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The impact of E-commerce on productivity: Firm-level evidence from Colombia

Gabriel Rodríguez-Puello
Universidad Tecnológica de Bolívar, Colombia.
Center of Entrepreneurship and Spatial Economics (CEnSE),
Jönköping International Business School, Jönköping University, Sweden.
grpuello@utb.edu.co

Yaneth Sands Lambraño
Universidad Tecnológica de Bolívar, Colombia.
ysands@utb.edu.co

Andrea Méndez-Rodríguez
Universidad Tecnológica de Bolívar, Colombia.
anmendez@utb.edu.co

Luna Castilla Castilla
Universidad Tecnológica de Bolívar, Colombia.
castillal@utb.edu.co

Abstract: The e-commerce usage of companies and consumers in different economic scenarios has positively modified global economic activity in recent years. This is important for companies since open-up new business opportunities, and enhances productivity, among other advantages. Nevertheless, most of these positive effects of e-commerce are found in the literature for developed countries, there is an existing gap for studies analyzing the impact of e-commerce on developing countries. The aim of this paper is to examine the impact of e-commerce on the productivity of manufacturing companies in Colombia, a developing country. To this end, we use a Panel dataset for Colombian manufacturing firms for the period 2016-2018. As a principal method, we take advantage of the panel data and use the system Generalized Method of Moments (GMM estimator). The main findings suggest a positive and significant impact of e-commerce on firms' productivity, robust to different measures of both variables. When analyzing observed heterogeneity in the results, we find that the impacts are concentrated in a few types of economic activities inside the manufacturing sector, and are also concentrated in SMEs and non-exporting firms, while for the large and exporting firms there is no impact.

JEL classification: L60, O30.
Keywords: E-commerce; Productivity; Manufacturing firms; Colombia.

Resumen: El uso del comercio electrónico por parte de empresas y consumidores en diferentes escenarios económicos ha modificado la actividad económica mundial durante los últimos años. Con este se abren nuevas oportunidades de negocio y de mejoras en la productividad, entre otras ventajas. Sin embargo, la mayoría de estos efectos positivos se ha documentado para países avanzados, por lo que existe un espacio importante en la literatura sobre su impacto en los países en desarrollo. Este trabajo examina el impacto del comercio electrónico en la productividad de las empresas manufactureras en Colombia. Para ello, utilizamos un conjunto de datos de panel para empresas manufactureras colombianas para el periodo 2016-2018. Como método principal, aprovechamos los datos de panel y utilizamos el estimador del Método de Momentos Generalizado. Los principales hallazgos sugieren un impacto positivo y significativo del comercio electrónico en la productividad de las empresas, robusto a diferentes medidas de ambas variables. Al analizar la heterogeneidad observada en los resultados, encontramos que los impactos se concentran en unos pocos tipos de actividades económicas dentro del sector manufacturero, y también se concentran en las PYMES y empresas no exportadoras, mientras que para las empresas grandes y exportadoras no hay impacto.
Clasificación JEL: L60, O30.
Palabras clave: Comercio electrónico; Productividad; Empresas manufactureras; Colombia.

1 Introduction

The electronic commerce (e-commerce) usage of companies and consumers in different economic scenarios has positively modified global economic activity in recent years. The implementation of e-commerce strategies is a phenomenon that has grown exponentially worldwide, for the case of countries that have data available, the OECE (2011) estimated that on average 13% of the total volume of business transactions is made via e-commerce. This is important for companies since generates several advantages, for example, e-commerce open-up new business opportunities for companies and generates commercial expansion. Additionally, the usage of e-commerce optimizes efficiency in the automatization of transactions, brings the company closer to its customers, reduces transaction costs and information costs, allows greater interaction between the company and its customers, and is expected to enhance productivity (Lucking-Reiley & Spulber, 2001; Garicano & Kaplan, 2001; Liu *et al.*, 2013; Atasoy, 2013).

Since the beginning of the 21st century, the term e-commerce has gained relevance, leading a wide variety of authors from different disciplines of study to try to define it. According to Liu et. al (2013), e-commerce is an evolutionary business model. Turban *et al.* (2001), define it as a tool that facilitates the purchase of goods or services in electronic media, including the process of customer service, i.e., it takes into account what is related to consumer satisfaction (Bharadwaj & Soni, 2007; Liu *et al.*, 2013). Lucking-Reiley & Spulber (2001) associate it with the replacement of labor activities by economic transaction processes, in which data, communications, and technology are involved, all using the Internet.

According to the literature, e-commerce increases the productivity of companies, by reducing transaction and information costs, and bringing firms closer to the customers. Nevertheless, most of these positive effects of e-commerce are found in the literature for developed countries, there is an existing gap for studies analyzing the impact of e-commerce on developing countries. Therefore, the aim of this paper is to examine the impact of e-commerce on the productivity of manufacturing companies in Colombia, a developing country.

As mentioned, the empirical and theoretical evidence focuses more on developed countries and relatively less on developing countries, as is the case of Colombia. Even with the fact that e-commerce is a recent and growing phenomenon in the world, the low quantity of available data makes it difficult to study, especially at the company level (UNCTAD, 2017). This makes it difficult to evaluate the e-commerce effectiveness in developing countries (Fraumeni, 2001), making this a contribution of this document. Specific features of companies in developing countries, like the level of the hierarchical structure or market potential, may affect the adoption of e-commerce and how it affects productivity. Therefore, we believe this study will serve to pave the way for the analysis of future research on the topic, especially in Colombia.

There are several studies that analyze the impact of e-commerce on different aspects of companies' performance. For example, household income (Luo & Niu, 2019), internationalization (Eduardsen, 2018), and employment (Atasoy, 2013; Biagi & Falk, 2017). Focusing on firm productivity, there are also some studies that analyze the effect of e-commerce on this topic (Bertschek *et al.*, 2006; Liu *et al.*, 2013; Sabherwal & Jeyaraj, 2015; Fernandes *et al.*, 2019). To mention a few, Selim (2008) finds that e-commerce improves the profit margin by improving operational efficiency and effectiveness. Bharadwaj & Soni (2007) affirm that e-commerce has become recently a factor that can guarantee the success of organizations in the highly competitive environment in which they find themselves. The authors find that, on average, small companies tend to implement e-commerce for productivity reasons (Bharadwaj & Soni, 2007). Poorangi *et al.* (2013) analyze the impacts of e-commerce implementation on SMEs and conclude that it reduces costs and optimizes productive processes.

We use a Panel dataset for Colombian manufacturing firms for the period 2016-2018 to achieve the main objectives of this paper. As a principal method, we take advantage of the panel data and use the system GMM estimator with lagged variables as instrumental variables. The main findings suggest a positive and significant impact of e-commerce on firms' productivity, robust to different measures of both variables. Additionally, we analyze the observed heterogeneity in the results, dividing the sample into groups, by economic sub-sectors, firm size, and exporting firms. The main results show that there is high observed heterogeneity across economic sub-sectors, where the impacts are concentrated in a few types of activities. At the same time, the positive main result is concentrated in SMEs and non-exporting firms, while for the large and exporting firms there is no impact.

The remainder of this paper is organized as follows. Section 2 outlines the data. Section 3 sketches the empirical strategy. The main results are presented in Section 4, and finally, Section 6 concludes.

2 Data

To analyze the relationship between e-commerce and productivity, we use the Colombian annual manufacturing survey (AMS), which is a longitudinal survey, provided by the National Administrative Department of Statistics (DANE) of Colombia. We use waves of 2016, 2017, and 2018, that include firm-level information on both e-commerce and productivity, for manufacturing plants. This survey covers all the plants with a minimum of ten employees, and has information on each plant's stocks of capital, industry, ownership structure, expenditure, labor, and sales, among other factors (see Roberts (1996) and Isgut (2001) for a detailed description of the data set).[1]

The AMS survey started in 1995 and is conducted annually, and its objective is to obtain basic information on the manufacturing sector. It is a census-type survey, meaning that has information on all manufacturing establishments in the country. We use waves of 2016, 2017, and 2018 since are the ones with information about e-commerce and ICTs. The selected sample for this study consisted of 24,437 plants. After dealing with missing values among the key variables, the final sample corresponds to 24,413 observations distributed across 23 Colombian departments, which let us with an unbalanced panel data set.

This survey contains several firm-level characteristics, but more importantly, it includes data regarding productivity and e-commerce. As a dependent variable in our study, we follow Liu *et al.* (2013) and define productivity as the value-added, measured by sales minus the sum of water, electricity, intermediate goods, and fuel expenses. This is the simplest indicator of productivity that our data allows us to compute, and its main advantage is its easy interpretation. As a robustness check, we use a second measure of productivity, which is the Solow-residual productivity measure (Solow, 1957; McCombie, 2000). According to the empirical literature, this indicator is more difficult to construct, and most fulfill several data and econometric properties (Kneip & Sickles, 2011). Additionally, according to Kneip & Sickles (2011) and Kniep *et al*. (2012), this measure fits panel data better, which is our case.

The key independent variable in the study is e-commerce. We measure it as the value of transactions made via e-commerce. In other words, the share of a company's sales made through a website or mobile application, excluding orders via traditional email. To measure this, respondents are asked the following question: "Of the total value of sales made by the company, without VAT, indicate the percentage of those that were made through electronic commerce, that is, by receiving requests for orders, and/or reservations of goods and services through an application or electronic platform, whether the form of payment has been online, cash or bank consignment. (Do not include canceled or unfulfilled orders or reservations, or sales made through email, fax, landline, or cell phone calls. Do not include sales made by staff through mobile devices – laptops, tablets, or cell phones – when serving customers personally)". As a robustness check, we also measure e-commerce as a binary variable that represents the

[1] It is important to note that, as happens in manufacturing surveys from other countries, the unit of analysis of this data set is the plant and not the firm.

decision of a company to adopt and use e-commerce, this variable allows us to compare the results with most existing literature (Bertsheck *et al.*, 2006; Bharadwaj & Soni, 2007).

Following Liu *et al.* (2013), we explain value-added (productivity) following the standard analytical approach and assuming the production function approximated by a Cobb-Douglas function. Therefore, we control for physical capital, labor input, and knowledge capital. The labor input is measured by the total number of employees, and knowledge capital is approximated by the e-commerce variable. Additionally, we control for ICT expenditure, as the company's expenditure on communication services and ICTs over the total expenditure. Finally, we control for the company market potential area, measured as the percentage of exports over the company's total sales (exports done directly or through intermediaries).

Table 1 reports the summary statistics, data description, and definition of variables. The mean and standard deviation are calculated using the unbalanced panel data for the 2016-2018 period. On average, 6.14% of the sales of the companies in the sample are made via e-commerce. Additionally, Table A.1 in the annex shows the sample distribution and e-commerce by Colombian departments. As expected, most of the sample is concentrated in Bogotá D.C (capital of the country), and the companies located in Bolívar have the highest share of sales through e-commerce (8.07%). Finally, Table A.2 in the annex shows the sample distribution and e-commerce by economic sectors.

Table 1: Variable's definition and summary statistics, 2016-2018

Variable	Description	Mean (SD)
Productivity	Value added ($COP)	11,130,661 (43,197,095)
E-commerce	Share of sales made through a website or mobile application, excluding orders via traditional email. (Between 0 and 100)	6.14 (17.21)
Capital	Stock of capital ($COP)	20,038,579 (165,000,000)
Employment	Total number of employees	88.51 (159.13)
ICT expenditure	Company's expenditure on communication services and ICTs over the total expenditure.	2.43 (3.42)
Market potential	Percentage of exports over the company's total sales (exports done directly or through intermediaries).	6.29 (16.58)
Sample size		24,119

Notes: Sample used in estimations.

3 Empirical strategy

We build on the standard analytical approaches assuming the production function approximated by a Cobb-Douglas function (Liu *et al.*, 2013), and estimate the following linear regression specification:

$$Ln(Y_{it}) = \beta_1 + \beta_2 Ln(cap_{it}) + \beta_3 Ln(lab_{it}) + \beta_4 ecomm_{it} + \beta_5 x'_{it} + \varepsilon_{it} \quad (1)$$

Where the dependent variable ($Ln(Y_{it})$) is the value-added in Napierian logarithms. The terms ($Ln(cap_{it})$) and ($Ln(lab_{it})$) are the physical capital and labor input (total number of employees), respectively, both in Napierian logarithms. The variable $ecomm_{it}$ is the main independent variable of interest and consists of the company's electronic commerce transaction. Finally, we include a vector of control variables (x_{it}), fixed effects by economic sectors, departments, and years, and a stochastic error term (ε_{it}). The subscripts i and t denote firm and year, respectively; and β_2, β_3, β_4, and β_5 are the parameters of concern, where β_4 shows the main expected result, the impact of e-commerce on productivity.

As mentioned in the previous section, we have a three-period panel data. As is common in the empirical literature with this kind of data, we allow in the estimations the existence of individual (firm) effects that are correlated with independent variables, in the form:

$$\varepsilon_{it} = \delta_i + u_{it} \quad (2)$$

Where δ_i is a firm-specific effect that can be understood as a fixed effect across firms, but not within a firm over time (unobserved heterogeneity across firms). And u_{it} is an error term known as "with noise".

When estimating this model, we need to address the potential problem of endogeneity in the adoption and use of e-commerce (Bertschek *et al.*, 2006). For example, we do not observe all the firm characteristics that affect the choice of adopting e-commerce, therefore, there may be unobserved characteristics in the error term biasing the results. To deal with this empirical issue, the literature suggests following an instrumental variables approach. We follow the common literature and take as a base the GMM estimation method for the linear panel data model. Which estimates the first-difference transformation of the equation, using the lags of all variables as instruments. This approach controls all the time-invariant characteristics of the firms. Nevertheless, according to Blundell & Bond (1998), this method results in imprecise estimates when the panel data have a small number of time periods, as is our case.

Therefore, Arellano & Bover (1995) and Blundell & Bond (1998) developed the system GMM, an estimator based on an augmented system. This method, in addition to the previous one, includes level equations with lagged differences as instruments (Liu *et al.*, 2013). The previous empirical literature has shown that this approach performs better than the GMM estimator (Blundell *et al.*, 2001; Badinger 32, 2004).

An additional problem that needs to be addressed is the potential sample selection bias, since the adoption and use of e-commerce may not be a random process. We use the Heckman (1979) correction by estimating a selection equation that controls for the elements that affect the company's decision to adopt or not e-commerce. We use a dummy variable as the dependent variable takes the value of one if the company adopts e-commerce, and zero otherwise. Taking Bertsheck *et al*. (2006) and Bharadwaj & Soni (2007) as a base, we use the following independent variables: market potential, the use of the internet looking for information on goods and services, the use of the internet looking for information on the government; online customer services, online transactions with government, online financial services, online delivery of goods and services, employees receive capacitation on ICTs, online hiring of employees, the use of apps, and online calls.

Due to the discrete nature of the dependent variable, the probit model is used as an estimation method. With this estimation, we can obtain the inverse of the Mills ratio:

$$\lambda_i = \frac{\phi(Z_i)}{1 - \Phi(Z_i)} \qquad (3)$$

Where $\phi(Z_i)$ and $\Phi(Z_i)$ are the density function and cumulative distribution, respectively, for a variable that follows a normal distribution. Therefore, the expression $\Phi(Z_i) = \Pr(Z_i = 1|s_i)$ is a function of the probability that a company adopts e-commerce depending on the independent variables included. We incorporate this inverse of the Mills ratio as a regressor on the estimations, this allows us to control for the probability to adopt e-commerce and correct the selection bias in the estimates. Table A.3 in the annex shows the descriptive statistics for the variables included in this estimation and the probit model results. As can be seen, 21% of the sample adopt and use e-commerce, and most variables are highly significant in the e-commerce adoption equation.

4 Results

Table 2 presents the main results on the impact of E-commerce on productivity, for the period 2016-2018 using the System-GMM estimation method. Column (1) includes the continuous measure of e-commerce, while column (2) shows the robustness check and includes the dummy measure. Finally, columns (3) and (4) are robustness checks where we use the Solow residual productivity measure as a dependent variable. In all columns, we include the control variables described in section 2 and in Table 1.

The results shown in column (1) Table 2 are the benchmark model, where we analyze the impact of e-commerce (share of sales made through electronic commerce) on the productivity (value-added) of firms. As can be seen in Table 2, e-commerce has a positive and significant impact on productivity at the 1% statistical level. This result suggests that e-commerce does contribute in a positive way to promoting the productivity of Colombian firms. As expected, this result is consistent with previous literature, for example, for United States firms (Goss, 2001), European firms (Bertschek *et al.*, 2006), and Taiwanese firms (Liu *et al.*, 2013).

As can be seen in column (1) the effect does not seem large (0.002), this suggests that there is space to increase productivity in Colombian firms by investing in e-commerce and enhancing the usage of activities related to electronics (Liu *et al.*, 2013). As the literature affirms, the adoption and usage of e-commerce generate many external benefits, like cost savings, reorganization of firms, automation of transactions (Litan & Rivlin, 2001; Lucking-Reiley & Spulber, 2001), and expansion of sales via better client proximity, among others (Atasoy, 2013). These benefits may not be well represented in the productivity statistics and combined with the actual small percentage of e-commerce transactions on Colombian firms, there is an enormous potential for a higher impact of e-commerce on future economic growth (Fraumeni, 2001; Liu *et al.*, 2013).

Regarding the rest of the control variables, the results for both the capital and labor factors have the expected positive sign and are statistically significant at the 1% level, with total employment showing a higher effect on productivity than capital, a result also found by Liu *et al.* (2013) for the case of Taiwanese firms. The result for ICT expenditure has the negative expected sign and is statistically significant at the 1% level. Finally, the market potential control variable shows the expected positive effect on productivity and is statistically significant at the 1% level. According to the literature, the greater a firm degree of internationalization (share of exports on total sales), the greater its market area or potential, and therefore, the greater the impact we expect on productivity (Ottaviano & Pinelli, 2006; Holl, 2012).

We use the dummy variable as a proxy for e-commerce in columns (2) and (4) of Table 2 to be able to directly compare our results with most previous existing studies (Bertsheck *et al.*, 2006; Bharadwaj & Soni; 2007). This dummy variable, as explained in section 2, takes the value of 1 when the firm adopts and uses e-commerce, and 0 otherwise. As can be seen in column (2) of Table 2, and in line with the principal result, e-commerce has a positive and significant impact on productivity at the 1% statistical level, suggesting that e-commerce does contribute in a positive way to promoting the productivity of manufacturing firms in Colombia. Bertsheck *et al.* (2006) analyze the impact of e-commerce on labor productivity for German firms and measure e-commerce as a dummy variable. The authors find a positive relation, where firms using B2B e-commerce employ their input more efficiently than non-users.

Finally, as a robustness check, we use a second measure of productivity as a dependent variable in the estimations, which is the Solow-residual productivity measure. These can be seen in columns (3) and (4) of Table 2. As in Liu *et al.* (2013), when comparing the main result (effect of e-commerce on productivity), the result is very similar and robust. In other words, the coefficient of e-commerce is positive and statistically significant, giving more evidence of the positive association between e-commerce and productivity at the firm level in the Colombian case.

Table 2: System GMM Estimates. Impact of E-commerce on productivity, 2016-2018

Dependent variable:	Value-added	Value-added	Solow residual	Solow residual
	(1)	(2)	(3)	(4)
	B / SE	B / SE	B / SE	B / SE
E-commerce	0.002***		0.003***	
	(0.001)		(0.001)	
E-commerce (dummy)		1.764***		1.772***
		(0.210)		(0.187)
Log(capital)	0.249***	0.244***	-0.023**	-0.028***
	(0.009)	(0.009)	(0.009)	(0.009)
Log(employment)	0.890***	0.881***	-0.033**	-0.043***
	(0.015)	(0.015)	(0.014)	(0.143)
ICT expenditure	-0.030***	-0.029***	-0.044***	-0.043***
	(0.003)	(0.003)	(0.003)	(0.003)
Market potential	0.006***	0.006***	0.008***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)
Lambda	-0.023	-1.101***	-0.018	-1.087***
	(0.018)	(0.133)	(0.015)	(0.117)
Constant	7.616***	6.724***	8.649***	7.765***
	(0.096)	(0.143)	(0.098)	(0.132)
Department Dummies	Yes	Yes	Yes	Yes
Economic sector Dummies	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
Observations	24,119	24,119	24,119	24,119

Notes: The models were estimated by System GMM procedure with the value-added (productivity) as a dependent variable. Standard errors (in parentheses) are clustered by company. p < 0.1; **p < 0.05; ***p < 0.01.

We repeat the previous estimations for each of the 22 economic sub-sectors inside the manufacturing sector available in our data to analyze the observed heterogeneity on the impact of e-commerce on productivity across types of economic activities. In this case, we use the value-added measure of productivity and the share of total sales made through e-commerce as the main independent variable. All models include all the control variables described in previous sections, and department and year dummies. As can be seen in Table 3, there is high observed heterogeneity across economic sub-sectors in the impact of e-commerce on productivity, where the impacts are concentrated in a few types of activities. The highest positive and statistically significant effect of e-commerce on productivity is experienced by the manufacturing firms located in the economic sub-sector *wood processing and manufacture of wood and cork products; except furniture; manufacture of basketry and esparto weaving (s16)*. While for the sector *leather tanning and retaining; shoe manufacturing; manufacture of travel articles, suitcases, handbags and the like, and manufacture of saddlery; fur dressing and dyeing (s15)* the impact of e-commerce on productivity is negative and statistically significant. These results suggest a high degree of heterogeneity among

economic sectors, which may have specific observed and unobserved characteristics affecting the impact of e-commerce on their productivity levels, this aspect need more research in the future.

Table 3: System GMM Estimates. Heterogeneity on the impact of E-commerce on productivity (value-added) by economic sub-sectors, 2016-2018

Economic sector in the estimation	1 E-commerce B / SE	2 Observations N
Manufacture of food products (s10)	0.003**	4421
	(0.001)	
Manufacture of beverages (s11)	-0.007	322
	(0.008)	
Manufacture of textile products (s13)	0.008***	786
	(0.002)	
Clothing making (s14)	0.002	2513
	(0.002)	
Leather tanning and retaining; shoe manufacturing; manufacture of travel articles, suitcases, handbags and the like, and manufacture of saddlery; fur dressing and dyeing (s15)	-0.009**	973
	(0.004)	
Wood processing and manufacture of wood and cork products; except furniture; manufacture of basketry and esparto weaving (s16)	0.013***	495
	(0.004)	
Manufacture of paper, cardboard and paper and cardboard products (s17)	0.002	407
	(0.005)	
Printing activities and production of copies from original recordings (s18)	-0.004	1218
	(0.003)	
Coking, manufacture of petroleum refining products and fuel blending activity (s19)	0.002	309
	(0.004)	
Manufacture of chemical substances and products (s20)	0.002	1641
	(0.003)	
Manufacture of pharmaceutical products, medicinal chemical substances and botanical products for pharmaceutical use (s21)	-0.003	557
	(0.005)	
Manufacture of rubber and plastic products (s22)	0.005***	1967
	(0.002)	
Manufacture of other non-metallic mineral products (s23)	0.005**	1455
	(0.002)	
Manufacture of basic metal products (s24)	-0.004	462

	(0.003)	
Manufacture of fabricated metal products, except machinery and equipment (s25)	0.000	1792
	(0.002)	
Manufacture of computer, electronic and optical products (s26)	0.002	31
	(0.008)	
Manufacture of electrical appliances and equipment (s27)	0.003	531
	(0.004)	
Manufacture of machinery and equipment n.c.p. (s28)	-0.007*	1115
	(0.003)	
Manufacture of motor vehicles, trailers and semi-trailers (s29)	0.004	495
	(0.003)	
Manufacture of other types of transport equipment (s30)	0.006	86
	(0.007)	
Manufacture of furniture, mattresses and bed bases (s31)	-0.001	1030
	(0.003)	
Other manufacturing industries (s32)	0.004	1513
	(0.003)	

Notes: The models were estimated by System GMM procedure with the value-added (productivity) as a dependent variable. Standard errors (in parentheses) are clustered by company. All models include all the control variables, and department and year dummies. p < 0.1; **p < 0.05; ***p < 0.01.

In Table 4 we continue analyzing the observed heterogeneity, this time by the size of the firms and exporting behavior. Columns (1) and (2) are estimations dividing the sample into large firms (employees greater than 200) and Small and medium-sized enterprises (SMEs), respectively. The results show that the positive impact of e-commerce on productivity found for the full sample of Colombian manufacturing firms is concentrated in SMEs, while for the large firms there is no impact. In the case of Taiwanese firms, Liu *et al*. (2003) find that the impact exists both for large firms and SMEs, but the influence is much larger for SMEs. Therefore, these results suggest that e-commerce is particularly important for SMEs in reducing their transaction costs and enhancing productivity. In columns (3) and (4) we divide the sample into exporting firms and non-exporting firms, where the exporting ones are those that have a percentage of exports over the company's total sales different than 0. As in the previous case, the results show that the positive impact found for the full sample is concentrated in non-exporting firms, while for the exporting firms there is no impact.

Table 4: System GMM Estimates. Heterogeneity on the impact of E-commerce on productivity (value-added), 2016-2018

Variables	1 Large firms B / SE	2 SMEs B / SE	3 Exporting firms B / SE	4 Non-exporting firms B / SE
E-commerce	0.001	0.002***	0.001	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
Log(capital)	0.356***	0.231***	0.342***	0.199***
	(0.031)	(0.010)	(0.018)	(0.010)
Log(employment)	0.776***	0.889***	0.737***	0.897***
	(0.059)	(0.017)	(0.030)	(0.017)
ICT expenditure	-0.057***	-0.031***	-0.037***	-0.029***
	(0.021)	(0.003)	(0.012)	(0.003)
Market potential	0.001	0.006***	0.001*	0.000
	(0.001)	(0.001)	(0.001)	(0.000)
Lambda	0.021	-0.034*	-0.020	-0.025
	(0.031)	(0.020)	(0.023)	(0.023)
Constant	6.726***	7.823***	7.339***	8.185***
	(0.386)	(0.106)	(0.192)	(0.116)
Department Dummies	Yes	Yes	Yes	Yes
Economic sector Dummies	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes
Observations	2,658	21,461	7,273	16,846

Notes: The models were estimated by System GMM procedure with the value-added (productivity) as a dependent variable. Standard errors (in parentheses) are clustered by company. p < 0.1; **p < 0.05; ***p < 0.01.

5 Conclusions

In this paper, based on a gap in empirical studies about the impact of e-commerce on productivity in developing countries, we examine the impact of e-commerce on the productivity of manufacturing companies in Colombia, a developing country. To meet this objective, we employed a panel dataset for Colombian manufacturing firms for the period 2016-2018, the survey is called the Colombian annual manufacturing survey (AMS), which is a longitudinal survey, provided by the National Administrative Department of Statistics (DANE) of Colombia. As a principal method, we take advantage of the panel data and use the system GMM estimator with lagged variables as instrumental variables.

The main results confirm a positive and significant impact of e-commerce on firms' productivity, robust to different measures of both variables. This result suggests that e-commerce does contribute in a positive way to promoting the productivity of Colombian firms. And as expected, the result is consistent with previous literature for United States firms (Goss, 2001) and European firms (Bertschek *et al.*, 2006). The effect does not seem large (0.002), this suggests that there is space to increase productivity in

Colombian firms by investing in e-commerce and enhancing the usage of activities related to electronics (Liu *et al.*, 2013).

Additionally, we analyze the observed heterogeneity in the results, dividing the sample into groups, by economic sub-sectors, firm size, and exporting firms. The main results show that there is high observed heterogeneity across economic sub-sectors in the impact of e-commerce on productivity, where the impacts are concentrated in a few types of activities. At the same time, the positive impact of e-commerce on productivity found for the full sample of Colombian manufacturing firms is concentrated in SMEs and non-exporting firms, while for the large and exporting firms there is no impact.

One of the main contributions of this study is to provide empirical evidence on a developing and lower-income country, where studies about e-commerce and its effects on firm performance are scarce compared with Europe and the USA. This is mainly because data available for this group of countries is limited, especially at the company level (UNCTAD, 2017). Also, it is important to highlight that these findings are valuable, not only for scholars, but also for policymakers—particularly in Colombia, a country where SMEs have a great potential to enhance efficiency and reach bigger markets with the right incentives. In this regard, the main results of this study suggest that a higher and more efficient allocation of incentives and inversion on electronic related activities for companies could create an environment of higher productivity of the manufacturing firms.

Although this study provides valuable empirical evidence, it is not without limitations. The main limitation is related to the data availability, as this longitudinal survey for Colombia only includes the electronic commerce and ICTs-related questions for three years, which precludes researchers from performing a panel data analysis for a longer time period. Additionally, the available data is only for manufacturing firms, excluding other relevant economic sectors with specific characteristics. In the following years, future studies should address these empirical tasks along with some additional analyses about the effect of e-commerce on productivity.

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Annex

Table A.1: Sample distribution and e-commerce by departments, 2016-2018

Department	Full sample Mean (SD)	E-commerce Mean (SD)
Antioquia	0.22 (0.41)	6.45 (17.49)
Atlántico	0.04 (0.20)	3.62 (13.39)
Bogotá D.C.	0.34 (0.47)	6.74 (17.70)
Bolívar	0.02 (0.13)	8.07 (19.82)
Boyacá	0.01 (0.10)	6.92 (18.53)
Caldas	0.02 (0.13)	3.60 (12.93)
Cauca	0.01 (0.10)	2.39 (9.64)
Cesar	0.00 (0.06)	3.04 (9.95)
Córdoba	0.00 (0.06)	4.10 (13.33)
Cundinamarca	0.08 (0.27)	6.61 (17.87)
Huila	0.01 (0.09)	6.34 (16.90)
Magdalena	0.01 (0.08)	3.18 (12.68)
Meta	0.01 (0.08)	6.69 (19.40)
Nariño	0.01 (0.08)	0.41 (3.09)
Norte de Santander	0.01 (0.12)	0.57 (5.68)
Quindío	0.01 (0.08)	4.98 (12.65)
Risaralda	0.02 (0.14)	5.82 (18.01)
Santander	0.05 (0.21)	4.19 (14.33)
Sucre	0.00 (0.05)	2.31 (7.61)
Tolima	0.01 (0.11)	5.26 (17.61)
Valle del Cauca	0.13 (0.33)	7.12 (18.97)
Casanare	0.00 (0.05)	7.59 (18.27)
Vichada	0.00 (0.05)	0.62 (2.00)

Notes: Sample used in estimations.

Table A.2: Sample distribution and e-commerce by economic sub-sectors, 2016-2018

Economic sector	Full sample Mean (SD)	E-commerce Mean (SD)
Manufacture of food products (s10)	0.18 (0.39)	6.63 (17.84)
Manufacture of beverages (s11)	0.01 (0.11)	1.53 (6.89)
Manufacture of textile products (s13)	0.03 (0.18)	6.25 (17.99)
Clothing making (s14)	0.10 (0.31)	5.90 (17.29)
Leather tanning and retaining; shoe manufacturing; manufacture of travel articles, suitcases, handbags and the like, and manufacture of saddlery; fur dressing and dyeing (s15)	0.04 (0.20)	4.62 (13.89)
Wood processing and manufacture of wood and cork products; except furniture; manufacture of basketry and esparto weaving (s16)	0.02 (0.14)	4.98 (14.30)
Manufacture of paper, cardboard and paper and cardboard products (s17)	0.02 (0.13)	5.89 (17.05)
Printing activities and production of copies from original recordings (s18)	0.05 (0.22)	8.11 (19.81)
Coking, manufacture of petroleum refining products and fuel blending activity (s19)	0.01 (0.11)	10.87 (28.86)
Manufacture of chemical substances and products (s20)	0.07 (0.25)	7.52 (19.02)
Manufacture of pharmaceutical products, medicinal chemical substances and botanical products for pharmaceutical use (s21)	0.02 (0.15)	11.16 (23.08)
Manufacture of rubber and plastic products (s22)	0.08 (0.27)	6.03 (16.45)
Manufacture of other non-metallic mineral products (s23)	0.06 (0.24)	3.80 (13.17)
Manufacture of basic metal products (s24)	0.02 (0.14)	3.44 (11.69)
Manufacture of fabricated metal products, except machinery and equipment (s25)	0.07 (0.26)	6.22 (17.07)
Manufacture of computer, electronic and optical products (s26)	0.00 (0.04)	9.84 (23.40)
Manufacture of electrical appliances and equipment (s27)	0.02 (0.15)	6.75 (17.88)
Manufacture of machinery and equipment n.c.p. (s28)	0.05 (0.21)	5.35 (16.10)
Manufacture of motor vehicles, trailers and semi-trailers (s29)	0.02 (0.14)	5.47 (15.83)
Manufacture of other types of transport equipment (s30)	0.00 (0.06)	9.27 (21.29)
Manufacture of furniture, mattresses and bed bases (s31)	0.04 (0.20)	5.45 (15.01)
Other manufacturing industries (s32)	0.06 (0.24)	5.53 (16.12)

Notes: Sample used in estimations.

Table A.3: Probit model for Heckman correction model on the probability of adopting e-commerce

	1 **Mean** (SD)	2 **Probit** B / SE
Decision to adopt e-commerce	0.21	
	(0.41)	
Market potential	6.29	-0.002***
	(16.58)	(0.001)
Use of the internet for information on goods and services	0.97	-0.055
	(0.16)	(0.073)
Use of the internet for information government	0.90	0.020
	(0.30)	(0.040)
Online customer services	0.87	0.483***
	(0.34)	(0.038)
Online transactions with government	0.83	-0.060*
	(0.38)	(0.031)
Online financial services	0.97	0.420***
	(0.18)	(0.081)
Online delivery of goods and services	0.28	0.391***
	(0.45)	(0.021)
Employees capacitation on ICTs	0.60	0.162***
	(0.49)	(0.024)
Online hiring of employees	0.44	0.166***
	(0.50)	(0.023)
Use of apps	0.82	0.209***
	(0.38)	(0.031)
Online calls	0.56	0.109***
	(0.50)	(0.023)
Constant		-2.119***
		(0.098)
Observations		24,413
Pseudo R-squared		0.069

Notes: The models were estimated by the ML procedure with the decision to adopt e-commerce as a dependent variable. *p < 0.1; **p < 0.05; ***p < 0.01.


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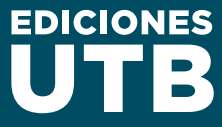
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