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ICTs Impacts on Trade:

A Comparative Dynamic Analysis for Internet, Mobile Phones and Broadband

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ERNESTO RODRIGUEZ-CRESPO
Department of Economic Structure and Development Economics
Autonomous University of Madrid
Ciudad universitaria de Cantoblanco
28049 Madrid Spain
e-mail: ernesto.rodriguez@uam.es
phone number: 0034914978490

ROCIO MARCO[1]
Department of Applied Economy
Autonomous University of Madrid
Ciudad universitaria de Cantoblanco
28049 Madrid Spain
e-mail: rocio.marco@uam.es
phone number: 0034914972899
fax number:0034914974676

MARGARITA BILLON
Department of Economic Structure and Development Economics
Autonomous University of Madrid
Ciudad universitaria de Cantoblanco
28049 Madrid Spain
e-mail: margarita.billon@uam.es
phone number: 0034914978777

[1] Corresponding author

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Abstract

We investigate the impact of internet use, mobile phones, and broadband on bilateral trade flows using a dynamic gravity model and panel data for 2004–2013. We find a significant and positive relationship between each type of ICT and bilateral exports, although the impacts vary depending on the type of technology. Our findings suggest that the effect of ICT use is larger for mobile phones and smaller for broadband. The impact on trade is greater for the exporter than for the importer. Mobile phones register the greatest effect for import countries in trade flows from high-income to low- and middle-income countries.

Keywords: exports, ICT, Internet, gravity model, digital divide, dynamic model

JEL Classification: F10, F14

1. Introduction

In the recent decades, the expansion of international trade has taken place together with the diffusion of information and communication technologies (ICT). According to the World Bank´s indicators the world export value multiplied almost by five during the period 2000–2013 (the 2013 export value index for the 2000 base period was 496%). In the same period, the percentage of total internet users grew from 6.8% to 38.0%, the mobile phone subscriptions per 100 people increased from 12.1 to 93.2 and the fixed broadband subscriptions per 100 people rose from 0.8 in 2001 to 23.3 in 2013.

The effects of ICTs on trade have been explored based on the role of the impacts that trade costs have on trade flows (Krugman 1980; Venables 2001). The transport costs associated with distance, information and communication costs and, in general, entry costs to new markets are considered as trade barriers that may affect opportunities for trade (Melitz 2003; Fink, Mattoo, and Neagu 2005). ICT usage may reduce the transaction costs associated with international trade operations (Venables 2001; Kauffman and Kumar 2008). In general, the use of these technologies may help firms to decrease their search, management and control, shipping and time costs (Venables 2001; Demirkan et al. 2009; Ahmad, Ismail, and Hook 2011). ICT and internet use, in particular, contribute to facilitating the access to and diffusion of information and knowledge about markets, products, suppliers and agents.

The academic literature has investigated how ICT use has different impacts on reducing the trade costs associated with the role played by geographical distance (Venables 2001; Kauffman and Kumar 2008; Bojnec and Fertö 2009). Some empirical studies, usually employing a gravity model framework, have explored the relationship between ICT use and trade and found a positive influence of ICT (Freund and Weinhold 2002, 2004; Clarke and Wallsten 2006; Vemuri and Siddiqi 2009). However, many of the available studies have referred mainly to internet hosts (Freund and Weinhold 2002, 2004; Clarke and Wallsten 2006; Liu and Nath 2013) and internet use (Bojnec and Fertö 2009). Other researchers have studied ICT´s impacts on trade using an ICT index (Marquez-Ramos and Martinez-Zarzoso 2005; Vemuri and Siddiqi; 2009). However, very few authors have compared the effects of several ICTs and most of them are referred to emerging and APEC countries. Furthermore, the evidence is far from conclusive.

Ahmad, Ismail, and Hook (2011) investigate the impact of mobile and fixed-line telephone subscribers and personal computer and internet users, but the study only covers trade flows between Malaysia and its 36 trading partners and the period from 1980 to 2008. The greatest effects are found for mobile and fixed-line telephone subscribers followed by personal computers and internet users. Chung, Fleming, and Fleming (2013) examine the impact of the use of the Internet, mobile telephones and fixed telephone lines on the bilateral flows of fruits and vegetables among APEC countries for the period 1997–2006. Although they identify a positive effect for internet use, they obtain the unexpected result that the greatest impact is due to fixed telephone lines, whereas no effect is found for mobile phones. Liu and Nath (2013), using panel data for 40 emerging market economies for the period from 1995 to 2010, investigate the growth of telecom investment, broadband, Internet subscriptions and Internet hosts. Their empirical results show that Internet subscriptions and Internet hosts have significant positive impacts on the export and import flows in the emerging economies selected. However, these authors do not investigate the effects of either mobile phone use or broadband subscriptions, and the study only refers to emerging countries.

In addition, many of the studies investigating ICT use in the previous decades have employed cross-sectional data (Freund and Weinhold 2002; Clarke and Wallsten 2006). Scholars who have used panel data (Bojnec and Fertö 2009; Liu and Nath 2013) covering both developed and developing economies have not differentiated the effects by type of technology or by income levels (Freund and Weinhold 2004; Bojnec and Fertö 2009; Vemuri and Siddiqi 2009). Finally, those studies using panel data have employed static models that do not take into account trade as a dynamic process.

As far as we know, there are no studies that compare the effects of various technologies on bilateral flows of goods for both developed and developing countries which simultaneously cover the most recent period of ICT diffusion while taking into account trade dynamics. The academic literature has demonstrated that ICT adoption and use shows technology- and country-specific diffusion patterns. According to Liu and Nath (2013), the nature of ICT as General Purpose Technologies (Bresnahan and Trajtenberg 1995; Helpman and Trajtenberg 1998) cannot be captured by any single technology. The cost reduction associated with the use of each technology is influenced by several factors, such as the trajectories of the diffusion process, the type and intensity of use in each case, trade specialization, and other features associated with the level of development (Clarke and Wallsten 2006; Demirkan et al. 2009; Vemuri and Siddiqi 2009).

First, this study investigates whether broadband, internet use and mobile phone subscriptions positively influence trade at the aggregate level. Second, the research aims to determine possible differences in impacts depending on the type of technology. Finally, we test the impacts according to country income levels. We use a gravity model approach with panel data for the period 2004–2013 for 55 countries.

The three technologies selected play a key role in international trade activities. Fixed broadband subscriptions enable us to investigate the impact of ICT infrastructure on trade, whereas internet users per 100 inhabitants and mobile phone subscribers capture the use of two technologies that show different diffusion patterns and characteristics of use across the developed and developing world. Fixed broadband is the necessary telecommunications infrastructure to benefit from most other ICTs. The use and diffusion of other ICTs depend increasingly on higher speeds and bandwidth. Broadband contributes to the creation of networks and the tradability of services (OECD 2008; Kneller and Timmis 2016). As bandwidth increases, new services can be traded, especially information-intensive ones, which are delivered over communication networks (Kneller and Timmis 2016). By facilitating access and use to information and knowledge in an easy, efficient and cheaper way, the internet impacts on transaction costs, favoring efficiency at different stages, for example, new digital marketing strategies. Firms that use the Internet may be more able to improve the quality of communication while reducing information and coordination costs (Freund and Weinhold 2002; Venables 2001). Internet use facilitates the creation of new communication channels, entry into new markets and the creation of new ones. At the same time, online platforms mean smaller firms can become exporters. Finally, mobile phones also reduce communication costs, facilitates interactions between trade agents, increase information about markets and open up new possibilities to use information more efficiently. In many developing countries, such as many African ones, mobile phone use has also generated particularly interesting impacts in rural areas, increasing information about basic products and so enabling the entry of small producers to new markets (World Bank 2016; UNCTAD 2017). In these countries impacts on trade might be associated to their use in informal economic sectors (Asongu and Nwachukwu 2016), in which a great bulk of the population cannot use mobile phones to browse the Internet (James 2014).

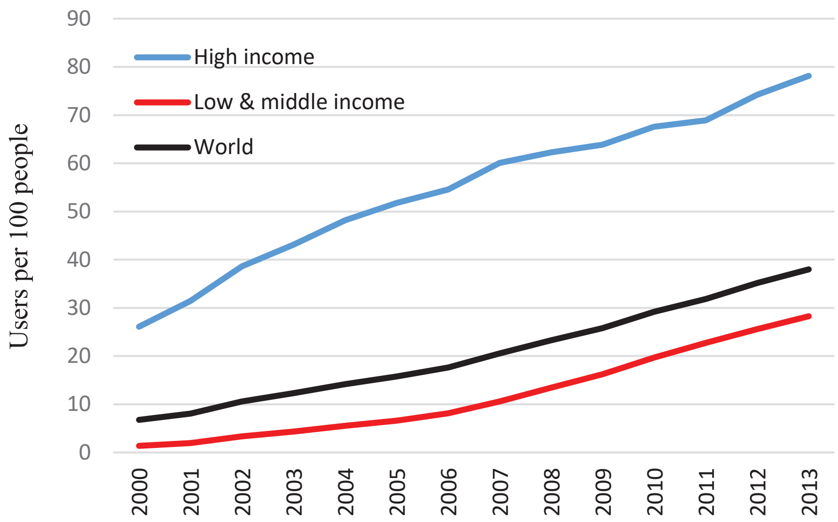
This paper contributes to the literature in various ways. First, it sheds light on the effects of ICTs on bilateral trade in the period of the greatest diffusion of three different technologies (2004–2013). Second, by disaggregating the analysis by the type of ICT and the income level, we provide new evidence about the trade relationships affected by ICT use. Third, by using a dynamic panel model, we overcome some methodological issues, such as omitted variable bias (Egger 2000), as we provide consistent estimates of the ICT impacts by taking into account the significant persistence of trade flows. In addition, we tackle endogeneity and reverse causality issues by using lagged variables as instruments and the generalized method of moments estimators.

The rest of the article is organized as follows. Section 2 shows some features of the current ICT diffusion process. Section 3 presents the research model and variables. Section 4 focuses on data and methodological issues. Section 5 assesses the proposed dynamic model specification, and section 6 presents the main findings of our research. We finish the paper with some conclusions and a discussion.

2. ICT diffusion: differences by types of technology and income levels

Technology diffusion is usually represented by s-shaped curves that show the evolution of technology adopters over time. In the period 2000–2013, a remarkable transformation occurred in ICT s-shaped curves.

The literature has demonstrated that, in addition to the technology-specific diffusion patterns, the ICT diffusion trajectories are country-specific. In fact, the ICT diffusion patterns appear to be associated with differences in income levels (Dewan, Ganley, and Kraemer 2005; Lechman 2015). Figure 1 shows the diffusion pattern for internet use in high-income and low- and middle-income economies according to the World Bank's indicators.

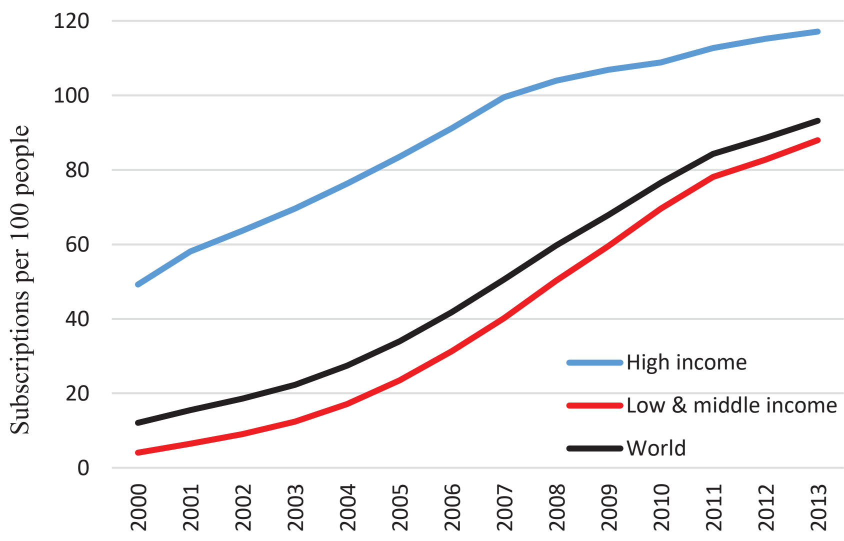


Source: World Bank data

Figure 1. Diffusion curve of internet users for the world, high-income countries and low- and middle-income countries

The percentage of total internet users grew from 6.8% in 2000 to 38.0% in 2013. This rate increased from 26.1 to 78.2 in high-income economies and from 1.4 to 28.3 in low- and middle-income ones.

Figure 2 presents the diffusion pattern for mobile phone subscriptions per 100 people, which grew from 12.1% in 2000 to 93.2% in 2013, at the aggregate level. The rate rose from 49.2% to 117.1% in rich countries and from 4.1% to 88.0% in low- and middle-income ones.

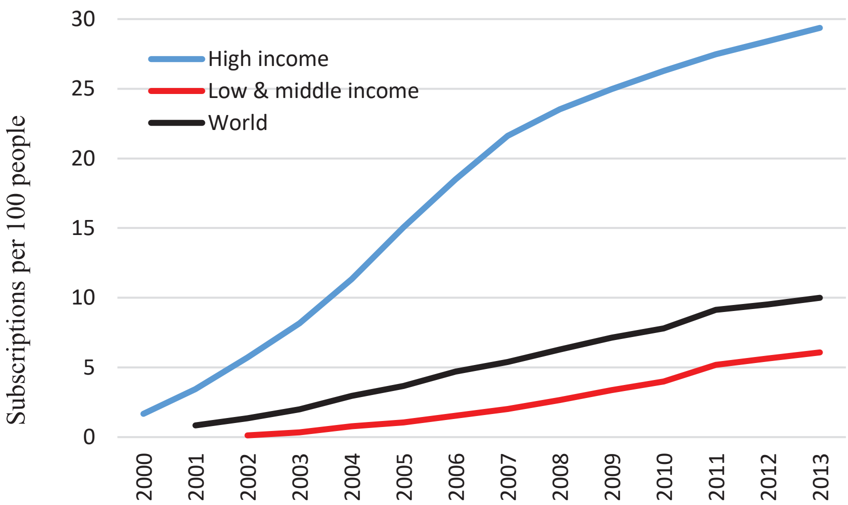


Source: World Bank data

Figure 2. Diffusion curve of mobile phone subscriptions for the world, high-income countries and low- and middle-income countries

In the case of the African countries, the fast growth in mobile phone subscriptions is remarkable. It is mainly associated with internet use, internet applications and public services (*Etransform* in Africa). According to James (2013), low-cost innovations are more likely to be expanded quickly and may exhibit higher growth rates in the final stages. The mobile phone diffusion in these types of countries is explained by the fact that many of them do not have access to a fixed telephone infrastructure. As for the type of use, the vast majority of mobile phone use is related to social interaction rather than business use, which is still very low (James 2014).

Regarding fixed broadband subscriptions, Figure 3 shows that the aggregate rate grew from 0.8% in 2001 to 23.3% in 2013. The broadband rate increased from 3.4% to 29.4% in developed countries in the 2001–2013 period and from 0.1% in 2002 to 6.1% in 2013 in developing countries.



Source: World Bank data

Figure 3. Diffusion curve of fixed broadband subscriptions for the world, high-income countries and low- and middle-income countries

These differences in ICT diffusion according to the types of technology and considering the differences in income levels justify the interest in investigating the impacts of several technologies on trade separately.

3. Research model and variables

Following the previous literature, the present research investigates whether ICT positively influences trade considering trade dynamics, differences in types of technology and country income levels. First, we test whether the use of the Internet, mobile phones and broadband shows a positive influence on bilateral trade flows. Second, taking into account the differences in ICT diffusion patterns, we aim to test whether ICTs' impacts on bilateral trade vary according to the type of ICT. Third, we investigate whether ICTs' impacts differ according to development levels.

We present as a baseline the standard gravity trade model usually used to investigate bilateral trade flows. Within this framework bilateral trade is assumed to be associated positively with country size and negatively with distance (Tinbergen 1962; Pöyhonen 1963; Anderson and Van Wincoop 2003). We propose an augmented gravity equation that includes the lagged bilateral exports and the ICT influence, so we define the dynamic gravity equation, in log-linear form, as follows:

$$\ln EXP_{ijt} = \beta_0 + \beta_1 \ln EXP_{ij,t-1} + \beta_2 \ln ICT_{i,t-1} + \beta_3 \ln ICT_{j,t-1} + \beta_4 \ln GDP_{i,t-1} + \beta_5 \ln GDP_{j,t-1} + \beta_6 RTA_{ij,t-1} + \beta_7 \ln DIST_{ij} + \gamma_t + \eta_{ij} + v_{ijt} \qquad (1)$$

where ln denotes variables in natural logs and subscripts i, j and t denote the exporter country, importer country and time, respectively. The dependent variable, EXP_{ijt}, represents the bilateral exports from country i to country j in year t. $ICT_{i,t-1}$ and $ICT_{j,t-1}$ are the one-year-lagged ICT usage in countries i and j, respectively. $GDP_{i,t-1}$ and $GDP_{j,t-1}$ are the one-year-lagged GDP at current PPP US$ of the exporting and importing countries, respectively. $RTA_{ij,t-1}$ is a one-year-lagged dummy included to capture whether *i* and *j* are both members of a regional trade agreement in year *t*, and $DIST_{ij}$ stands for the bilateral distance between exporter and importer countries.

The persistence of trade flows is captured by the lagged bilateral exports, $EXP_{ij,t-1}$. The ICT explanatory variable stands alternatively for internet users, mobile phone subscriptions and fixed broadband subscriptions per 100 people. In the next section, we elaborate on the selected measurements for ICT variables. We expect ICTs to be associated positively with exports due to lower entry market costs, such as those related to information, communication, shipping costs and management costs (Venables 2001; Freund and Weinhold 2004; Clarke and Wallsten 2006), as previously mentioned. Additionally, we take in account the potential endogeneity issues usually associated with trade models. First, we consider that the relationship between ICTs and exports might influence each other (reverse causality). Those countries that trade more are also those that register higher levels of ICT use (Freund and Weinhold 2002; Freund and Weinhold 2004; Clarke and Wallsten 2006; Bojnec and Fertö 2009). To avoid endogeneity problems, ICT usage is lagged by one year. Besides, the evidence confirms that the highest level of ICT usage corresponds to high-income countries. That would explain why some researchers consider the GDP to be treated as endogenous (Vemuri and Siddiqi 2009) and why it is also included in the model as a lagged variable. The academic literature takes into account the potential endogeneity associated with the effect of trade agreements on trade relationships (Baier, Bergstrand, and Feng 2014), given that countries concentrate on trade with those countries with which they currently trade (Krishna 2005). To capture this effect, control variables for trade agreements are usually included in gravity models (De Sousa 2012). We incorporate the trade agreement variables lagged by one year due to the potential endogeneity issue.

$DIST_{ij}$ is included as an explanatory variable in the basic gravity models (Tinbergen 1962), assuming that countries tend to concentrate on bilateral relations within nearby countries (Anderson and Van Wincoop 2003). Lastly, we include time effects γ_t to control for cyclical factors affecting all countries, while η_{ij} represents the unobservable bilateral country pair term and v_{ijt} denotes the idiosyncratic error term.

In sum, we incorporate the lagged bilateral trade to capture the dynamics of the trade flows, which allows us to control for the omitted variable bias. In this sense, having the lagged dependent variable on the right-hand side, we are also controlling for the time-varying component of the multilateral resistance term (Baldwin 2006), and thus country–time exporter and importer dummies are not included in the dynamic specification. Besides, we incorporate the one-year-lagged variables for ICT usage, GDP, and regional trade agreements to deal with the aforementioned endogeneity issues. As long as the error term is not serially correlated, the lagged endogenous variables are predetermined regressors. In this way lags naturally become the instrumental variables that allow us to identify the parameters.

4. Data and methodology

We use panel data covering the period 2004–2013 for 55 countries, 34 being high-income countries and 21 being low- and middle-income economies according to the World Bank's classification (list available in Table A1 in the appendix). The list of countries includes those with data availability for the full period from 2004 to 2013. Bilateral exports and countries' GDP are taken from the International Monetary Fund.

Unlike other previous studies that use ICT indexes elaborated by various institutions or those summarizing the information of several types of technologies to measure different dimensions of ICT adoption, we are interested in single variables that allow us to evaluate the differentiated impact of each technology on trade. For that purpose we employ three single ICT measures: Internet users per 100 inhabitants to capture internet use, broadband subscriptions per 100 inhabitants, and mobile phones per 100 inhabitants to capture the ICT infrastructure (ITU 2015). The selected variables are traditional indicators of technology diffusion that take into account the number of adopters (Comin and Mestieri 2014). They are taken from the World Bank and the ITU. We do not consider other possible measurements that are frequently used in early studies on ICT adoption, such as fixed telephone lines. The reason is that we aim to capture the effect of those technologies that are more directly associated with internet use and exhibit the highest diffusion rates in recent years, as is the case of mobile phones and broadband subscribers. Table A2 describes all the variables, units, and data sources.

The database is a balanced panel with some zero flows. Specifically, the database contains 623 observations with zero bilateral trade that affected 136 country pairs (4.7% of the pairs). After dropping these country pairs, the number of combinations of exporter and importer pairs is 2,753, giving a total of 35,789 observations. Table A3 shows the main descriptive statistics for all the variables as well as the slight differences in the main descriptive statistics between the full and the non-zero sample.

Working with panel data allows us to study the bilateral export process while taking account of both the dynamic effects and the unobserved heterogeneity across country pairs that are not detectable in cross-sectional analyses. However, some econometric issues arise in the estimation of a dynamic panel data model given that the compound disturbance ($\eta_{ij} + v_{ijt}$) in equation (1) will be correlated with the lagged dependent variable, $\ln EXP_{i,t-1}$. The OLS and GLS approaches are inconsistent in the pooled regression. Taking either first differences or orthogonal deviations controls for the unobserved bilateral effects, η_{ij}, as well as for exporter and importer country fixed effects and the potential source of bias due to time-invariant omitted variables. However, the correlation between the disturbance differences, ($v_{ijt} - v_{ij,t-1}$), and the lagged differences dependent variable ($\ln EXP_{ij,t-1}$ - $\ln EXP_{ij,t-2}$), persists. The general approach to solving the econometric problem relies on instrumental variables and on generalized method of moments (GMM) estimators (Arellano and Bond 1991; Arellano and Bover 1995). Once the country-pair term is removed from the model, a simple instrumental variables estimator is available. Lagged differences, lagged levels or both can be used as instrumental variables for the lagged differences dependent regressor. Arellano and Bover (1995) suggest a GMM estimator system in which the original equation in levels is added to the first-differenced equation. This "system GMM" estimator allows us to increase the efficiency by using a larger set of moment conditions that exploits all the available information in the sample. The same approach is extended to estimate consistently those variables that are not strictly exogenous in the model (potentially predetermined or endogenous regressors). Besides, the system GMM also makes it possible to provide estimates for time-invariant variables, as distance. The Stata/MP 13 software is used in the analysis.

In addition, the interpretation of the regression model changes when we move to a dynamic one. In a static specification, the explanatory variables represent the full set of information that produces the observed outcome, $\ln EXP_{ijt}$. However, in a dynamic specification, the complete history of the right-hand-side variables is now included in the equation through the lagged dependent variable. Any regressor influence is measured conditioned on this history, which implies that the impacts now represent the effect of new information (Greene 2012). Considering this, if trade is a dynamic process, a static specification may produce upward-biased estimates of the regressors' influence.

5. Impacts of ICT on trade: Dynamic gravity equation results

5.1 Analysis by type of ICT

The dynamic gravity model specification defined in (1) is applied to compare consistently the trade effects from different ICT measures. Table 1 displays the results for internet users per 100 people (Column 1), mobile phone subscriptions per 100 people (Column 2) and fixed broadband subscriptions per 100 people (Column 3). The dependent variable is the natural logarithm of bilateral trade flows. The lack of available broadband data for a majority of countries prior to 2004 explains the estimation of the three panel regressions in the 2004–2013 span for the sake of timing comparability. We incorporate the potential endogenous variables (*IU*, *GDP* and *RTA*) as one-year-lagged regressors to avoid endogeneity problems with respect to the time-variant error term, v_{ijt}. All the specifications include time fixed effects (γ_t). Time data transformations to control for the unobservable country pair heterogeneity term also control for any time-invariant variable. Therefore, exporter and importer fixed effects are absorbed in η_{ij} in the regression. The dynamic model is estimated using the system GMM estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998). Robust two-step estimates are provided.

Table 1 Results for different ICT technologies under the dynamic gravity equation

	Internet users	Mobile phones	Broadband
ln $EXP_{ij,t-1}$	0.703***	0.688***	0.717***
	(0.065)	*(0.075)*	*(0.063)*
ln $IU_{i,t-1}$	0.166***		
	(0.044)		
ln $IU_{j,t-1}$	0.101***		
	(0.029)		
ln $MOB_{i,t-1}$		0.230***	
		(0.075)	
ln $MOB_{j,t-1}$		0.002	
		(0.061)	
ln $BRB_{i,t-1}$			0.098***
			(0.025)
ln $BRB_{j,t-1}$			0.046***
			(0.016)
ln $GDP_{i,t-1}$	0.325***	0.354***	0.301***
	(0.072)	*(0.086)*	*(0.068)*
ln $GDP_{j,t-1}$	0.236***	0.251***	0.221
	(0.052)	*(0.060)*	*(0.050)*
$RTA_{ij,t-1}$	0.031	0.108***	0.037
	(0.025)	*(0.039)*	*(0.028)*
ln $DIST_{ij}$	-0.285***	-0.286***	-0.265***
	(0.065)	*(0.072)*	*(0.061)*
Constant	-8.220***	-9.072***	-7.009***
	(1.845)	*(2.196)*	*(1.564)*
Time effect	yes	yes	yes
Arellano-Bond AR(1) test	-9.11 [0.000]	-8.34 [0.000]	-9.42 [0.000]
Arellano-Bond AR(2) test	1.64 [0.101]	1.62 [0.105]	1.81 [0.071]
Hansen test	9.48 [0.342]	10.91 [0.451]	9.74 [0.554]
Observations	24,777	24,777	24,678

Time span: 2004–2013. Standard robust errors in parentheses. *, ** and *** denote significance at 10%, 5% and 1%, respectively. System GMM estimates for the dynamic panel data model. The dependent variable is the log-transformation of bilateral trade flows ($\ln EXP_{ijt}$).). All the specifications include time fixed effects (γ_t). The AR(1) and AR(2) Arellano–Bond tests assess no first- and second-order autocorrelation in the differenced residuals. The Hansen test assesses the validity of the instruments used in the system GMM estimation. The *p*-values of the tests are shown in brackets. The instruments are (*t-2*) and (*t-3*) lags of $\ln EXP_{ij}$, $\ln IU_i$, $\ln IU_j$, $\ln GDP_i$, $\ln GDP_j$ and RTA_{ij}.

No autocorrelation in the error term in levels is a necessary condition for the valid instrumentation. The Arellano–Bond tests for autocorrelation on the differenced residuals are reported. The differenced residuals present first-order but no second-order autocorrelation, which means no serial correlation in the disturbance term in levels. Consequently, the lags from (*t-2*) to (*1*) are valid for instrumenting the lagged dependent variable and the predetermined regressors. In most cases the model is overidentified, since there are more orthogonality conditions (instrumental variables) than parameters. Among all the available instruments, we use the (*t-2*) and (*t-3*) lags, since more distant lags will be weaker instrumental variables (Greene 2012). The robust Hansen test of over-identifying restrictions is reported. The null hypothesis is not rejected in the three regressions, confirming the validity of the instrument set. In sum, the system-GMM estimates are consistent and the dynamic specification of the gravity equation is validated by the data.

The first result that should be emphasized is that the lagged dependent variable is significant in all three specifications. This finding shows that past values determine current values of bilateral exports and confirms that, in a context of persistence, the implementation of a dynamic panel is appropriate. The magnitude of the persistence effect lies in a narrow range between 0.688 and 0.717.

The results evidence a positive and significant impact on trade from internet, mobile phones and broadband for the exporter country. We also find a positive and significant effect for the importer country in the case of the Internet and broadband, albeit lower than that for the exporter country. The impact of internet use in the exporter country on bilateral trade is 0.166, whereas the effect on the importer country is 0.101 (Column 1). In the case of mobile phones, the positive impact on bilateral exports (0.230) is only significant for the exporter country (Column 2). The results obtained for broadband elasticity are significant for both the exporter country (0.098) and the importer country (0.046) (Column 3), although they are more modest than the coefficients obtained for the Internet and mobile phones.

Regarding the rest of the variables included in the model, our results show a positive and significant impact of exporter and importer economic sizes, even when accounting for their potential endogeneity, with the exception of the importer country GDP for broadband (Column 3). Again, the elasticities to the exporter country size are larger than those to the importer country size. The distance coefficients, which are negative and significant for all the regressions, also corroborate the basic theory of gravity. In the case of RTAs, the results point to a positive influence of trade agreements to stimulate trade only for mobile phones (Column 2).

In sum, the findings obtained from the dynamic panel gravity model and the system-GMM estimation for the 2004–2013 period confirm the dynamic character of trade flows and the positive influence of the three types of ICT on bilateral trade flows, mobile phones being the technology that shows the greatest impact, particularly in the exporter country.

5.2 Analysis by development levels

Having analyzed the impacts of the Internet, mobile phones and broadband on bilateral exports for the whole sample we focus on investigating these effects disaggregating by income levels. Table 2 displays the results by income groups and types of technology.

Table 2 Results by income groups and types of technology considered for the analysis

Column	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Exporter	*High*	*High*	*Low and middle*	*High*	*High*	*Low and middle*	*High*	*High*	*Low and middle*
Importer	*High*	*Low and middle*	*High*	*High*	*Low and middle*	*High*	*High*	*Low and middle*	*High*
ln $EXP_{ij,t-1}$	0.871***	0.777***	0.752***	0.830***	0.797***	0.800***	0.863***	0.778***	0.750***
	(0.056)	*(0.129)*	*(0.105)*	*(0.063)*	*(0.129)*	*(0.097)*	*(0.061)*	*(0.129)*	*(0.108)*
ln $IU_{i,t-1}$	0.178**	0.279**	0.001						
	(0.077)	*(0.130)*	*(0.061)*						
ln $IU_{j,t-1}$	0.262**	0.142***	0.191						
	(0.108)	*(0.055)*	*(0.137)*						
ln $MOB_{i,t-1}$				0.257**	0.200	0.058			
				(0.112)	*(0.147)*	*(0.199)*			
ln $MOB_{j,t-1}$				-0.133	0.285***	-0.366			
				(0.135)	*(0.105)*	*(0.391)*			
ln $BRB_{i,t-1}$							0.085**	0.200***	0.012
							(0.038)	*(0.076)*	*(0.066)*
ln $BRB_{j,t-1}$							0.084**	0.151***	-0.015
							(0.038)	*(0.050)*	*(0.091)*
ln $GDP_{i,t-1}$	0.114**	0.232	0.275**	0.174**	0.233	0.227**	0.118**	0.215	0.276**
	(0.055)	*(0.146)*	*(0.115)*	*(0.068)*	*(0.153)*	*(0.103)*	*(0.060)*	*(0.146)*	*(0.120)*
ln $GDP_{j,t-1}$	0.071*	0.202*	0.201**	0.118**	0.198*	0.166**	0.080*	0.186*	0.221**
	(0.039)	*(0.106)*	*(0.093)*	*(0.049)*	*(0.106)*	*(0.084)*	*(0.045)*	*(0.103)*	*(0.105)*
$RTA_{ij,t-1}$	0.065*	0.016	-0.102	0.006	0.076*	-0.059	0.023	0.055	-0.098
	(0.037)	*(0.035)*	*(0.074)*	*(0.031)*	*(0.042)*	*(0.078)*	*(0.029)*	*(0.039)*	*(0.074)*
ln $DIST_{ij}$	-0.093**	-0.234*	-0.251**	-0.150**	-0.165	-0.197	-0.114**	-0.220*	-0.245**
	(0.044)	*(0.133)*	*(0.112)*	*(0.060)*	*(0.130)*	*(0.120)*	*(0.054)*	*(0.128)*	*(0.112)*
Constant	-4.049**	-7.180*	-6.889**	-4.122**	-8.416**	-3.710	-2.708*	-5.856*	-6.516**
	(1.874)	*(3.799)*	*(2.969)*	*(1.692)*	*(3.552)*	*(2.614)*	*(1.427)*	*(3.360)*	*(2.855)*
Time effect	yes***	yes***	yes***	yes***	yes***	yes***	yes***	yes***	yes***
AR(1) test	-5.95 [0.000]	-5.26 [0.000]	-5.50 [0.000]	-5.82 [0.000]	-5.29 [0.000]	-5.77 [0.000]	-5.87 [0.000]	-5.20 [0.000]	-5.47 [0.000]
AR(2) test	1.68 [0.092]	1.82 [0.069]	0.21 [0.831]	1.62 [0.106]	1.92 [0.055]	0.33 [0.745]	1.67 [0.095]	1.79 [0.073]	0.36 [0.717]
Hansen test	9.03 [0.619]	15.55 [0.159]	13.77 [0.246]	6.28 [0.854]	15.76 [0.150]	15.13 [0.177]	8.55 [0.663]	12.83 [0.304]	13.15 [0.284]
Observations	9,891	5,922	5,805	9,891	5,922	5,805	9,891	5,888	5,772

Time span: 2004–2013. Standard robust errors in parentheses. *, ** and *** denote significance at 10%, 5% and 1%, respectively. System-GMM estimates for the dynamic panel data model. The dependent variable is the log-transformation of bilateral trade flows ($lnEXP_{ijt}$). All the specifications include time fixed effects (γ_t). The AR(1) and AR(2) Arellano–Bond tests assess no first- and second-order autocorrelation in the differenced residuals. The Hansen test assesses the validity of the instruments used in the system GMM estimation. The *p*-values of the tests are shown in brackets. The instruments are (*t-2*) and (*t-3*) lags of $lnEXP_{ij}$, $lnIU_i$, $lnIU_j$, $lnGDP_i$, $lnGDP_j$ and RTA_{ij}.

The lagged dependent variable is significant in all three specifications and scenarios regardless of the type of technology and the income level, indicating the robustness of the dynamics in trade flows. The results for internet use are displayed in Columns 1, 2 and 3. The results show that the positive effects of internet use on exports for the export country are mainly registered in trade flows between high-income countries (Column 1, 0.178) and from high-income to low- and middle-income countries (Column 2, 0.279). As for the effects for the import country, internet use also influences the bilateral flows between high-income countries (Column 1, 0.262).

With regard to mobile phones (Columns 4, 5, and 6), the results clearly show differences between high-income and low- and middle-income countries. The impacts on trade due to mobile phone use are significant and positive for the exporter country in the case of trade flows between high-income economies (Column 4, 0.257). The effects of using mobile phones in the trade flows from high-income to middle- and low-income countries are only significant for the importer country (Column 5, 0.285). These findings might be related to the expansion of mobile phones in certain developing economies in which fixed-line telephones could have been substituted by mobile phones, in particular in those countries in which firms use mobile phone to perform trade activities.

Lastly, with regard to broadband use, the results are significant and positive for trade flows between high-income countries for both the exporter and the importer country (Column 7, 0.085 and 0.084, respectively) as well as for exports from high-income economies to low- and middle-income ones (Column 8, 0.200 and 0.151, respectively). In fact, the highest coefficients are found for the bilateral relationships between high-income countries and low- and middle-income countries, the greatest impact being for the exporter country.

Regarding the rest of the variables, the size effects for the exporter and the importer country are positive and statistically significant, meaning that countries tend to trade with larger countries, in line with the standard gravity theory. An exception is the result obtained for the exporter country's GDP for exports from high to low- and middle-income countries (Columns 2, 5, and 8). Bilateral trade agreements only result as significant in Columns 1 and 5.

The results for the whole sample demonstrate that the ICT effects on trade are larger for the exporter in the case of mobile phones, followed by users and broadband subscribers, respectively. For trade flows between high-income countries, these results are also true. For this group, the impact of the Internet is also greater than that of broadband for the importer country. In the trade relationships from high-income to low- and middle-income countries, the largest impact is again found for mobile phones but for the importer country, whereas for exporters internet use shows the largest effect above that of broadband. These results may be explained by differences in the diffusion rates of each of these technologies over the selected period, since mobile phones also exhibit the highest rate of diffusion, followed by Internet and broadband subscribers (ITU 2015). The results also demonstrate that the strongest impacts on trade derived from ICT use correspond to trade flows involving high-income countries. These economies exhibit the greatest levels of digitalization and diffusion, and therefore we can expect the reduction in trade costs associated with ICT use to be greater than that in low- and middle-income countries. A great bulk of trade flows between high-income countries themselves, and between high-income countries (exports) and low- and middle-income ones, is associated with information and knowledge flows, also related to trade in knowledge-intensive sectors. Trade specialization might also explain the larger impacts of ICT use on trade costs together with those other impacts associated with the digital transformation in areas such as logistics and transport (UNCTAD 2017). Accordingly, trade specialization together with a lower degree of ICT diffusion would explain why trade flows involving exports from low- and middle-income countries are less affected by the use of these technologies. Many of these countries still have a trade pattern based on raw materials, agricultural products, and generally lower levels of knowledge-intensive exports.

6. Concluding comments and discussion

This paper aims to investigate the impacts of ICTs on bilateral trade flows using panel data for the 2004–2013 period. In particular, we investigate the influence of Internet, mobile phone, and broadband use on bilateral flows for high-income countries and low- and middle-income economies. Our results demonstrate a significant and positive relationship between each of the three technologies and bilateral trade flows. Second, we demonstrate that the effect of ICTs on bilateral exports should consider differences in impacts depending on the type of technology. Moreover, the results depend not only on the type of ICT use but also on the income level of the trade partners. Although the vast majority of the previous empirical evidence refers to internet use, the findings for the whole sample suggest that the effects of ICT use on trade are greater for mobile phones and for exporter countries. The impacts of internet and broadband use are significant and positive for both exporter and importer countries, although the effect is larger in the case of internet use. When we disaggregate by income groups, we find that in general the effects of ICT use are significant for trade flows between high-income countries and from high-income to low- and middle-income countries. In the case of internet use and broadband, the greatest effect is found for exports from high-income to low-middle-income countries. We also find that, although mobile phone use positively influences exports between high-income countries, the results are not significant for the importer country. For low- and middle-income countries, the use of ICTs is only significant when they import from rich countries. This result may point to the fact that the use of ICTs in trade flows involving low-and middle-income countries is related more to imports from the high-income economies given the greater extent of ICT use in these parts of the world. These results may indicate that the type of trade exchange in south–south trade flows is still not as influenced by the use of these technologies. By the type of technology, the coefficients of the use of mobile phones and broadband for the importer country in the case of low- and middle-income imports from high-income economies are remarkable. The result emphasizes the role played by mobile devices and the broadband infrastructure in trade relationships for the developing world. We also find that the positive and significant coefficient of the lagged dependent variable justifies the use of a dynamic gravity framework rather than the static one that has usually been employed in the literature. Moreover, not taking into account the persistence of trade would lead to upward-biased estimates of the regressors' influence, as demonstrated by comparing the static and dynamic model specifications (section 6). Hence, the present research provides consistent estimates of ICT and size impacts on trade flows.

Our results highlight the role that digital and telecommunication policies should play in promoting ICT use and diffusion across firms, public administrations, and individuals in general to increase their role in international trade, especially in low- and middle-income countries. Mobile phones' impact on trade reveals the need to boost the ICT infrastructure in those areas registering a wide digital gap with the developed world. Infrastructure investments and telecommunication policies are critical to make the ICT infrastructure, for example mobile broadband, affordable for the less developed economies. However, especially in less developed countries, ICT policies have to be combined with educational, industrial, and trade public actions. Educational policies are needed to facilitate the acquisition of ICT skills across sectors to guarantee the efficient use of these technologies. Industrial and trade policies should aim to promote firms' adaptation to face the challenges of international trade in a digital world. Trade measures devoted to favoring ICT use in the several phases of the internationalization process should also be implemented both in high-income and in low- and middle-income countries. Measures oriented towards guaranteeing the greatest use and diffusion of a large variety of information and communication technologies may help companies in the various stages of the process of going global by dramatically reducing the costs and facilitating the access to and use of information and knowledge about markets and clients. These range from production to marketing and from logistics and transport to distribution and post-service activities and apply not only to large companies but also to SMEs. In high-income countries, the evident positive effects of ICT on trade associated with their use and diffusion highlight the need for continuous investment in ICT innovation to benefit from the technological advantages that facilitate international exchanges derived from its use. Finally, public initiatives oriented towards facilitating the transition towards trade specialization schemes should increasingly be based on information- and knowledge-intensive sectors that would facilitate the integration and use of ICT across the economy.

This paper sheds light on how the impacts of ICT use on trade are distributed according to the types of technology and trade relationships considering income-level groups. However, some limitations need to be mentioned. First, further research should overcome the limitations related to the availability of ICT use data for some developing countries that would have allowed us to cover a larger sample during the period considered. Second, the present study should be complemented with a sectoral analysis that may help us to understand the relevance of trade specialization when exploring the impacts of ICT use on trade relationships between rich and low- and middle-income countries, on the one hand, and between low- and middle-income countries, on the other. The increasing share of bilateral flows between less developed economies opens up new opportunities for research by disaggregating the analysis by sectors/products and countries.

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Appendix

Table A1. List of countries included in the study

High income countries (34)			Low and Middle income countries (21)	
Australia	Hungary	Singapore	Argentina	Peru
Austria	Ireland	Slovakia	Brazil	Romania
Bulgaria	Israel	Slovenia	China	Russia
Canada	Italy	South Korea	Colombia	Sri Lanka
Chile	Japan	Spain	Costa Rica	Thailand
Cyprus	Latvia	Sweden	Ecuador	Tunisia
Czech Republic	Lithuania	Switzerland	Egypt	Turkey
Denmark	Netherlands	United Kingdom	India	Ukraine
Finland	New Zealand	United States	Malaysia	Venezuela
France	Norway	Uruguay	Mauritius	
Germany	Poland		Mexico	
Greece	Portugal		Panama	

Source: Authors´ own elaboration

Table A2. Variables description and sources

Variable	Description	Units	Source
EXP_{ijt}, $EXP_{ij,t-1}$	Aggregate bilateral exports from *i* to *j* during year *t* and 1-year lagged, respectively.	USD'000	IMF-Direction of Trade Statistics
$IU_{i,t-1}$, $IU_{j,t-1}$	Internet users for *i* and *j* during year *t,* 1-year lagged.	Users per 100 inhabitants	World Bank-WDI and ITU
$MOB_{i,t-1}$, $MOB_{j,t-1}$	Mobile phone subscriptions for *i* and *j* during year *t,* 1-year lagged.	Users per 100 inhabitants	World Bank-WDI and ITU
$BRB_{i,t-1}$, $BRB_{j,t-1,}$	Broadband subscriptions for *i* and *j* during year *t,* 1-year lagged.	Users per 100 inhabitants	World Bank-WDI and ITU
$GDP_{i,t-1}$, $GDP_{j,t-1}$	GDP for *i* and *j* during year *t,* PPP adjusted, 1-year lagged.	USD'000	IMF-WEO
$RTA_{ij,t-1}$	Variable that takes value 1 for a regional trade agreement in force and 0 otherwise, 1-year lagged.		De Sousa (2012)
$DIST_{ij}$	Bilateral distance that separates *i* and *j*	Kilometres	CEPII

Source: Authors' own elaboration. ITU corresponds to "International Telecommunications Union", WDI "World Development Indicators" and WEO "World Economic Outlook"

Table A3. Descriptive statistics

Variable	Only pairs with all $x_{ijt}>0$			Full sample		
	Observations	Mean	Std. Dev.	Observations	Mean	Std. Dev.
$ln\ EXP_{ijt}$	24 777	5.299	2.776			
$ln\ IU_{i,t-1}$	24 777	3.723	0.737	26 001	3.702	0.743
$ln\ IU_{j,t-1}$	24 777	3.708	0.752	26 001	3.706	0.746
$ln\ MOB_{i,t-1}$	24 777	4.499	0.467	26 001	4.494	0.472
$ln\ MOBj_{,t-1}$	24 777	4.491	0.474	26 001	4.491	0.472
$ln\ BRB_{i,t-1}$	24 726	2.112	1.360	25 948	2.071	1.373
$ln\ BRBj_{,t-1}$	24 729	2.085	1.385	25 951	2.074	1.383
$ln\ GDP_{i,t-1}$	24 777	19.869	1.457	26 001	19.807	1.482
$ln\ GDP_{j,t-1}$	24 777	19.848	1.487	26 001	19.797	1.497
$RTA_{ij,t-1}$	24 777	0.343		26 001	0.333	
$ln\ DIST_{ij}$	27 530	8.487	1.030	28 890	8.514	1.024

Source: Authors' own elaboration