TIC) (2013-2016) and two waves of the Technological Development and Innovation Survey (EDIT) (EDIT VII, 2013-2014 and EDIT VIII, 2015-2016), to obtain an unbalanced panel data of four years (2013-2016) with 30,381 observations corresponding to 10,094 firms.

Firms ICT variables are captured by a set of dichotomous variables reported in the EAM-TIC survey. In particular, we have the use of electronic devices, optical fiber, the use of intra and extranet, other different internet uses and the broadband and LAN internet connection. We do not focus on the traditional ICT measures used in previous studies, such

as internet or website, as we are more interested in those ICT that may potentially contribute to gain efficiency in the transmission of information in the export activity process.

Electronic devices include computers, laptops, tablets, cell phones, personal digital assistants (PDAs), and mobile capture devices. The optical fiber is the fiber-optic communications that allow firms to transmit information over longer distances using higher bandwidths than electrical cables. The intranet is the private network used by companies that use the internet protocol technology to securely share information, operating systems or computer services within an organization. The extranet is similar to the intranet, but allows sharing internal information with suppliers, buyers, partners, clients or any other business or organizations. Other different internet uses refers to sending or receiving e-mails, search for information on goods and services, official agencies and authorities, electronic banking and other financial services. It also refers to transactions with government agencies, customer services, online product distribution (delivery of products or services over the internet), personnel training, internal or external hiring, the use of applications for telephone calls or use of video conferences. Finally, broadband and LAN internet connection is defined as the usage of internet in one or more computers within a small and limited scope and with an intermediate connection speed (between 2 and 10 Mbps).

In Table 1 below, we present some descriptive statistics of the ICT variables for the different internationalisation strategies pursued by firms: firms only exporting, firms only importing, firms that export and import (two-way traders) firms that do neither of them (none).

Table 1. Firms internationalisation strategies and ICT.

	Devices	Optical Fiber	Extra/Intranet	Other internet uses	Broadband
Firms					
<i>Only-Exporter</i>	87.10%	58.00%	84.30%	42.60%	52.60%
<i>Only-Importer</i>	87.50%	58.00%	84.00%	41.20%	58.20%
<i>Two-way traders</i>	94.70%	70.20%	91.30%	57.10%	64.80%
<i>None</i>	72.40%	49.70%	76.90%	25.10%	47.50%

For the whole manufacturing Colombian industry, the figures show that regardless of the ICT element analysed, two-way traders are the firms that use ICTs more intensively. We observe that 94.7% and 91.3% use electronic devices and intra/extranet, respectively. Further, firms that only export or only import display similar usage of these technologies. Finally, non-trader firms (strategy none) have the lowest usage of ICT. This pattern found for all firms is replicated when we breakdown by firm's size (not shown in the table).³ Other variables like *market concentration* and *skills* show low figures as a typical emerging economy, where the number of SMEs are large and the labour skills are severely poor. It is worth mentioning that the mean of the depreciation pattern of sunk costs are decreasing over time.

4. Empirical specification.

In our specification, we consider that a firm decides to export in year t whenever the increase in gross operating profits associated to export plus the discounted expected future returns from being an exporter in t exceed sunk costs (Roberts and Tybout, 1997; Clerides et al., 1998). The rationale that motivates the consideration of sunk costs is that when firms decide to start/continue exporting they have to engage in some specific activities that are associated only to exporting, such as establishing marketing and distribution channels, exploring foreign demand and competition, learn about international taxation, and adapting the characteristic of the own product to meet foreign preferences and/or fulfil other countries quality and security legislation. All these activities are associated to sunk costs which the firm cannot recover in case it terminates exporting.

The existence of sunk costs associated to exporting entails that firms current export choices depends on past export choices. In order to consider this state dependence, we formulate the likelihood of exporting in terms of sunk cost (that we capture by firm's export status in year $t - 1$) and a reduced-form vector of variables proxying for the payoffs of

³ Table A2 of the Appendix, display the means and standard deviations of other variables that will be introduced in our specifications.

exporting. This vector of variables should capture firms' capabilities to obtain expected profits above the sunk costs associated to start/continue exporting. In this work, we will include in this reduced form vector a series of variables capturing firm ICT strategies (see Añon and Bonvin, 2019; or Hagsten and Kotnik, 2017; for similar approaches).

Therefore, we estimate the following dynamic discrete model for the decision to export, in which firm's export decision in period t is conditioned on the previous vector of state variables for that year:

$$dX_{it} = \begin{cases} 1 & \text{if } \gamma dX_{it-1} + \beta ICT_{it-1} + \delta Z_{it-1} + \sum_{j=1}^3 \phi_j \tilde{dX}_{it-j} + v_i + v_s + u_{it} \geq 0 \\ 0 & \text{Otherwise} \end{cases} \quad (1)$$

In specification (1), dX_{it} is a dummy variable that takes value 1 if firm i exported in year t and zero otherwise, and, the coefficient γ identifies the sunk cost of exporting; ICT_{it} is a vector of variables capturing firm i ICT strategy in t ; and, Z_{it} is a vector of control variables (labour productivity, firm's import intensity, a measure of industry concentration, proportion of skilled labour, whether the firm invest in R&D, firm's mark-up and wage per worker) that may affect firms' expected returns of exporting.⁴

It is important to note that including labour productivity will allow us to test for the hypothesis of self-selection/continuation of the more productive firms into exporting; and, including import intensity would allow to explore the potential links between exporting and importing suggested among others by Máñez et al. (2020). In this sense, the import experience and/or knowledge acquired with providers or about trade international legislation could help to boost exports as it would reduce the sunk costs that firms would have to incur to start/continue exporting. Finally, v_i is a vector of year dummies and v_s is a vector of industry dummies included to control for industry specific effects and for common macro conditions, respectively.

Furthermore, following Roberts and Tybout (1997), to consider the possibility of lower sunk entry costs for firms that restart exporting after j years without exporting, we include in estimation a set of dummy variables \tilde{dX}_{it-j} , which take value 1 if the last time

⁴ Table A1 of the Appendix, shows the description of the variables used in the model.

the firm exported was in year $t - j$ (in estimation we assume $j \leq 4$). Finally, it is necessary to account for the possible existence of unobserved factors that may affect the expected returns from exporting such as exports department abilities, managerial skills or product characteristics. With this aim, we assume that the error term, u_{it} , has two components: a firm specific effect (α_i) and a transitory component (ϵ_i), $u_{it} = \alpha_i + \epsilon_i$. Therefore, we consider two possible sources of serial correlation in u_{it} . Regardless of whether ϵ_i is independent across t , u_{it} will be always serially correlated because of α_i .

In the estimation of the panel data discrete choice model of the decision to export of equation (1), we control for correlated unobserved firms' heterogeneity using the approach proposed by Blundell et al. (1999). This approach implies making assumptions about the distribution of the unobserved effect (α_i) conditional on observed covariates and adopting a conditional maximum likelihood approach. Therefore, we model the distribution of α_i as:

$$\alpha_i = \delta_0 + \delta_1 \overline{dX}_{pre} + e_{it} \quad (2)$$

where \overline{dX}_{pre} is the pre-sample mean of the dependent variable. Blundell et al. (1999) suggest that the firms' permanent effect might be captured by the entry pre-sample mean of the dependent variable, which should act as a sufficient statistic for unobserved firm heterogeneity. Finally, e_{it} represents the error term which is assumed to be independent of the pre-sample mean of the dependent variable, the explanatory variables and the idiosyncratic error term of the main equation. Since, we use as the pre-sample period 2008-2012 and the explanatory variables in the export decision equation, equation (1), are lagged one period, we perform the estimation procedure for the period 2013-2016.⁵

Table 2 reports the estimation results for the export decision, equation (1). We estimate this equation using a random effects *probit* model in which we include pre-sample means of the dependent variable to capture firms unobserved heterogeneity. Due to the strong correlation between the ICT variables considered, we include them one by one in

⁵ We would like to note that experimenting with different pre-sample periods produced very similar results.

each specification to avoid multicollinearity. Our approach follows the empirical literature (see for example Añon and Bonvin, 2019; and, Vemuri and Siddiqi, 2009). Thus, we consider five different specifications depending on the proxy for ICT used. First, we specify the model using the variable *devices* (a dummy variable taking value 1 if the firm uses electronic devices and zero otherwise), see column 1. Second, the model is specified using a dummy variable taking value one if the firm uses *Optical fiber* (column 2). In the third specification we use a dummy taking value 1 if the firms uses *Extra/intranet* net (column 3). Fourth, the model is specified using a dummy variable taking value 1 if the firm makes *Other internet uses* (column 4). Finally, we specify the model using a dummy taking value 1 if the firm uses *Broadband* connection.

Table 2: Export propensity. Marginal Effects.

	Devices	Optical fiber	Extra/Intranet	Internet Uses	Broadband
dX_{it-1}	0.516*** (0.014)	0.521*** (0.013)	0.520*** (0.013)	0.522*** (0.013)	0.521*** (0.013)
$Devices_{it-1}$	0.032** (0.013)	-	-	-	-
$Optical\ fiber_{it-1}$	-	0.024*** (0.009)	-	-	-
$Extra/Intranet_{it-1}$	-	-	0.022* (0.012)	-	-
$Other\ Internet\ use_{it-1}$	-	-	-	0.015* (0.009)	-
$Broadband_{it-1}$	-	-	-	-	0.021** (0.009)
$Lab.\ productivity_{it-1}$	0.014** (0.006)	0.012** (0.006)	0.012* (0.006)	0.011* (0.006)	0.011* (0.006)
$Import\ intensity_{it-1}$	0.060*** (0.021)	0.060*** (0.021)	0.061*** (0.021)	0.060*** (0.021)	0.059*** (0.021)
$Concentration_{it-1}$	0.011*** (0.003)	0.011*** (0.003)	0.011*** (0.003)	0.012*** (0.003)	0.011*** (0.003)
$Mark-up_{it-1}$	-0.022** (0.009)	-0.020** (0.009)	-0.020** (0.009)	-0.020** (0.009)	-0.020** (0.009)
$Size_{it-1}$	0.028*** (0.007)	0.027*** (0.007)	0.028*** (0.007)	0.027*** (0.007)	0.027*** (0.007)
$Skill_{it-1}$	0.026*** (0.005)	0.026*** (0.005)	0.026*** (0.005)	0.026*** (0.005)	0.026*** (0.005)
$R\&D_{it-1}$	0.023** (0.011)	0.024** (0.011)	0.025** (0.010)	0.024** (0.011)	0.024** (0.011)
$Wages_{it-1}$	-0.019* (0.010)	-0.018* (0.010)	-0.018* (0.010)	-0.018* (0.010)	-0.018* (0.010)
\tilde{dX}_{it-2}	0.178***	0.177***	0.178***	0.178***	0.178***

	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
$d\tilde{X}_{it-3}$	0.120***	0.120***	0.120***	0.120***	0.121***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
$d\tilde{X}_{it-4}$	0.066**	0.080***	0.079***	0.080***	0.080***
	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)
\overline{dX}_{pre}	0.250***	0.250***	0.250***	0.250***	0.251***
	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)
Year/Industry	Yes	Yes	Yes	Yes	Yes
Number obs.	16,171	16,466	16,466	16,437	16,466

Notes:

1. Robust standard errors are in parenthesis.
2. ***, ** and * mean statistically significant at the 1%, 5% and 10% levels, respectively.

As for the estimates of the main variables of interest, all the variables used to proxy for ICT usage are positive and statistically significant. This indicates that ICT has a positive effect on the probability of exporting. Comparing the results of the specifications using the different types of ICT allows qualifying our results. Thus, the ICT variable with a higher impact on the likelihood of exporting is the use of different electronic *Devices* (column 1). Further, the ICT with the lowest impact is *Other internet uses* (column 5). The use of *Optical fiber* has a slightly higher effect on the likelihood of exporting than the use of *Broadband internet* and the use *Extra/intranet* (these last two ICT have a quite similar effect on the probability of exporting).

Comparing the different types of ICT, we can conclude that firms export decisions seem to be more affected by the use of those ICT that facilitate the firm's external communication than those related to internal communication.⁶ This is so, as we find that the highest impact comes from using electronic *Devices* (that are the hardware to communicate), followed by the use of *Optical fiber* (that allows to transmit information over longer distances) and the use of *Extra/intranet* (that permits to share internal and external information with customers, providers and others).

In general, our results are similar to those obtained by the recent literature in developed countries, such as Hagsten and Kotnik (2017) or Añon and Bonvin (2019),

⁶ According Leonidou et al. (2007), the external ICT are related with those oriented to link the firm with clients (like having website) or engaging in online transactions; while the internal ICT are related with those that depend on the internal environment of the firm, for example, the employees schooled in ICT.

where they find that the ICT (website, mostly) impacts positively on the decision to participate in export activities. Nevertheless, it should be noted that the variables that we use to capture ICT use are not the same as in these studies. As for the comparison to the other studies for Latin America, our results are in line with the findings of Mathews and Bianchi (2010), for Chile, where the ICT variable (internet marketing use) fosters firms exports. However, it should be noted that they use a different methodology and their database is a cross-section of firms and not a panel.

The estimates of our control variables are quite robust to the different specifications estimated. First, as suggested in previous studies, past export experience is a relevant determinant of current export participation (the estimate of dX_{it-1} is positive and statistically significant in all the specifications). Furthermore, the role of persistence in exporting is reinforced by the positive and highly significant effect of the pre-sample means (which capture their permanent effect through firms' individuals effect). Second an interestingly, the positive and decreasing estimates for the variables capturing past export experience (i.e., $d\tilde{X}_{it-2}$, $d\tilde{X}_{it-3}$, $d\tilde{X}_{it-4}$), suggests that export experience depreciates progressively. Firms that last exported four years ago are more likely to start exporting than firms which have never exported but are less likely to export than firms that last exported three years ago, and these are less likely to export than firms that last exported two years ago. Third, our results confirm the self-selection of previously more productive firms into exporting, either to start exporting or continuing exporting (the estimate for *Lab. productivity* is positive statistically and significant).

Fourth, previous import intensity has a positive effect on the likelihood of exporting. In line with the results in Máñez et al. (2020), this could be signalling that importing intermediates eases firms exporting activities. The positive effect of importing on the probability of exporting could happen through at least two channels. On the one hand, importers of intermediate inputs may have access to a wider range of intermediate inputs and/or higher quality inputs. Hence, they may profit from the diffusion and adoption of new technologies embodied in imported inputs, which can favour productivity enhancements and so foster export participation. On the other hand, when importing intermediates firms may have access to superior quality inputs with superior embodied technology. The

incorporation of these inputs into the production process may result in higher quality products which are easier to sell in international markets.

Fifth, our results also suggest that larger firm, firms with a higher proportion of high-skilled workers and firms that perform R&D are more likely to export. Very likely, larger firms are better endowed to face the costs associated to exporting. An important factor related to size that can help overcome exporting costs is that larger firms may have easier access to external financial resources than SMEs. Máñez and Vicente-Chirivella (2020) find that large firms have better financial profiles than SMEs. The positive and significant estimate of the variable measuring the proportion of high-skilled workers points out the relevance of human capital as a factor determining the ability to export of Colombian manufacturing firms. The positive relationship between R&D performance and exporting could arise from the fact that innovative firms produce higher quality products which are easier to sell international markets.

Finally, both the wage per worker and firm's mark-up have negative and significant impacts on the likelihood of exporting. Higher labour costs might imply higher prices if these costs are transferred to final prices, what reduces firm's competitiveness (Xiong and Zhang, 2016). Higher mark-ups also contribute to worsen firms' competitiveness in international markets making exporting more difficult. These results are not surprising if we consider that for very long the main source of competitive advantage in international market for an emerging economy as Colombian has been the low prices (Giraldo et al., 2015).

In general, the main results we have described above are in line with those obtained by the scarce literature (mostly for developed countries). The main result is that ICT usage boosts the probability to export, after controlling for an array of determinants. However, we should point out that our results are not directly comparable to the related literature as the ICT variables considered in this study are not the same as those used in previous studies.

5. Concluding remarks.

In this work we have investigated whether performing ICT activities fosters the probability to export for Colombian manufacturing firms. For that purpose, we use a sample of 30,380 observations corresponding to 10,094 firms provided by DANE, for the period 2013-2016.

From our main findings, we get that that all the ICT components considered have a positive and significant impact on the firm's decision to export. Further, we provide strong evidence that firms deal with sunk costs when decide to enter in international markets, what confirms that there is a self-selection process into exports activities. A third result we obtain is that import and exports activities are related, as importing fosters exporting. Finally, the inclusion of export depreciation experience shows that the cost of restarting to export increases with the number of years without exporting.

Despite these favourable results, we observe that Colombian industrial sectors show little improvements in terms of ICT adoption and, therefore, there is a long way to go. Although the basic ICT (electronic devices and internet) are widely spread among firms, as pointed out by [Ruiz \(2014\)](#), these are categorized as information technologies level 1; what implies that these serve almost exclusively for the firms' operating processes. The more advanced levels, such as level 2, that involve using online commercial transactions, have a low rate of participation in the industry. Finally, those related to level 3, used for the development of strategic planning and business intelligence, are practically non-existent.

Unfortunately for Colombia, the last two levels are those that seem to play a fundamental role in the internationalisation of firms. Thus, the outlook for the future is not clear for the Colombian industry because there is still a need to make the leap to incorporate cutting-edge ICT and thus gain competitiveness in international markets. This seems to be difficult, as firm's financial capabilities are limited and there is also a lack of recognition of the importance of the ICT in productive processes. Therefore, the government can play a key role in supporting the development of the digital economy, designing a regulatory framework accompanied by public policies that might help the adoption of these new technologies, especially among SMEs that represent the majority of the industry.

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Appendix.

Table A1. Variables description.

Exports (<i>dX</i>)	Dummy variable equal to 1 if the firm exports output, and 0 otherwise.
Devices (<i>Devices</i>)	Dummy variable equal to 1 if the firm uses any of the following ICT electronic devices: desktop computers, laptops, tablets, cell phones, electronic agendas or mobile capture devices, and 0 otherwise.
Optical Fiber (<i>Optfib</i>)	Dummy variable equal to 1 if the firm uses optical fiber, and 0 otherwise.
Extranet or intranet (<i>Extra/Intranet</i>)	Dummy variable equal to 1 if the firm uses extranet and/or intranet, and 0 otherwise.
Internet Uses (<i>Int. Uses</i>)	Dummy variable equal to 1 if the firm use internet: to send or receive emails; look for information on goods and services, official agencies and authorities, electronic banking and other financial services; to perform transactions with government agencies; for customer service; for online product distribution (delivery of products or services over the Internet); for personnel training, internal or external hiring; and uses applications for telephone calls over the Internet / VoIP or use of video conferences (Skype, etc.); and 0 otherwise.
Internet-Broadband-LAN (<i>Broadband</i>)	Dummy variable equal to 1 if the firm uses internet with broadband and LAN connection and 0 otherwise.
Labour productivity (<i>Lab. prod</i>)	Logarithm of value added per employee.
Import intensity	Total purchases of intermediates abroad divided by the total purchases of the firm.
Market concentration (<i>Concentration</i>)	Logarithm of Herfindahl-Hirschman index.
Mark-up	Logarithm of output elasticity of materials divided by the revenue share lagged in one period. The revenue share is defined as the total cost of that input over firm's total output.
Size (<i>Size</i>)	Logarithm of number of employees.
Skill (<i>Skill</i>)	Proportion of high skill labour in the firm's labour force.
R&D investment (<i>R&D</i>)	Dummy variable taking value 1 if the firm invests in R&D activities, and 0 otherwise.
Labour wages (<i>Wages</i>)	Logarithm of the wage per worker.

Table A2. Descriptive statistics.

Variable	Mean	s.d.
<i>Exports (dX_{it-1})</i>	0.246	0.431
<i>Devices</i>	0.780	0.414
<i>Optical fiber</i>	0.539	0.498
<i>Extra/Intranet</i>	0.802	0.399
<i>Other Internet uses</i>	0.325	0.468
<i>Broadband</i>	0.511	0.500
<i>Labour productivity (log)</i>	10.42	1.060
<i>Import intensity</i>	0.071	0.192
<i>Market concentration</i>	0.001	44.43
		4
<i>Mark-up (log)</i>	0.614	0.583
<i>Size</i>	32.98	3.518
		6
<i>Skill</i>	0.128	2.519
<i>R&D investment</i>	0.173	0.378
<i>Wages (log)</i>	9.688	0.492

Source: Author's calculations and DANE.