Digital technology and international trade:

is it the quantity of subscriptions or the quality of data speed that matters?

Ana L. Abeliansky[a] and Martin Hilbert [b] [1]

a) University of Göttingen; Department of Economics

email: ana-lucia.abeliansky@wiwi.uni-goettingen.de

b) University of California, Davis; Department of Communication; email: hilbert@ucdavis.edu

This is the author's version of the article finally published as
Abeliansky, A. L., & Hilbert, M. (2016/2017). Digital technology and international trade: Is it the quantity of subscriptions or the quality of data speed that matters? *Telecommunications Policy*. https://doi.org/10.1016/j.telpol.2016.11.001

We would like to thank the participants of the CESifo Conference on Estimation of Gravity Models of Bilateral Trade, XVI Goettingen International Economics Workshop, ETSG 2014, Economics of Global Interactions' Conference and the GLAD research seminar in Hannover. We are grateful to Badi Baltagi, Jeffrey Bergstrand, Tristan Kohl, Astrid Krenz, Inmaculada Martinez-Zarzoso, Atika Pasha, Klaus Prettner, Johannes Schuenemann, Holger Strulik, Timo Trimborn and Katharina Werner for helpful advice and discussion. Special thanks to the ECLAC Summer School 2013 where this project started. Martin Hilbert was affiliated to UN-ECLAC when this project commenced. Funding from the DFG is gratefully acknowledged.

Abstract

Information and communication technologies affect global trade patterns through transaction costs on the supply and demand sides. The relevant transaction costs are affected by both the number of telecommunication subscriptions and the speed of the available bandwidth. We test for the differential effects of telecommunication *quantity* (data subscriptions per capita) and *quality* (bandwidth data speed per subscription) of fixed and mobile telephony and internet services on countries' bilateral exports of goods. We use an augmented Gravity Model and control for multilateral resistance. Regression results for 122 countries over 1995-2008 show a significant effect on export performance of both variables. In the sub-sample analysis we find that data speed *quality* is what matters most for developing countries, while the *quantity* of subscriptions is more relevant for developed ones. We explain this by the disadvantage developing countries derive from being far from the technological communication frontier in terms of data speed, while the diffusion of additional high speed subscriptions in developed countries open up new markets there. This illustrates the importance of going beyond the traditional assessment of telecommunication infrastructure in terms of the number of subscriptions, and urges both scholars and policy-makers to start considering bandwidth quality.

Keywords: International trade; broadband; data speed; digital divide; Gravity Model; Development; Export.

1 Introduction

Both international trade and digital networks have increased during the past decades. Between 1995 and 2008, global trade of goods and services has grown with an annual compound growth rate of approximately 10%, while global Gross National Income (GNI) has grown less than 6%. The number of worldwide installed telecom end-user subscriptions (such as phones and Internet) has grown at 15.5% annually during the same period, and the corresponding installed telecommunication bandwidth capacity at 45%. Communication has been easier, faster and less expensive and it has changed the way we live, work and interact (Castells, 2009).

In the economic sphere, it has been shown that the increasing digitizing of economic processes has led to a general reorganization of economic activities (Rosenblat and Mobius, 2004; Acemoglu et al., 2007). Real-time communication among economic actors (Brynjolfsson and Hitt, 1995) and the reduction of search costs through blatant transparency (Bakos, 2001; Borenstein and Saloner, 2001) has helped to overcome geographical distance, resulting in the much-cited "death of distance" (Cairncross, 2001). Castells (2009, p. 442-443) discusses the resulting "space of flows", in which it is not physical geography that creates space in the digital age, but "a circuit of electronic exchanges, constituted by its nodes and hubs". It can be expected that this digital network geography affects and interacts with the geography of international trade networks. Digital networks allow buyers and sellers to connect quicker (lowering search costs), trading partners and employees can be monitored more easily (less management and control costs), and communication and coordination costs can be reduced (diminished shipping costs) (Fink et al., 2005; Demirkan et al., 2009). A positive relationship between digital technology and international trade can therefore be expected.

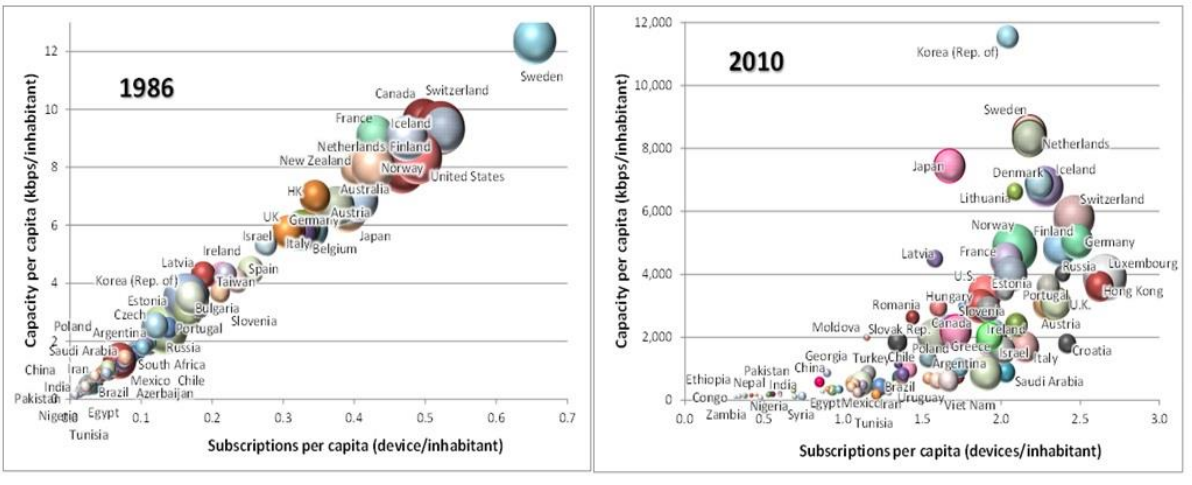
Related research has been growing, but has been lagging behind other questions in the literature of both international trade and digital technologies. Just over a decade ago, Freund and Weinhold (2002; 2004) provided the first empirical evidence on the matter, while studying the effect of the growth of Information and Communication Technologies (ICTs) on international trade growth. Several studies followed that include only cross-sectional data (Clarke and Wallsten, 2006; Demirkan et al., 2009, Márquez-Ramos and Martínez-Zarzoso, 2010; Choi, 2010), while the ones with panel data are either of a short time span (Portugal-Perez and Wilson, 2012) or include only a limited international perspective, with few or no developing countries in the sample (Vemuri and Siddiqi, 2009; Timmis, 2012; Mattes et al., 2012; with a notable exceptions for cross-sectional impact on service trade by Choi (2010)).

We see two major shortcoming in the past literature, one of methodological and another one of empirical nature. The methodological shortfall is the lack of consideration of the multilateral resistance terms, which "capture the fact that bilateral trade flows do not only depend on bilateral trade barriers but also on trade barriers across all trading partners" (Behrens et al., 2012, p. 773). The main shortcoming in terms of empirical evidence is that the independent variable used to represent the digital capacity does not directly represent the digital communicational capacity (Zwart et al., 2015). It is standard in the literature to consider the number of ICT subscriptions as a representation of the digital communication capacity (mainly drawing from the administrative registers of the International Telecommunication Union (ITU; 2014)), including the number of personal computers, phone lines and Internet users (Vemuri and Siddiqi, 2009; Ahmad et al., 2011; Clarke and Wallsten, 2006); the number of broadband subscriptions (e.g. Demirkan et al., 2009), or some (un)weighted index including these variables (Minges, 2005; Francois and Manchin, 2013; Portugal-Perez and Wilson, 2012; Márquez-Ramos and Martínez-Zarzoso, 2010; Mattes et al., 2012).

The problem with using the number of ICT subscriptions as a proxy for communication capacity arises from the fact that the number of subscriptions is not necessarily representative of communication capacity, since bandwidth speed is highly diverse across subscriptions (Hilbert et al., 2010; Hilbert, 2014b; 2016). This problem has become increasingly severe over past decades, as telecom access became ever more diversified. In the analog age of the late 1980's, the vast majority of telecom subscriptions were fixed-line phones, and all of them had the same performance (see Figure 1). Given the linear relationship, there was no methodological problem in equating subscriptions with capacity. Twenty years later, there is a myriad of different telecom subscriptions with the most diverse range of performances (see Figure 1). While some countries have reached a certain level of saturation in terms of subscriptions (at about 2-3 telecommunication subscriptions per capita), bandwidth speed capacity in kbps (kilobits per second) continues to thrive (ITU, 2012). Using the number of subscriptions as an independent variable (solely or within some kind of index) does not consider the fact that countries like Saudi Arabia count with an average installed bandwidth speed of less than 1 optimally compressed Mbps per capita in 2010, while countries like South Korea counted with almost 12 Mbps per subscription (see Figure 1b).

A recent OECD-WTO survey (2013) reported that least developing countries suppliers "consider poor physical infrastructure, including inadequate power (59%), unreliable internet access or low bandwidth (35%) and inadequate national telecommunications network (24%) as the most important barriers to connect to ICT value chains" (WTO, 2013, p.32). It is to be expected that such differences have an effect on international trade of goods and therefore it is important to also take this aspect of ICTs into account.

Figure 1: Subscriptions per capita (fixed and mobile telecom) vs. capacity per capita (in optimally compressed kbps of installed capacity) for (a) 1986 and (b) 2010. Size of bubbles represents Gross National Income (GNI) per capita (N = 100).



In order to test whether there is a differential effect of more and better connectivity, we employ a unique dataset of the installed telecommunication data speed in kbps per subscription additionally to the traditional measure of subscriptions. We cover the period from 1995 till 2008 across 122 countries.[1] We estimate a Gravity Model to analyze the relationship between ICTs and

[1] The period was chosen given the availability of harmonized data from both the trade and telecommunication datasets at the time of the beginningof this study.

international trade, adjusting for multilateral resistance with the methodology of Baier and Bergstrand (2009). Our main results show that both the quality and quantity of ICTs matter, with differential effects for developing and developed countries. Moreover, we also test the impact of both aspects of ICTs on different kinds of goods, and find the highest impact on the trade of differentiated goods.

Section 2 provides an overview of the related literature on the relationship of ICTs and international trade, while Section 3 examines the development of ICT across the globe. Section 4 describes the empirical strategy, including the variables and data sources used. Section 5 shows the results and finally Section 6 concludes and outlines further lines of research.

2 Background literature

Pioneering studies of the social impact of ICTs have focused on economic and productivity growth. The predominant independent proxies for a society's information processing capacity were the number of installed ICT devices and subscriptions (e.g. Hardy, 1980; Roller and Waverman, 2001; Datta and Agarwal, 2004; Duggal et al., 2007) and the monetary value of the respective investments (e.g. Bresnahan, 1986; Siegel and Griliches, 1992; Oliner et al., 1994; Jorgenson and Stiroh, 1995; Vu, 2011). In general, the literature finds positive effects of ICT on economic growth and productivity (Jorgenson and Vu, 2016). While most of the literature focuses on highly industrialized countries (Jorgenson and Vu, 2007; Dimelis and Papaioannou, 2011; van Ark et al., 2008; Spiezia,2012), studies that include developing countries found differential effects among world regions (Campos, 2010; Hofman et al., 2016).

The initial papers on the relationship between ICTs and international trade use internet penetration as the independent variable of interest (Freund and Weinhold, 2002) or the number of internet hosts (Freund and Weinhold, 2004). They find a robust positive relationship with export performance. Their gravity panel estimates do not study the differential effects of ICTs on the exporter and importer. In another early study, Clarke and Wallsten (2006) find a positive effect of the number of internet users on trade between developing countries to developed ones. This same proxy for ICTs has been used by Demirkan et al. (2009) when estimating a 2005 cross-section for 175 countries. They find a positive effect in the whole sample, and conduct an interesting subsample analysis, which finds that the effect is higher between smaller economies. Vemuri and Siddiqi (2009) also find a positive and statistically significant effect of personal computers, telephone lines and Internet users. Ahmad et al. (2011) estimate the effect of Malaysian internet and mobile phone subscriptions, personal computers and internet users with a time series analysis between 1980 and 2008. They find a statistically significant effect of all variables in a pooled, fixed effects - as well as a random effects model. Timmis (2012) estimates a panel data model with different fixed effects for OECD countries between 1990 and 2010 while controlling for multilateral resistance. He understands ICTs as internet users, broadband subscriptions and fixed lines connections and finds that country pairs with high adoption rates trade more with each other. Nevertheless, the results are not robust to the use of different dummies and are not able to assess the impact of ICTs on the exporter or importer independently when accounting for multilateral resistance.

Other studies use technology indexes as independent variable. Márquez-Ramos and Martínez-Zarzoso (2010) use the technological achievement index (TAI) constructed on the basis of four indicators: level of technological innovation, diffusion of old innovations, diffusion of recent innovations, and a human skills index. They find in several cases a positive relationship between

technological innovations and export performance (plus a non-linear effect with respect to these same variables). Mattes et al. (2012) use the ICTs development index of the International Telecommunication Union (ITU) and account for multilateral resistance for EU trade between 1995 and 2007. They find a positive impact if both countries have a high level of ICTs development. Nevertheless, in doing so they are not able to establish the effect of ICTs on trade at the exporter and importer levels[2]. Similarly, Francois and Manchin (2013) construct an infrastructure index that includes ICTs, among other variables, based on principal component analysis and find a positive effect of this index on the exporting and importing activity.

Portugal-Perez and Wilson (2012) study the effects of hard (physical infrastructure and ICTs[3]) and soft infrastructures (border and transport efficiency and the business regulatory environment) on the export performance of developing countries. With a panel of 101 countries for the period 2004-2007 they find that infrastructure improves export performance.

In short, previous studies have generally found that digital tools seem to facilitate trade. However, specific policy recommendations are usually not possible, either because the studies are not able to quantify the effect for the exporter and importer separately, or because the infrastructure measure is too aggregate and ICTs are just one component.

This paper innovates on the basis of these previous findings in four complementary ways. The two main contributions refer to the consideration of multilateral resistance terms (which allows for an independent identification of the relationship of ICTs and trade on the exporter and importer country), and the additional use of a novel continuous independent variable (bandwidth data speed in kbps per subscription). This is more informative than using subscriptions alone, and more direct than using a subjective "ICT index". In combination with the traditional indicators for ICT subscriptions it allows us to test for the effects of "better" ICT, besides "more" ICTs (Hilbert, 2014a). Besides, we use a large sample of countries and analyze differential effects between developing and developed countries. Finally, we show the results controlling for country-pair heterogeneity which is rarely done in the respective literature. The four innovations combine the strengths of different previous exercises in one coherent large-scale approach and aim to show new evidence on the importance of ICTs with the use of a new independent variable.

3 International trade, ICTs quality and quantity

Since we do not count with ICT indicators of exporting companies of different countries over time, we use aggregate data per country. Nevertheless, our assumptions are not too far-fetched: for developing countries Clarke and Wallsten (2006) document a statistically significant correlation between internet usage among the general population and exporting firms (from the Enterprise Survey from the World Bank).

Figure 2 depicts the main variables, namely international trade of goods, and the quality and quantity of telecom access. It shows the rise in international trade (in terms of GDP) for the countries in the sample over the last two decades, especially in the 2000s when the digital revolution took off.

[2] Their ICTs dummy is constructed using the exporter and importer information jointly (takes the value of one if both countries have above average ICTs levels, otherwise zero), in order to be able to use the country-year dummies.

[3] ICTs are proxied by an indicator that includes information on availability of latest ICTs technology, extent of business internet use, level of technical absorption and government prioritization of ICTs.

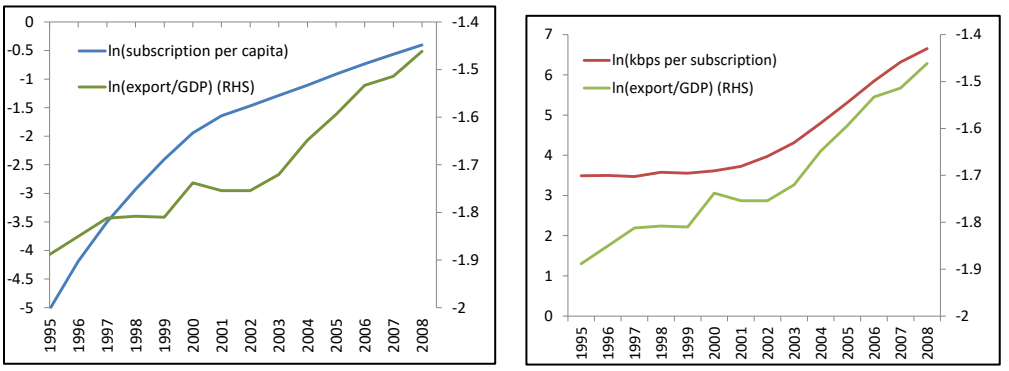


Figure 2: Evolution of World Trade of goods and telecommunication 1995-2008, (a) with subscription per capita (b) installed bandwidth data speed (kbps) per subscription.

The number of telecommunication subscriptions (quantity) is provided mainly by the well-known database of International Telecommunication Union (ITU) (2014), which we complement with other sources for data gaps (especially for the diffusion of fiber optics). We include the installed bandwidth capacity of all telecommunication services except voice, which includes the data services of fixed-line telephony-based internet in the form of dial-up, ISDN (Integrated Services Digital Network), DSL (Digital Subscriber Line), Satellite broadband, Cable modem and FTTH/B (Fiber to the Home/Business); and 2G, 2.5G, 3G and 4G mobile telephony (internet and short-message-service (SMS)).

With regard to data speed quality we estimate the installed domestically bandwidth data speed (not international internet bandwidth between countries, which was shown to correlate negatively with exports (Liu and Nath, 2013)). We follow the methodology of Hilbert and López (2011) (see also Hilbert and López, 2012a; 2012b). This estimates the installed telecommunication bandwidth capacity in optimally compressed kbps. We divide the result by the amount of ICTs subscriptions in each country. The variable is therefore measured in kbps/subscription and is an indicator of the average communication quality. The variable is created for each country (and year) as follows:

$$quality = \sum \frac{(Number\ of\ subscriptions) * (Data\ speed\ of\ technology)}{Total\ subscriptions} \quad (1)$$

where the sum is taken over each subscription of the different data technologies (fixed and mobile). Up until 2005/2006 the corresponding bandwidth speed was obtained per access technology by identifying the data speed performance of specific access technology. For example, a digital fixed-line phone provides a general (uncompressed) data speed of 64 kbps, and an ISDN internet modem 128 kbps (we then adjusted for data compression to obtain meaningful time series, see Hilbert and López, 2012b). This strategy was used for more traditional technologies, like fixed phones, dial-up, ISDN and 2G/2.5G mobile telephony. After the introduction of global broadband solutions like DSL and cable modem, and 3G mobile telephony, the direct assignment of data speed to specific technologies becomes less viable. Therefore, for 2007 and 2008 we approximate the installed data speed by recurring to crowed-sourced data from end-user-initiated bandwidth speed velocity tests, which allows us to maintain a very wide geographical focus, through Speedtest.net

and Pingtest.net[4]. We assume that the national average data speed test result for fixed broadband is the weighted mean of all nationally installed DSL, cable modem, and FTTH/B subscriptions (Hilbert and López, 2011, 2012a, 2012b). We consulted both upload and download tests and added both in our assessment of broadband speed.

It is important to point out that given its crowd-sourced nature, the resulting data has potential self-selection and server-selection problems (Bauer, Clark and Lehr, 2010; Yoo, 2014). Speedtests are unequally distributed across and within countries (resulting in a power-law like distribution). On average there are some 96,000 speed tests per country per day in 2008, but the standard deviation among countries is around 262,000 (max: U.S. 2.4 million; min: Tanzania: 6 per day). Inequalities within countries (e.g. rural vs. urban representativeness) are less worrisome for our comparative purposes as they can expected to be replicated across different countries. With these important caveats in mind, the choice of this database to approximate installed bandwidth speed potential in 122 countries has also brutally practical reasons: it might be imperfect, but nevertheless "the best of the currently available data sources for assessing the speed of ISPs broadband access service" (Bauer, Clark and Lehr, 2010; p.3).

Working with a time series that spans 14 years, it is important to consider varying compression rates of the information content that is communicated through a certain data speed. The necessity for normalizing on compression rates is similar to the reason why economists adjust for inflation: one bit in a later year might carry more information than one bit in an earlier year, due to advances in compression algorithms[5]. We normalized the kbps variable on its optimal level of compression in order to estimate information flow, not merely installed hardware capacities (see Hilbert and López, 2012b).

Equation (1) makes clear that the quantity of subscriptions and the quality of data speed are related, which might lead to multicollinearity in multivariate statistical analysis. However, the correlation matrix of Supporting Material (Table S.10) shows that the respective correlations lie between 0.4 and 0.58, which is well within the commonly accepted tolerance levels for multicollinearity. This also underlines that the quantity and quality of telecommunication subscriptions are not equivalent. Figures 3a and 3b visualize such differences. The tendencies of subscriptions per capita are concave and show convergence between developed and developing regions, while data speeds grow according to a convex curve, with an increasing capacity gap with non-OECD countries. For more on the closing digital divide in terms of subscriptions and the widening divide in terms of bandwidth speed see Hilbert (2014b; 2016).

[4] Data source is Ookla, retrieved from http://www.netindex.com/source-data/

[5] As compression technologies evolve, we are able to send more information using the same installed infrastructure and this should be accounted for. As Hilbert and López (2011; p. 63) remark, "optimal compression is indispensable for obtaining meaningful time series of digital technologies because more efficient compression algorithms enable us to handle more information with the same amount of hardware. For example, we estimated that a hard disk with a hardware performance of 1 MB for video storage was holding the equivalent of 1 optimally compressed MB in 2007 ("optimally compressed" with MPEG-4) but only 0.45 optimally compressed MB in 2000 (compressed with MPEG-1) and 0.33 in 1993 (compressed with cinepack)".

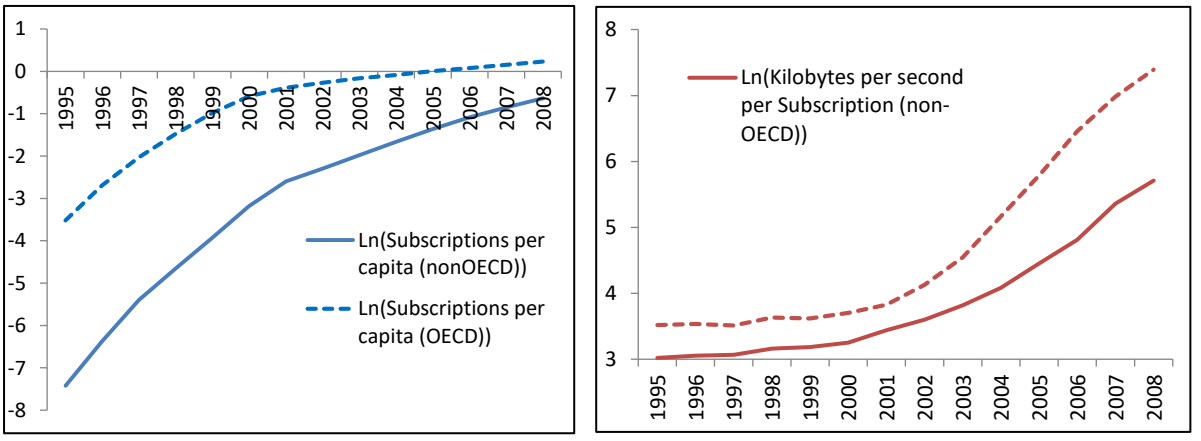


Figure 3: OECD versus Non-OECD countries, 1995-2008: (a) Total ICT subscriptions; (b) average installed bandwidth data speed per subscription (in kbps).

4 Empirical strategy

4.1 The Gravity Model

We start with the baseline structural gravity equation[6]:

$$X_{eit} = \frac{Y_{et} * Y_{it}}{Y_{wt}} * \left(\frac{tc_{eit}}{P_{et} * P_{it}}\right)^{1-\sigma}$$

$$where\ tc_{eit} = D_{ei}^{\alpha} * v_{et}^{\beta} * v_{it}^{\mu} * e^{\varrho * q_{eit} + \varphi * b_{ei}} \quad (2)$$

Sub-index *e* refers to exporter and *i* to importer country, respectively, while *t* stands for time and *w* for the world (in our sample, 122 countries). X_{eit} is the export flow from country *e* to country *i* in year *t*. *Y* should be gross production but given the lack of data we use the Gross Domestic Product instead. tc_{eit} denotes transport costs that include distance (D_{ei}) and other costs (v_{et}, v_{it}, q_{eit} and b_{ei}). Variables $v_{e,i;t}$ stand for variables that remain constant for each country, irrespective of the partner but do change over time. Variables included in *q* and and *b* are specific to the bilateral relationship of the trading countries. Other costs include the information costs (usually dummy variables related to cultural variables like common language, that enter into the equation as the dummy variable b_{ei}). Moreover, other trade costs could be included, that can relate to regional trade agreements or common currency (that enter into the equation as the dummy variable q_{eit} for example). Furthermore, our main variables of interest included are ICTs quality and quantity at a certain point in time (belonging to v_{et} for exporter and v_{it} for the importer). Finally, P_{et} and P_{it} are the multilateral resistance terms. They can be expressed as:

[6] For a detailed derivation of the Gravity Equation refer to Anderson and van Wincoop (2003) or Baier and Bergstrand (2009). This equation is the panel data equivalent of the original Anderson and van Wincoop (2003) theoretically founded gravity equation though the trade cost equation is different since it includes other variables. The multiplicative form of the trade cost equation is common to most of the theoretical gravity models such as Anderson and van Wincoop (2003).

$$P_{et} = \left(\sum_{i=1}^{Ni} s_i * \left(\frac{tc_{eit}}{P_{it}} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \qquad (3a)$$

$$P_{it} = \left(\sum_{e=1}^{Ne} s_e * \left(\frac{tc_{eit}}{P_{et}} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \qquad (3b)$$

where $s_{e;i}$ are the shares of the countries' GDP of world GDP . We apply logs to Equation (2) and obtain the following equation:

$$\ln(X_{eit}) = k + \ln(GDP_{et}) + \ln(GDP_{it}) + \ln(GDP_{wt}) + (1-\sigma)\alpha * \ln(D_{ei}) + (1-\sigma)\beta * \ln(v_{et}) + (1-\sigma)\mu * \ln(v_{it}) + (1-\sigma)\varrho * q_{eit} + (1-\sigma)\varphi * b_{ei} + (1-\sigma) * \ln(P_{et}) + (1-\sigma) * \ln(P_{it}) + u_{eit} \qquad (4)$$

In order to account for multilateral resistance, Baier and Bergstrand (2009) (hereupon called BB) have derived an equation to consistently estimate the gravity equation with OLS. They use a log-linear first order Taylor series approximation based on the bilateral trade cost specification. Given the nature of our data we follow this line of research instead of using exporter and importer-year dummies (for other applications to country-level data see also Berden et al., 2014; Egger and Gassebner, 2014; Francois and Manchin, 2014; Portugal-Perez and Wilson, 2012). For the definition of the estimating equation we will follow the implementation of the methodology by Márquez-Ramos et al. (2012)[7], who use simple averages (i.e. replace s_{et} and s_{it} in Equations (3a) and (3b) above by $\frac{1}{N}$), instead of country shares. As Baier and Bergstrand (2010, p. 103-104) note, the use of simple averages has the advantage of addressing the concern of the endogeneity of the weights, providing marginally less biased coefficients (shown by Monte Carlo simulations), and the benefit of expanding around a symmetric world in all variables (which is in line with the Taylor expansion centered in *t* and the means-based Ordinary Least Squares (OLS) estimates). The first-order-log-linear Taylor expansion would deliver the same equation but with equal weights for shares (instead of the weighted shares). Head and Mayer (2014, p. 157) also note that the "estimates (of the weighted shares) are not robust to missing data and it is very imprecise as we see in the high standard deviation of the coefficients" (see their simulation results on p.156 to observe the superiority of the un-weighted version).

Applying the Taylor expansion and some algebra we obtain the following (focusing on distance for simplicity and a cross-sectional setting):

$$-\ln(P_e^{1-\sigma}) = (\sigma-1)\left(\frac{1}{N_r} \sum_{r=1}^{Nr} \ln(D_{er}) - \frac{1}{2}\frac{1}{N_r}\frac{1}{N_m} \sum_{r=1}^{Nr}\sum_{m=1}^{Nm} \ln(D_{rm}) \right) \qquad (5a)$$

$$-\ln\left(P_i^{1-\sigma}\right) = (\sigma-1)\left(\frac{1}{N_m} \sum_{m=1}^{Nm} \ln(D_{mi}) - \frac{1}{2}\frac{1}{N_r}\frac{1}{N_m} \sum_{r=1}^{Nr}\sum_{m=1}^{Nm} \ln(D_{rm}) \right) \qquad (5b)$$

[7] Others such as Portugal-Perez and Wilson (2012), Carrére et al. (2010); Carrére et al. (2013) and de Jong and Bogmans (2011) also only correct bilateral variables for multilateral resistance, while also including other country-level variables.

r is an index for the country partners of *e* and *m* of the country partners of *i*. So we get the next equation for the bilateral trade costs adjusting for the ideal price indices of country *e* and country *i*, known as multilateral resistance (the adjusted variables will be denoted with a prefix "mr"):

$$mrD_{ei} = \ln(D_{ei}) - \frac{1}{N_r}\sum_{r=1}^{Nr}\ln(D_{er}) + \frac{1}{N_r}\frac{1}{N_m}\sum_{m=1}^{Nm}\sum_{r=1}^{Nr}\ln(D_{mr}) - \frac{1}{N_m}\sum_{m=1}^{Nm}\ln(D_{mi}) \qquad (6)$$

Where the subscripts *e*, *i* and *t* refer to the exporting and importing partner countries and time (year) as before. *r* is an index of the trading partners of *e*, while *m* is an index of the trading partners of *i*. N is the total number of countries. The second term is a simple average of the trading cost of the exporter across all partners *r*, the third one the average trade costs between all partners, and the last term the average trading cost of the importer with all of its partners *m*.

The augmented model of Equation (7) includes further covariates, namely the Gross Domestic Products (*GDP*), *Population*, ICTs quantity of subscriptions (*Quantity*), and quality of bandwidth data speed (*Quality*), and dummy variables for regional trade agreements (*RTA*) and common currency (*Currency*). Moreover, the traditional time invariant gravity variables are included: distance (*Distance*), colonial relationship (*Colony*), common legal origin (*LegalOrigin*) and whether countries share a common language (*Language*)[8]. Time dummies dy_u are also included. Most of the variables used are logged, except for the dummy variables:

$$\begin{aligned}\ln(X_{eit}) = {} & \alpha + \omega_1\ln(GDP_{et}) + \omega_2\ln(GDP_{it}) + \omega_3\ln(Population_{et}) + \omega_4\ln(Population_{it}) \\ & + \delta_1\ln(Quantity_{et}) + \delta_2\ln(Quantity_{it}) + \delta_3\ln(Quality_{et}) \\ & + \delta_4\ln(Quality_{it}) + \sum_{u=1}^{U-1}\sigma_u dy_u + \gamma_1 mrRTA_{eit} + \gamma_2 mrCurrency_{eit} \\ & + \gamma_3\, mr\ln(Distance_{ei}) + \gamma_4 mrColony_{ei} + \gamma_1 mrLegalOrigin \\ & + \gamma_1 mrLanguage + \epsilon_{eit} \qquad (7)\end{aligned}$$

4.1.1 Empirical Specifications

We run our model for different model specifications that consider different variables (they are presented as columns in Tables (1-3)). We start with the full sample and estimate the model as outlined in Equation (7). To assess the robustness of these results, the next specification controls for (time invariant) multilateral resistance with continent dummies of origin and destination,[9] while the one thereafter uses origin and destination country dummies. In other words, we remove the heterogeneity that is exporter/importer specific and that does not change over time. We then assess whether the results hold while controlling for country-pair heterogeneity (using bilateral fixed effects) with the BB adjustment. We follow the approach of Egger and Nelson (2011) who apply the BB methodology with the inclusion of time dummies in a fixed effects framework that controls for country-pair unobserved heterogeneity. We use this as a robustness test and not as our main model since we lose a considerable part of variability of our data just analyzing the within

[8] These variable take the value of 1 if the country pair has ever been in a colonial relationship, have a common legal origin or share the same official language (respectively).

[9] Although this is not strictly controlling for time invariant multilateral resistance, it is less strict than country dummies since it keeps more variation in the data.

variation.[10] In the next two specifications we first add a measure of institutions (average of the Worldwide Governance Indicators from the World Bank - *WG*) and then an infrastructure measure - percentage of paved roads (*Roads*). Moreover, we report the results for the EK-Tobit estimator from Eaton and Kortum (2001), also used by Crozet et al. (2012) in order to include the zeroes into the dependent variable. It employs a Tobit regression but the censoring for the missing values corresponds to the minimum value of imports per country per year. We also do the BB adjustment in this instance.

We then analyze the full model as specified by Equation (7) in further subsamples, by differentiating between OECD or non-OECD countries as exporters and importers. As a robustness check, we control in each subsample for the institutional and infrastructure variables (see Supplementary Material (S.4) and (S.5)). We then report the fixed effects results and the ones employing the EK-Tobit estimator as well for the subsamples with zeroes in the dependent variable. As an additional check, we also include the estimations from a Feasible Generalized Least Squares (FGLS) regression, as well as the Multinomial Poisson Pseudo-Maximum Likelihood (MNPML). While FGLS corrects for potential heteroskedasticity, the MNPML is robust to it, additionally allowing the introduction of the zeroes.

Moreover, since we can expect that ICTs matter differently according to the type of products, we estimate the main model for each product group as classified by Rauch (1999). The classification involves differentiated goods, reference priced goods and homogenous goods (or "goods sold in an organized exchange"). Finally, we compare our results with a model including internet users from the World Development Indicators, one of the traditional independent variables used in the literature (Supporting Material S.8).

4.2 Data sources and variables

We obtained bilateral trade data from the BACI dataset from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) (Gaulier and Zignago, 2010). Originating from the United Nations COMTRADE database, it is extensive and detailed, but only includes products, not services. It is a mirrored dataset, which is of relevance in this case given the amount of developing countries of the sample and the reporting errors that could potentially arise. The values are in current US dollars since the theoretical model predicts nominal trade flows. This is justified because there is no suitable deflator for bilateral trade flows and because it avoids the so-called "*bronze medal mistake"* (Baldwin and Taglioni, 2007).[11]

The Gross Domestic Product (*GDP*) was obtained from the World Development Indicators (WDI) from the World Bank, measured in current US dollars. Regional trade agreements

[10] In a panel data setting, using country-pair dummies (which is equivalent to employ the least squares dummy variable estimator) is similar to analyzing the within variation of the data. So we are essentially removing heterogeneity of each country-pair, e.g. taking out the effect that being a landlocked country could have and we are only keeping the time variation of the data.

[11] The *bronze medal mistake* is the incorrect deflation of bilateral trade. Some authors have considered the US aggregate price index to deflate values (given the valid claim of the inexistence of a bilateral trade defaltor), but "since there are global trends in inflation rates, inclusion of this term probably creates biases via spurious correlations. Fortunately, Rose (2000) and others offset this error by including time dummies" (Baldin and Taglioni, 2007 p. 790). We do include time dummies in the analysis as can be read in the text. Moreover, for consistence, all of the variables measured in currency terms are in the same unit of measurement.

(*Agreement*) are important (Baier and Bergstrand, 2007) and take the value 1 if the country is engaged in a regional trade agreement with the partner country, otherwise it is 0 (obtained from De Sousa's website[12]; Baier and Bergstrand, 2007; the WTO website and Frankel et al., 1997). The dummy for currency (*comcur*) takes the value of 1 if it is shared among trading partners (obtained also from de Sousa, 2012). Common language (*Language*), colonial ties (*Colony*), common border/contiguity (*Border*), common legal origin (*LegalOrigin*), and distance (*Distance*) were obtained from CEPII (Mayer and Zignago, 2011). Except for the distance between capital cities, these variables are binary. Population was obtained from the World Development Indicators from the World Bank, accessed online.

Given data availability, an unbalanced panel from 1995 to 2008 was estimated for 122 countries (refer to Table (S.1) of the Supplementary Material for a list of countries). Descriptive statistics can be found in Table (S.2) of the Supplementary Material. The variables for the robustness checks came from the World Bank World Development Indicators (percentage of paved roads, which provided a smaller sample size of countries) and from the World Governance Indicators (see Kaufmann et al., 2011), also accessed online. The main drawback of this last source for this exercise is that there are gaps in terms of years of data coverage,

Based on theoretical considerations, we predict country pairs to trade more goods if they have a common border, a regional trade agreement, a common currency, a common language, a colonial relationship, or the same legal system. The effect of population size is not clear. Economies of scale for the exporter and demand for a greater variety of goods for the importer could lead to a positive relation with population size, while at the same time bigger domestic markets are more likely to produce domestically (Gradeva and Martínez-Zarzoso, 2015). As discussed above, most of the empirical literature finds that the role of ICT *Quantity* has a positive coefficient for both exporters and importers, due to transaction cost reduction and access to new markets. We extend our expectations to the yet untested indicator of ICT *Quality*. Finally, the estimated coefficients of GDPs should be close to unity, as the theoretical foundations establish.

5 Results and discussion

5.1 Quality versus quantity: full sample

We find that *Quality* and *Quantity* are positively associated with the bilateral trade flows, for both exporter and importer countries. The diverse specifications of models that include different sets of variables are shown in the columns of Table (1). In most of the specifications, we observe that the estimated elasticities for quality (bandwidth) are higher than the ones for quantity (subscriptions). This difference is larger for exporter countries (the effect size of quality being almost twice that of quantity). The coefficient diminishes in size when we include the country dummies due to the fact that we are analyzing only one part of the variation in the data. There is a wide variation in ICTs between countries (when only using the country dummies of origin and destination we are not considering this variation, which explains why the coefficient is smaller). Something similar happens with the fixed effects.[13] Column (1) of Table (1) tells us that a 1 percent increase in the

[12] http://jdesousa.univ.free.fr/data.htm

[13] When we use fixed effects we are removing all of the cross-sectional heterogeneity, i.e. we are partialling out all of the differences of the country pairs that do not change over time. In so doing, further variation is removed.

average data speed quality per subscription is associated with an increase of 0.5 percent of bilateral trade, while a 1 percent increase of the quantity of subscriptions is associated with 0.3 percent of additional trade. Similar elasticities can be observed in column (7) with the EK-Tobit estimator.

In terms of time dimension and country coverage, our sample is similar to Vemuri and Siddiqi (2009). We find a higher overall impact of ICT, since we are better able to identify the differential effects of quality and quantity. Portugal-Perez and Wilson (2012) have a similar country coverage but fewer years in the sample. In contrast to their findings, our results do not require high GDP per capita to find a positive effect of ICT.

Table (S.3) of the Supplementary Material presents the regression results from a MNPML regression.[14] It portrays lower elasticities of both variables, although they are still statistically significant and have the expected signs.[15] We analyzed the residuals of the OLS, EK-Tobit and MNPML regression with the MaMu test as proposed by Manning and Mullahy (2001). Results show that the error term is more consistent with the OLS or EK-Tobit's assumptions, rather than to the MNPML[16], which suggests to keep our OLS and EK-Tobit's estimates as our main results. Similar differences on the estimates with MNPML and OLS have been documented by Melitz and Toubal (2014) who also use the same CEPII dataset for a large number of countries and a similar time period.[17] They also keep the OLS as the main specification.

The estimated coefficients of *GDP* lie between the values found in the gravity literature (Table 1). In most cases they are close to one, as theory predicts. Regional trade agreements have a positive and statistically significant effect in all of the specifications. Usage of the same currency has a positive and statistically significant effect on some of the specifications. Glick and Rose (2015) document these divergent results when using different specifications of the gravity equation. Population of the exporter country has a positive effect on the exporter in most specifications, while the effect on the importer is less clear. Distance has a robust negative effect across specifications, as countries that are further away trade less. The cultural variables –namely common language, former colony and common legal origin– have a positive and statistically significant effect.

[14] This method is encouraged by Head and Mayer (2014) since it performs better in simulations than the PPML and was first proposed by Eaton et al. (2012). Although this method as well as the EK-Tobit imply using country-year dummies for a panel data setting, since we are unable to do so, we make a modification - since the estimating equation resembles the traditional gravity equation, we control for multilateral resistance with the BB methodology. Moreover, we also employ the methodology here for better comparison of the coefficients. Although the methodology was derived for OLS, applications have extended to PPML as well.

[15] A difference in using this method is that it gives less weight to large values of exports and that exports are measured in shares.

[16] The test implies estimating $\ln(y_{eit} - \hat{y}_{eit}) = \lambda_0 + \lambda_1 \ln(\hat{y}_{eit}) + \varepsilon_{eit}$. While a λ=1 would be in support of a Poisson error structure, a λ=2 would be in favor of a log-linear model. The estimates of λ are 1.78 (OLS), 1.85 (EK-Tobit) and 1.72 (MNPML).

[17] We also tried to estimate the FGLS as proposed by Martí nez-Zarzoso (2013) for the full sample but due to software limitations we were unable to do so. We do report the results for the subsample analysis.

Table 1: ICTs and trade - full sample

	(1) Equation 7	(2) continent dummies	(3) country dummies	(4) Fixed effects	(5) With Governance	(6) With Roads	(7) EK-Tobit
ln(Quality$_e$)	0.514***	0.579***	0.040***	0.023*	0.387***	0.611***	0.534***
	(0.020)	(0.020)	(0.013)	(0.013)	(0.024)	(0.031)	(0.020)
ln(Quantity$_e$)	0.285***	0.329***	0.015**	0.019**	0.264***	0.239***	0.279***
	(0.011)	(0.012)	(0.008)	(0.007)	(0.015)	(0.014)	(0.011)
ln(Quality$_i$)	0.213***	0.277***	0.049***	0.032***	0.169***	0.239***	0.226***
	(0.019)	(0.020)	(0.013)	(0.012)	(0.023)	(0.029)	(0.019)
ln(Quantity$_i$)	0.133***	0.194***	0.059***	0.052***	0.129***	0.109***	0.128***
	(0.011)	(0.011)	(0.007)	(0.007)	(0.014)	(0.014)	(0.011)
ln(GDP$_e$)	0.772***	0.700***	0.325***	0.378***	0.679***	0.764***	0.774***
	(0.019)	(0.020)	(0.030)	(0.029)	(0.024)	(0.025)	(0.018)
ln(GDP$_i$)	0.769***	0.721***	0.645***	0.728***	0.700***	0.706***	0.769***
	(0.017)	(0.018)	(0.027)	(0.026)	(0.022)	(0.023)	(0.017)
ln(Population$_e$)	0.402***	0.558***	-0.018	0.011	0.393***	0.275***	0.264***
	(0.022)	(0.023)	(0.122)	(0.114)	(0.025)	(0.025)	(0.018)
ln(Population$_i$)	-0.047***	-0.022	0.467***	0.528***	0.166***	0.124***	0.082***
	(0.011)	(0.014)	(0.114)	(0.104)	(0.022)	(0.024)	(0.017)
mrRTA	0.517***	0.632***	0.469***	0.071***	0.576***	0.337***	0.580***
	(0.050)	(0.043)	(0.043)	(0.027)	(0.055)	(0.062)	(0.048)
mrCurrency	-0.012	0.509***	-0.012	0.205***	-0.072	0.001	0.058
	(0.138)	(0.119)	(0.128)	(0.039)	(0.142)	(0.166)	(0.134)
mr(ln)Distance	-1.308***	-1.048***	-1.317***		-1.274***	-1.308***	-1.248***
	(0.026)	(0.024)	(0.023)		(0.028)	(0.030)	(0.025)
mrLanguage	0.740***	0.857***	0.764***		0.693***	0.846***	0.660***
	(0.052)	(0.046)	(0.044)		(0.056)	(0.064)	(.050)
mrColony	0.674***	0.575***	0.633***		0.677***	0.626***	0.701***
	(0.102)	(0.086)	(0.089)		(0.108)	(0.117)	(0.100)
mrBorder	0.579***	0.832***	0.591***		0.650***	0.331***	0.604***
	(0.101)	(0.100)	(0.108)		(0.118)	(0.121)	(0.097)
mrLanguage	0.248***	0.260***	0.254***		0.250***	0.241***	0.257***
	(0.035)	(0.032)	(0.030)		(0.038)	(0.043)	(0.034)
ln(WG$_e$)					0.892***		
					(0.086)		
ln(WG$_i$)					0.515***		
					(0.078)		
ln(Roads$_e$)						0.198***	
						(0.025)	
ln(Roads$_i$)						0.336***	
						(0.023)	
Observations	174,443	174,443	174,443	174,443	109,672	61,126	204,562
Adj/Within/Pseudo R-sq.	0.718	0.721	0.777	0.198	0.726	0.730	-
Other Dummies	-	Continent	Countries	Country pair	-	-	-
# of country pairs				14,546			

Notes: Robust standard errors clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term and year dummies are included in all regressions but the coefficient is not reported. In columns (1) to (6) the log of bilateral trade is the dependent variable, while in (7) the EK-Tobit model was estimated so the dependent variable is the natural logarithm of the trade flow or of the minimum of trade reported by each importer each year. Except for Specifications (2) to (3), the bilateral variables are adjusted with the BB methodology.

5.2 Quality versus quantity: subsamples

Figure 1 and Figure 3 visualized the well-known digital divide between developed and developing countries. We now test if ICT quantity and quality have differential effects on trade in developed and developing countries. We estimate the full model for the different subsamples with the pooled OLS and different estimators and finally discuss the results exploiting the within variation of the data.

Interestingly, we consistently find a higher elasticity for quality in comparison to quantity for non-OECD countries (developing) (Table (2)). This holds for both export and import between non-OECD and other non-OECD countries (specification (3) in Table (2)), as well as for exports from non-OECD countries to OECD countries (developed) (specification (4)), and for imports of non-OECD countries from OECD countries (specification (5)). For developing economies, quality trumps quantity for both exports and imports. This has interesting implications for development policies: having internet access is important, but for developing countries, it is even more important to have good data speed.

On the contrary, in OECD (developed) countries quantity is consistently considered more important than quality. This holds for both export and import between OECD countries (specification (2) in Table (2)), imports of OECD countries from non-OECD countries (specification (4)), and exports from OECD to non-OECD countries (specification (5)).

The traditional time invariant gravity controls have the same sign and statistical significance for most of the subsamples. Regional trade agreements have a positive effect on most of the subsamples, except for trade within different country groupings. The sign of the common currency dummy is unstable across different subsamples. Overall, we can document a robust and sizeable effect of the quality for developing countries' exports, especially in developed nations. For non-OECD countries, the quantity is also sizeable for most estimators, although when we control for country pair heterogeneity this effect disappears.

Table 2: ICTs and trade - subsamples

	(1) ALL ALL	(2) OECD OECD	(3) Non-OECD Non-OECD	(4) Non-OECD OECD	(5) OECD Non-OECD
$\ln(Quality_e)$	0.514***	0.240***	0.490***	0.923***	0.384***
	(0.020)	(0.068)	(0.033)	(0.049)	(0.040)
$\ln(Quantity_e)$	0.285***	0.595***	0.246***	0.334***	0.413***
	(0.011)	(0.050)	(0.016)	(0.022)	(0.032)
$\ln(Quality_i)$	0.213***	-0.098	0.180***	0.103*	0.397***
	(0.019)	(0.071)	(0.033)	(0.061)	(0.032)
$\ln(Quantity_i)$	0.133***	0.310***	0.100***	0.290***	0.189***
	(0.011)	(0.055)	(0.016)	(0.050)	(0.016)
$\ln(GDP_e)$	0.772***	0.654***	0.778***	0.758***	0.844***
	(0.019)	(0.074)	(0.028)	(0.042)	(0.043)
$\ln(GDP_i)$	0.769***	0.764***	0.594***	0.908***	0.889***
	(0.017)	(0.077)	(0.027)	(0.068)	(0.027)
$\ln(Population_e)$	0.402***	0.468***	0.356***	0.647***	0.391***
	(0.022)	(0.104)	(0.030)	(0.063)	(0.051)
$\ln(Population_i)$	-0.047***	-0.289***	0.058***	-0.077	-0.201***
	(0.011)	(0.052)	(0.017)	(0.049)	(0.017)
mrRTA	0.517***	0.877***	1.167***	-0.034	0.069
	(0.050)	(0.209)	(0.081)	(0.119)	(0.089)
mrCurrency	-0.012	-0.113	0.475**	-0.872***	-0.289
	(0.138)	(0.139)	(0.236)	(0.229)	(0.199)

mr(ln)Distance	-1.308***	-0.825***	-1.444***	-1.261***	-1.397***
	(0.026)	(0.102)	(0.034)	(0.069)	(0.051)
mrLanguage	0.740***	-0.269	0.768***	0.273*	0.405***
	(0.052)	(0.196)	(0.067)	(0.139)	(0.099)
mrColony	0.674***	0.249	0.983***	0.697***	0.674***
	(0.102)	(0.228)	(0.212)	(0.177)	(0.129)
mrBorder	0.579***	0.329	0.426***	1.289***	1.026***
	(0.101)	(0.206)	(0.125)	(0.313)	(0.286)
mrLanguage	0.248***	0.505***	0.153***	0.457***	0.395***
	(0.035)	(0.104)	(0.047)	(0.086)	(0.062)
Observations	174,443	11,368	89,383	36,600	37,092
Adj. R-sq.	0.718	0.770	0.582	0.665	0.777
Exporter	ALL	OECD	Non-OECD	Non-OECD	OECD
Importer	ALL	OECD	Non-OECD	OECD	Non-OECD
Yr-dummies	YES	YES	YES	YES	YES

Notes: Robust standard errors clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term is included in all regressions but the coefficient is not reported. In columns (1) to (5) the log of bilateral trade is the dependent variable. The second line of the table indicates the exporter, while the third one the importer.

We further corroborated the robustness of these results including the institutional and then the infrastructural measure in Table S.4 and S.5 from the Supplementary Material. Moreover, in Table S.6 we also report the EK-Tobit estimates for the subsamples where there are missing values for the trade flows, namely trade within non-OECD countries, from OECD to non-OECD and vice-versa.[18] The coefficient for our variables of interest remain fairly the same, also when using the FGLS estimator (Table (S.7) of the Supplementary Material). The relationship between quantity and quality for the exporting countries is between twice and three times the size, while the quality and quantity are closer for the OECD countries, although the estimate for quantity is higher. The MNPML (Table (S.3) of the Supplementary Material) confirms the importance of quality for developing countries, as well as the one of quantity for developed ones. The main difference with previous estimates (with regard to MNPML) lies with the importer behavior, for which the coefficients become negative (and not always statistically significant). This makes the results inconclusive, although the other three estimators favor the positive effect on imports.

Table (3) focuses on the within variation. Here, some of the ICTs variables lose their statistical significance but the main conclusions remain. In columns (2) and (3) we observe that for developing countries' exports data speed quality is what matters the most. The effect is significantly higher than the one found in the regression including all of the countries. Moreover, when we compare these results to the ones using internet users in Table S.8 in the Supplementary Material, we are able to identify that quality is more important for the exports of these countries. The variable internet users was only able to identify a positive effects of ICTs for trade within developed countries (when controlling for country-pair unobserved heterogeneity). In contrary to our previous results, these results suggest that when controlling for country-pair heterogeneity (i.e. if we do not take into consideration the cross-sectional variation in the data), ICTs measured by internet users do not foster exports to high-income countries. For the subsamples of developed countries, we observe that the quantity of the subscriptions is what matters for their trading activity with other OECD countries, but not for developing countries. When controlling for potential country pair heterogeneity, it seems that the amount of subscriptions matters the most for trade within developed countries, while the effect of bandwidth quality is the most robust for exports of developing countries (be it to other developing or to developed countries).

[18] This estimator censors values for the missing observations and given that there is no missing/zero trade within OECD countries, we do not use this estimator for this subsample.

Table 3: ICTs and trade - subsamples with fixed effects

	(1) ALL ALL	(2) OECD OECD	(3) Non-OECD Non-OECD	(4) Non-OECD OECD	(5) OECD Non-OECD
ln(Quality$_e$)	0.023*	0.016	0.124***	0.121***	-0.026
	(0.013)	(0.027)	(0.024)	(0.030)	(0.022)
ln(Quantity$_e$)	0.019**	0.179***	-0.013	-0.016	0.022
	(0.007)	(0.019)	(0.012)	(0.013)	(0.021)
ln(Quality$_i$)	0.032***	0.003	0.051**	0.086**	0.017
	(0.012)	(0.021)	(0.023)	(0.038)	(0.019)
ln(Quantity$_i$)	0.052***	0.094***	0.041***	0.126***	0.034***
	(0.007)	(0.017)	(0.011)	(0.031)	(0.009)
ln(GDP$_e$)	0.378***	0.768***	0.212***	0.552***	0.434***
	(0.029)	(0.048)	(0.042)	(0.058)	(0.052)
ln(GDP$_i$)	0.728***	0.717***	0.716***	0.450***	0.849***
	(0.026)	(0.047)	(0.039)	(0.085)	(0.031)
ln(Population$_e$)	0.011	-3.323***	-0.056	-0.298	-0.822**
	(0.114)	(0.337)	(0.156)	(0.205)	(0.375)
ln(Population$_i$)	0.528***	-1.099***	0.710***	2.247***	-0.144
	(0.104)	(0.331)	(0.150)	(0.589)	(0.137)
mrRTA	0.071***	0.026	0.137**	-0.005	0.070*
	(0.027)	(0.064)	(0.055)	(0.064)	(0.037)
mrCurrency	0.205***	-0.085**	0.526	0.117	0.166
	(0.039)	(0.039)	(0.532)	(0.117)	(0.103)
Observations	174,443	11,368	89,383	36,600	37,092
R-squared	0.198	0.738	0.177	0.190	0.359
# of country pairs	14,546	812	8,342	2,695	2,697
Exporter	ALL	OECD	Non-OECD	Non-OECD	OECD
Importer	ALL	OECD	Non-OECD	OECD	Non-OECD
Yr-dummies	YES	YES	YES	YES	YES
FE	country pair	country pair	country pair	country pair	country pair

Notes: Robust standard errors clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term is included in all regressions but the coefficient is not reported. In columns (1) to (5) the log of bilateral trade is the dependent variable. The second line of the table indicates the exporter, while the third one the importer.

5.3 Disaggregated trade: types of goods

ICTs can provide more access to the global market for companies as well as for entrepreneurs. We believe that ICTs could have a higher impact on the trade of differentiated goods, whose specific product information sets them apart from others. Moreover, since these are usually more expensive goods it is important to have full information on the product and also on the company/person delivering the goods. Examples of such goods are machinery, shoes, and pharmaceuticals. The other two types of groups are the ones sold in organized exchanges (homogenous goods i.e. soybeans) or the ones with a reference price (i.e. certain chemicals for which prices are listed in specialized trade publications (Fink et al, 2005)). We would expect that the effect is lowest for homogenous goods, which would be in line with the findings of Fink et al. (2005).

Table (S.9) of the Supplementary Material shows that the effect of the quality and quantity of ICTs is higher for differentiated goods (columns (1-5)) compared to the effects for exports of reference priced goods (columns (6-15)). The highest coefficients for differentiated goods are found again for the subsample of non-OECD countries to OECD. The same pattern that ICTs quality have

a higher estimated elasticity with respect to trade for non-OECD countries can also be found here. The results for the full sample of our ICTs quantity variable are in line with those of Tang (2006), although our elasticities for quality are higher. Again, we expect the reason to be that our two variables of quantity and quality capture more than traditional ICT proxies.

6 Conclusion

In this paper we investigated whether there are differential effects of ICT quantity (subscriptions) and quality (bandwidth) on international trade for both developing and developed countries. We found a positive correlation between exports with both ICT quantity and quality, and showed that the quality of data speed is more important for developing countries than the number of ICT subscriptions.

Although this results could seem counter intuitive initially, it is important to remember that developing countries have been catching up equally in terms of the amount of subscriptions, while bandwidth speed quality is still diverse (Hilbert, 2016; see also Figure 1b). The variation in bandwidth speeds therefore plays a large role on the effect of ICTs on trade. Most developing countries are quickly closing the digital divide in terms of the number of subscriptions, while they are still far behind the technological frontier in terms of data speed (Figure 3). As such, our results can be interpreted in terms of a gap to the global technological frontier: not being able to communicate at the speed expected by the global technological frontier can inhibit the opportunity to participate in international trade. On the contrary, developed countries have already achieved a very good bandwidth speed. Actually, developed countries constitute the respective technological frontier in terms of bandwidth speed. Therefore the smaller estimated elasticity could be a result of decreasing marginal returns. Extra bandwidth is not associated with (robust) extra effects, as additional bandwidth would not allow them to explore more sophisticated communication channels (with whom?). But in developing countries it seems to matter to be as close as possible to the technological frontier in terms of data speed. Moreover, Rajabiun and Middleton (2015) have shown that countries that have higher average connectivity speeds have more stable connections. This could be another reason why the average of the connectivity would matter more for developing countries.

It is interesting to observe that the difference between the effect of quantity and quality is much larger for imports in developed countries (in favor of quantity) than for developing countries. The importance of more ICT subscriptions for import seems to suggest that once a certain level of data speed is guaranteed, further increases in the quantity of ICT subscriptions do lead to a positive effect on exports and imports. This might stem from the fact that more people are exposed to worldwide products through reliable and quality connections in global cyberspace. More ICT pervasiveness might favor demand for international products. This effect is detectable for developed countries. In short, our interpretation of our results is that trade thrives on getting closer to the technological frontier in terms of communication capacity. Once this is assured, more ICT subscriptions might lead to more imports by fostering demands for goods.

These results are relevant for both, hands-on policy recommendations and academic research. It shows that the effectiveness of policies that promote the adoption of more ICT for the sake of adopting more ICT has its limits, and that ICT quality matters, especially in developing countries. Recent studies have shown that the digital divide measured in terms of bandwidth speed it not closing: digital inequality fluctuates up- and down as technological progress constantly introduces new solutions to increase bandwidth speed, and technological diffusion tries to catch up (Hilbert,

2016). Additional mobile phones and internet connections might have important effects for many development goals regardless of their bandwidth speed (including transparency, democracy, security, empowerment, banking, etc.), but for international trade of developing countries, quality trumps quantity. This implies that development policy should carefully weight policies that aim at fostering both more and better ICT. When resources are scarce, there is often a trade-off between policies aiming at promoting incentives to investments in infrastructure expansion and infrastructure updating (e.g. roll-out of mobile networks vs. roll-out of fiber optic networks, etc.).

Considering both ICT quantity and quality we are able to detect higher effect sizes of ICT than previous studies that exclusively work with variables that mainly accounted for the quantity of ICT. Following the visual presentation in Figure 1b, we add an entire new dimension of the digital divide: both Saudi Arabia and South Korea count with 2 subscriptions per capita, but one counts with an average bandwidth of 1 Mbps per capita and the other one with 12 Mbps. We suspect that the main motivation for the preference for subscriptions statistics in international econometric exercises is the readily availability of subscription data and the difficulty of obtaining reliable bandwidth speed statistics (i.e. when lengthy time series require for normalization on compression rates; Hilbert and López, 2012b). While our dataset surely does not resolve this problem once and for all (as it comes with several caveats discussed above), our results show that technological progress over recent decades has made it is necessary to do this extra step and to account for both, quantity and quality. In this sense our results are a concrete case in point of the growing argument that digital connectivity metrics have to go beyond the accounting of technological devices (Zwart et al., 2015). While this study tested the differentiated effects of both ICT quantity and quality on international trade, we expect many interesting findings to be discovered once more fine-grained metrics of connectivity are applied to other aspects of socio-economic, cultural and political development (including latency, throughput, reliability, etc).

Supplementary Material

Table S.1: Countries included in the study

Albania	Dominican Rep.	Kuwait	Saudi Arabia
Algeria	Ecuador	Latvia	Senegal
Argentina	Egypt	Lebanon	Singapore
Australia	El Salvador	Lithuania	***Slovakia***
Austria	Estonia	Madagascar	Slovenia
Azerbaijan	Ethiopia	Malawi	South Africa
Bahrain	***Finland***	Malaysia	***Spain***
Bangladesh	***France***	Mali	Sri Lanka
Barbados	Gabon	Malta	Sudan
Belarus	Georgia	Mauritania	Suriname
Belgium	***Germany***	Mauritius	***Sweden***
Belize	Ghana	***Mexico***	***Switzerland***
Benin	***Greece***	Moldova, Rep.of	Syrian Arab Republic
Bolivia	Guatemala	Morocco	Tanzania
Brazil	Guinea	Mozambique	Thailand
Bulgaria	Guyana	Nepal	Togo
Burkina Faso	Honduras	***Netherlands***	Trinidad and Tobago
Cameroon	***Hungary***	***New Zealand***	Tunisia
Canada	***Iceland***	Nicaragua	***Turkey***
Chile	India	Niger	Uganda
China	Indonesia	Nigeria	Ukraine
Colombia	Iran	***Norway***	United Arab Emirates
Congo	***Ireland***	Oman	***United Kingdom***
Costa Rica	Israel	Pakistan	***United States***
Croatia	***Italy***	Panama	Uruguay
Cyprus	Jamaica	Paraguay	Venezuela
Czech Republic	***Japan***	Peru	Vietnam
CÃ´te d'Ivoire	Jordan	Philippines	Yemen
Dem. Rep. Congo	Kazakhstan	***Poland***	Zambia
Denmark	Kenya	***Portugal***	
Dominica	***Korea, Rep.***	Russian Fed.	

Notes: Countries in bold and italics are the countries considered as OECD- countries that entered OECD later than 2008 were not considered

Table S.2: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Full Sample					
ln(Quality)	174443	3.846	1.014	2.575	8.560
ln(Quantity)	174443	-2.456	2.631	-16.472	0.678
ln(Trade)	174443	1.882	3.575	-6.908	12.702
ln(Trade) (diff. goods)	164788	7.900	3.602	0	19.378
ln(Trade) (ref. p. goods)	140359	7.927	3.182	0	17.816
ln(Trade) (hom. goods)	124082	7.586	3.271	0	18.443
Regional Trade Agreements (RTA)	174443	0.121	0.326	0	1
Currency	174443	0.013	0.115	0	1
ln(GDP)	174443	10.811	2.015	5.412	16.469
ln(Distance)	174443	8.609	0.836	2.349	9.892
Colony	174443	0.018	0.134	0	1
Borders	174443	0.027	0.162	0	1
(common) Legal Original	174443	0.323	0.468	0	1
(common) Language	174443	0.136	0.343	0	1
ln(World Bank Governance)	118350	0.943	0.351	-1.298	1.501
ln(paved Roads)	100167	3.826	0.790	0.599	4.605
ln(Internet users)	166832	1.262	2.489	-10.953	4.511
OECD countries exporters and importers					
ln(Quality)	11368	4.414	1.327	3.007	8.560
ln(Quantity)	11368	-0.855	1.486	-8.056	0.678
Non-OECD countries exporters and importers					
ln(Quality)	89383	3.643	0.762	2.575	7.155
ln(Quantity)	89383	-2.264	2.650	-16.472	0.585
Non-OECD countries as exporters and OECD countries as importers					
ln(Quality)	36600	3.574	0.722	2.575	7.155
ln(Quantity)	36600	-3.341	2.841	-16.472	0.585
OECD countries as exporters and non-OECD countries as importers					
ln(Quality)	37092	4.429	1.329	3.007	8.560
ln(Quantity)	37092	-0.825	1.457	-8.056	0.678

Table S.3: ICTS and trade - MNPML

	(1)	(2)	(3)	(4)	(5)
ln(Quality$_e$)	0.0951***	0.0486	0.117**	0.606***	0.195***
	(0.0256)	(0.0524)	(0.0469)	(0.0614)	(0.0333)
ln(Quantity$_e$)	0.206***	0.518***	0.129***	0.258***	0.306***
	(0.0203)	(0.0753)	(0.0305)	(0.0354)	(0.0340)
ln(Quality$_i$)	-0.127***	-0.0468	-0.147***	-0.258***	-0.0278
	(0.0261)	(0.0617)	(0.0477)	(0.0762)	(0.0337)
ln(Quantity$_i$)	-0.0590***	0.212***	-0.0476**	-0.0981*	-0.0146
	(0.0138)	(0.0637)	(0.0220)	(0.0551)	(0.0153)
ln(GDP$_e$)	0.499***	0.536***	0.637***	0.580***	0.548***
	(0.0318)	(0.0662)	(0.0465)	(0.0561)	(0.0425)
ln(GDP$_i$)	-0.0449*	-0.164*	-0.0680	0.222**	0.000841
	(0.0247)	(0.0889)	(0.0439)	(0.0911)	(0.0262)
ln(Population$_e$)	0.221***	0.0344	0.0987**	0.231***	0.161***
	(0.0287)	(0.0686)	(0.0424)	(0.0481)	(0.0477)
ln(Population$_i$)	0.0125	0.143*	0.00180	-0.223**	0.00642
	(0.0240)	(0.0868)	(0.0415)	(0.0888)	(0.0267)
mrRTA	0.573***	0.309	0.700***	0.223*	0.0874
	(0.0678)	(0.195)	(0.0999)	(0.126)	(0.0817)
mrCurrency	0.190	0.212	0.396	-0.122	-0.877***
	(0.132)	(0.178)	(0.376)	(0.235)	(0.271)
mr(ln)Distance	-0.731***	-0.369***	-0.788***	-0.612***	-0.914***
	(0.0402)	(0.0809)	(0.0498)	(0.101)	(0.0382)
mrLanguage	0.262***	-0.189	0.334***	-0.0942	0.291***
	(0.0741)	(0.161)	(0.0942)	(0.159)	(0.0758)
mrColony	0.750***	0.0343	0.642***	0.540***	1.099***
	(0.130)	(0.198)	(0.173)	(0.133)	(0.115)
mrBorder	0.247**	0.825***	0.0806	0.641***	0.676***
	(0.112)	(0.162)	(0.129)	(0.220)	(0.257)
mrLegalOrigin	0.255***	0.376***	0.271***	0.510***	0.127**
	(0.0567)	(0.0954)	(0.0752)	(0.126)	(0.0547)
Observations	204,562	11,368	118,200	37,497	37,497
Exporter	ALL	OECD	Non-OECD	OECD	OECD
Importer	ALL	OECD	Non-OECD	Non-OECD	Non-OECD

Notes: Robust standard errors are clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term as well as year dummies are included in all regressions but the coefficients are not reported. The dependent variable is a market share constructed with the exports of country *e* to country *i* over the total imports of country *i* in year *t*.

Table S.4: ICTs and trade -subsamples including institutions

	(1)	(2)	(3)	(4)	(5)
ln(Quality$_e$)	0.387***	0.256**	0.309***	0.791***	0.230***
	(0.024)	(0.102)	(0.037)	(0.057)	(0.059)
ln(Quantity$_e$)	0.264***	0.768***	0.204***	0.337***	0.423***
	(0.015)	(0.076)	(0.021)	(0.028)	(0.042)
ln(Quality$_i$)	0.169***	-0.004	0.143***	0.173*	0.351***
	(0.023)	(0.110)	(0.038)	(0.090)	(0.037)
ln(Quantity$_i$)	0.129***	0.450***	0.090***	0.425***	0.221***
	(0.014)	(0.080)	(0.021)	(0.068)	(0.021)
ln(GDP$_e$)	0.679***	0.485***	0.754***	0.677***	0.803***
	(0.024)	(0.110)	(0.034)	(0.050)	(0.065)
ln(GDP$_i$)	0.700***	0.537***	0.540***	0.927***	0.832***
	(0.022)	(0.107)	(0.032)	(0.097)	(0.032)
ln(Population$_e$)	0.393***	0.362***	0.352***	0.485***	0.276***
	(0.025)	(0.124)	(0.032)	(0.047)	(0.076)
ln(Population$_i$)	0.166***	0.288**	0.227***	0.167	0.041
	(0.022)	(0.114)	(0.031)	(0.106)	(0.030)
mrRTA	0.576***	0.960***	1.232***	-0.256**	0.113
	(0.055)	(0.273)	(0.091)	(0.124)	(0.098)
mrCurrency	-0.072	-0.063	0.531**	-0.763***	-0.162
	(0.142)	(0.143)	(0.267)	(0.246)	(0.202)
mr(ln)Distance	-1.274***	-0.821***	-1.379***	-1.299***	-1.390***
	(0.028)	(0.107)	(0.038)	(0.075)	(0.055)
mrLanguage	0.693***	-0.290	0.728***	0.303**	0.398***
	(0.056)	(0.201)	(0.072)	(0.144)	(0.102)
mrColony	0.677***	0.507***	0.526	0.743***	0.711***
	(0.108)	(0.186)	(0.418)	(0.185)	(0.141)
mrBorder	0.650***	0.186	0.604***	1.279***	1.237***
	(0.118)	(0.192)	(0.143)	(0.359)	(0.319)
mrLegalOrigin	0.250***	0.479***	0.167***	0.360***	0.361***
	(0.038)	(0.108)	(0.050)	(0.091)	(0.066)
ln(WG$_e$)	0.892***	0.808	1.051***	0.843***	0.968***
	(0.086)	(0.511)	(0.107)	(0.168)	(0.317)
ln(WG$_i$)	0.515***	0.885*	0.482***	-0.550	0.235**
	(0.078)	(0.503)	(0.109)	(0.410)	(0.103)
Observations	109,672	7,020	56,870	22,736	23,046
Adj. R-sq.	0.726	0.764	0.585	0.672	0.778
Exporter	ALL	OECD	Non-OECD	Non-OECD	OECD
Importer	ALL	OECD	Non-OECD	OECD	Non-OECD

Notes: Robust standard errors clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term and year dummies are included in all regressions but the coefficients are not reported. In columns (1) to (5) the log of bilateral trade is the dependent variable.

Table S.5: ICTs and trade -subsamples including paved roads

	(1)	(2)	(3)	(4)	(5)
ln(Quality$_e$)	0.611***	0.346***	0.617***	1.095***	0.563***
	(0.031)	(0.094)	(0.054)	(0.071)	(0.060)
ln(Quantity$_e$)	0.239***	0.327***	0.219***	0.276***	0.107***
	(0.014)	(0.055)	(0.021)	(0.028)	(0.037)
ln(Quality$_i$)	0.239***	-0.035	0.167***	0.180**	0.429***
	(0.029)	(0.083)	(0.056)	(0.086)	(0.047)
ln(Quantity$_i$)	0.109***	0.107*	0.113***	-0.029	0.170***
	(0.014)	(0.058)	(0.020)	(0.059)	(0.020)
ln(GDP$_e$)	0.764***	0.637***	0.768***	0.766***	0.828***
	(0.025)	(0.093)	(0.038)	(0.054)	(0.056)
ln(GDP$_i$)	0.706***	0.761***	0.523***	0.960***	0.777***
	(0.023)	(0.091)	(0.036)	(0.088)	(0.033)
ln(Population$_e$)	0.275***	0.113	0.265***	0.341***	0.179***
	(0.025)	(0.097)	(0.036)	(0.051)	(0.061)
ln(Population$_i$)	0.124***	-0.028	0.195***	0.072	0.073**
	(0.024)	(0.092)	(0.035)	(0.091)	(0.032)
mrRTA	0.337***	0.987***	1.067***	-0.042	-0.025
	(0.062)	(0.218)	(0.108)	(0.154)	(0.118)
mrCurrency	0.001	-0.118	0.114	-0.360	-0.490*
	(0.166)	(0.174)	(0.284)	(0.336)	(0.263)
mr(ln)Distance	-1.308***	-0.843***	-1.533***	-1.159***	-1.397***
	(0.030)	(0.112)	(0.041)	(0.086)	(0.056)
mrLanguage	0.846***	-0.324	0.884***	0.373**	0.555***
	(0.064)	(0.228)	(0.082)	(0.167)	(0.120)
mrColony	0.626***	0.157	1.218***	0.601***	0.545***
	(0.117)	(0.282)	(0.297)	(0.183)	(0.126)
mrBorder	0.331***	0.439**	-0.024	1.270***	1.163***
	(0.121)	(0.206)	(0.161)	(0.362)	(0.270)
mrLegalOrigin	0.241***	0.611***	0.110*	0.557***	0.378***
	(0.043)	(0.121)	(0.060)	(0.101)	(0.073)
ln(Roads$_e$)	0.198***	0.825***	0.146***	0.087**	0.880***
	(0.025)	(0.109)	(0.032)	(0.044)	(0.074)
ln(Roads$_i$)	0.336***	0.619***	0.244***	0.860***	0.344***
	(0.023)	(0.101)	(0.032)	(0.095)	(0.030)
Observations	61,126	5,102	28,417	13,687	13,920
Adj. R-sq.	0.728	0.800	0.589	0.674	0.787
Exporter	ALL	OECD	Non-OECD	Non-OECD	OECD
Importer	ALL	OECD	Non-OECD	OECD	Non-OECD

Notes: Robust standard errors clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term as well as year dummies are included in all regressions but the coefficients are not reported. In columns (1) to (5) the log of bilateral trade is the dependent variable.

Table S.6: ICTS and trade -EK Tobit for subsamples

	(1)	(2)	(3)
ln(Quality$_e$)	0.550***	0.921***	0.385***
	(0.032)	(0.049)	(0.040)
ln(Quantity$_e$)	0.244***	0.335***	0.415***
	(0.015)	(0.022)	(0.032)
ln(Quality$_i$)	0.214***	0.105*	0.394***
	(0.032)	(0.061)	(0.032)
ln(Quantity$_i$)	0.103***	0.291***	0.189***
	(0.015)	(0.050)	(0.016)
ln(GDP$_e$)	0.760***	0.763***	0.848***
	(0.027)	(0.042)	(0.043)
ln(GDP$_i$)	0.582***	0.912***	0.891***
	(0.026)	(0.068)	(0.027)
ln(Population$_e$)	0.261***	0.354***	0.192***
	(0.025)	(0.039)	(0.047)
ln(Population$_i$)	0.156***	0.207***	-0.014
	(0.024)	(0.072)	(0.025)
mrRTA	1.212***	-0.031	0.044
	(0.077)	(0.119)	(0.089)
mrCurrency	0.663***	-0.869***	-0.281
	(0.216)	(0.227)	(0.196)
mr(ln)Distance	-1.313***	-1.252***	-1.394***
	(0.033)	(0.069)	(0.051)
mrLanguage	0.656***	0.248*	0.398***
	(0.065)	(0.139)	(0.099)
mrColony	1.017***	0.707***	0.676***
	(0.197)	(0.177)	(0.129)
mrBorder	0.500***	1.296***	1.028***
	(0.117)	(0.312)	(0.285)
mrLegalOrigin	0.150***	0.439***	0.391***
	(0.045)	(0.086)	(0.062)
Observations	118,200	37,497	37,497
Exporter	Non-OECD	OECD	OECD
Importer	Non-OECD	Non-OECD	Non-OECD

Notes: Robust standard errors are clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term as well as year dummies are included in all regressions but the coefficients are not reported. The dependent variable is the log of bilateral trade and when the values are missing the smallest recorded value (in logarithms) was used as the censored observation value.

Table S.7: ICTS and trade -FGLS for subsamples

	(1)	(2)	(3)	(4)
ln(Quality$_e$)	0.0562***	0.268***	0.322***	0.184***
	(0.0122)	(0.0126)	(0.0127)	(0.0121)
ln(Quantity$_e$)	0.153***	0.117***	0.109***	0.200***
	(0.00964)	(0.00588)	(0.00545)	(0.0103)
ln(Quality$_i$)	0.0263**	0.0372***	0.0795***	0.161***
	(0.0117)	(0.0118)	(0.0152)	(0.00952)
ln(Quantity$_i$)	0.0923***	0.0270***	0.135***	0.0796***
	(0.00885)	(0.00537)	(0.0122)	(0.00406)
ln(GDP$_e$)	0.762***	0.923***	0.921***	0.836***
	(0.0161)	(0.00952)	(0.0103)	(0.0143)
ln(GDP$_i$)	0.762***	0.693***	0.831***	0.940***
	(0.0151)	(0.00883)	(0.0176)	(0.00743)
ln(Population$_e$)	-0.0371**	0.123***	0.0977***	0.0997***
	(0.0171)	(0.00872)	(0.00917)	(0.0151)
ln(Population$_i$)	-0.0263	0.0733***	0.222***	-0.111***
	(0.0163)	(0.00836)	(0.0186)	(0.00691)
mrAgreement	0.101***	0.557***	0.0282	0.0930***
	(0.0266)	(0.0204)	(0.0221)	(0.0188)
mrCurrency	-0.0199	1.036***	-0.104	0.0250
	(0.0188)	(0.0848)	(0.0784)	(0.0577)
mr(ln)Distance	-1.077***	-1.428***	-1.120***	-1.351***
	(0.0199)	(0.00994)	(0.0178)	(0.0137)
mrLanguage	-0.108**	0.885***	0.130***	0.270***
	(0.0454)	(0.0216)	(0.0385)	(0.0280)
mrColony	0.0304	0.995***	0.688***	0.706***
	(0.0445)	(0.0730)	(0.0466)	(0.0329)
mrBorder	0.204***	0.306***	1.239***	0.836***
	(0.0414)	(0.0287)	(0.0715)	(0.0471)
mrLegalOrigin	0.481***	0.163***	0.393***	0.347***
	(0.0258)	(0.0153)	(0.0241)	(0.0174)
Observations	11,368	89,144	36,598	37,091
Exporter	OECD	Non-OECD	OECD	OECD
Importer	OECD	Non-OECD	Non-OECD	Non-OECD

Notes: Panels are assumed heteroskedastic and the autocorrelation structure was specified as AR(1). One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term as well as year dummies are included in all regressions but the coefficients are not reported. The dependent variable is the natural logarithm of the bilateral trade.

In Table S.8 we now perform the same analysis as before but including the amount of internet users instead of our quality and quantity measures. We observe that the elasticity for OECD countries as exporters is higher than for developing countries, though not always statistically significant for the latter group. This can be observed in Specification (13). If we compare it with the equivalent in Table 3 (column (6)) we can observe that quality is what matters for this subsample. Our results suggest that when developing countries have better access to the internet, their commercial opportunities do increase. The positive effect (while controlling for country pair heterogeneity and analyzing the changes over time) does not seem to stem from more equipments. As we saw in previous sections, developing countries do have more similar amounts of equipment- the issue is that that they are not able to communicate much information - equipments are either old or internet access is slow and is interrupted very often.

Table S.8: Internet users and international trade

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ln(internetUser$_e$)	0.194***	0.035	0.240***	0.281***	0.002	0.061***	0.174***	0.042***	0.003	0.034*
	(0.011)	(0.053)	(0.016)	(0.024)	(0.034)	(0.007)	(0.016)	(0.011)	(0.012)	(0.019)
ln(internetUser$_i$)	0.041***	-0.116**	0.062***	-0.269***	0.120***	0.062***	0.050***	0.052***	0.008	0.046***
	(0.010)	(0.049)	(0.016)	(0.048)	(0.015)	(0.006)	(0.017)	(0.011)	(0.028)	(0.008)
ln(GDP$_e$)	0.990***	1.152***	0.865***	0.959***	1.293***	0.329***	0.830***	0.175***	0.573***	0.453***
	(0.015)	(0.067)	(0.027)	(0.041)	(0.040)	(0.029)	(0.047)	(0.043)	(0.059)	(0.051)
ln(GDP$_i$)	0.919***	1.039***	0.665***	1.378***	1.019***	0.737***	0.803***	0.727***	0.566***	0.843***
	(0.014)	(0.069)	(0.025)	(0.061)	(0.025)	(0.026)	(0.045)	(0.040)	(0.083)	(0.031)
ln(Population$_e$)	0.092***	-0.374***	0.206***	0.201***	-0.262***	-0.258**	-3.006***	-0.363**	-0.583***	-0.881**
	(0.016)	(0.072)	(0.026)	(0.039)	(0.046)	(0.113)	(0.326)	(0.158)	(0.206)	(0.375)
ln(Population$_i$)	-0.047***	-0.295***	0.102***	-0.298***	-0.132***	0.441***	-0.919***	0.580***	2.384***	-0.231*
	(0.015)	(0.070)	(0.024)	(0.065)	(0.024)	(0.098)	(0.338)	(0.143)	(0.599)	(0.133)
ln(Population$_i$)	0.511***	0.895***	1.146***	-0.003	0.093	0.068**	0.033	0.132**	-0.009	0.069*
	(0.050)	(0.227)	(0.080)	(0.125)	(0.094)	(0.027)	(0.064)	(0.056)	(0.063)	(0.037)
mrCurrency	-0.009	-0.100	0.476**	-0.863**	-0.308	0.188***	-0.083**	-0.103	0.114	0.164
	(0.137)	(0.142)	(0.237)	(0.370)	(0.285)	(0.036)	(0.040)	(0.544)	(0.109)	(0.104)
mr(ln)Distance	-1.301***	-0.846***	-1.443***	-1.249***	-1.401***					
	(0.026)	(0.105)	(0.034)	(0.073)	(0.055)					
mrLanguage	0.731***	-0.257	0.755***	0.280**	0.406***					
	(0.053)	(0.193)	(0.068)	(0.142)	(0.104)					
mrColony	0.663*** *	0.226	0.973***	0.683***	0.667***					
	(0.103)	(0.231)	(0.222)	(0.180)	(0.129)					
mrBorder	0.574***	0.303	0.427***	1.307***	1.022***					
	(0.103)	(0.214)	(0.128)	(0.326)	(0.300)					
mrLegalOrigin	0.234***	0.504***	0.130***	0.462***	0.389***					
	(0.035)	(0.111)	(0.048)	(0.088)	(0.066)					
Observations	166,832	11,200	84,934	35,118	35,580	166,832	11,200	84,934	35,118	35,580
Adj./Within R-sq.	0.716	0.752	0.583	0.659	0.767	0.201	0.737	0.176	0.192	0.364
Exporter	ALL	OECD	Non-OECD	Non-OECD	OECD	ALL	OECD	Non-OECD	Non-OECD	OECD
Importer	ALL	OECD	Non-OECD	OECD	Non-OECD	ALL	OECD	Non-OECD	OECD	Non-OECD
Yr-dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Other dummies	-	-	-	-	-	country-pair	country-pair	country-pair	country-pair	country-pair
# of country-pairs	14,514	812	8,310	2,695	2,697	14,514	812	8,310	2,695	2,697

Notes: Robust standard errors clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term is included in all regressions but the coefficient is not reported. In columns (1) to (10) the log of bilateral trade is the dependent variable.

Table S.9: ICTs and trade- Rauch classification

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
ln(Quality$_e$)	0.860***	0.355***	0.777***	1.577***	0.526***	0.298***	-0.049	0.174***	0.759***	0.272***	-0.276***	-0.404***	-0.204***	0.071	-0.427***
	(0.020)	(0.074)	(0.032)	(0.053)	(0.042)	(0.022)	(0.084)	(0.036)	(0.055)	(0.050)	(0.032)	(0.136)	(0.052)	(0.072)	(0.081)
ln(Quantity$_e$)	0.460***	0.867***	0.358***	0.608***	0.622***	0.251***	0.322***	0.165***	0.391***	0.167***	-0.138***	-0.272***	-0.105***	-0.040	-0.450***
	(0.012)	(0.054)	(0.016)	(0.024)	(0.033)	(0.013)	(0.057)	(0.019)	(0.027)	(0.039)	(0.018)	(0.095)	(0.025)	(0.034)	(0.064)
ln(Quality$_i$)	0.093***	-0.102	0.034	-0.261***	0.422***	0.109***	-0.124	-0.002	0.155**	0.456***	0.251***	0.096	0.112**	0.189**	0.663***
	(0.019)	(0.081)	(0.033)	(0.063)	(0.034)	(0.022)	(0.081)	(0.037)	(0.068)	(0.041)	(0.029)	(0.129)	(0.049)	(0.088)	(0.060)
ln(Quantity$_i$)	0.069***	0.307***	0.022	0.064	0.210***	0.088***	0.298***	0.008	0.216***	0.207***	0.142***	0.682***	0.034	0.496***	0.239***
	(0.011)	(0.062)	(0.016)	(0.051)	(0.017)	(0.012)	(0.065)	(0.019)	(0.057)	(0.019)	(0.016)	(0.095)	(0.024)	(0.070)	(0.029)
ln(GDP$_e$)	0.674***	0.352***	0.641***	0.465***	0.700***	0.697***	1.015***	0.690***	0.719***	0.772***	0.690***	1.666***	0.764***	0.861***	1.187***
	(0.018)	(0.081)	(0.026)	(0.043)	(0.046)	(0.020)	(0.082)	(0.032)	(0.048)	(0.050)	(0.027)	(0.141)	(0.043)	(0.059)	(0.083)
ln(GDP$_i$)	0.769***	0.724***	0.519***	1.175***	0.876***	0.694***	0.830***	0.545***	0.693***	0.846***	0.561***	0.542***	0.480***	0.335***	0.498***
	(0.018)	(0.085)	(0.026)	(0.069)	(0.029)	(0.020)	(0.091)	(0.031)	(0.076)	(0.034)	(0.026)	(0.130)	(0.039)	(0.093)	(0.050)
ln(Popul$_e$)	0.391***	0.591***	0.346***	0.668***	0.407***	0.189***	-0.354***	0.160***	0.311***	0.071	0.010	-1.040***	-0.092**	0.055	-0.394***
	(0.019)	(0.087)	(0.025)	(0.040)	(0.050)	(0.021)	(0.092)	(0.029)	(0.045)	(0.056)	(0.028)	(0.152)	(0.039)	(0.055)	(0.088)
ln(Popul$_i$)	-0.044**	0.028	0.013	-0.147**	-0.012	0.092***	0.022	0.085***	0.397***	0.046	0.222***	0.468***	0.182***	0.744***	0.237***
	(0.017)	(0.088)	(0.025)	(0.072)	(0.026)	(0.020)	(0.095)	(0.029)	(0.081)	(0.031)	(0.027)	(0.138)	(0.037)	(0.098)	(0.046)
mrAgreem.	0.635***	0.982***	1.099***	0.049	0.059	0.734***	0.603**	1.129***	-0.055	0.277**	0.564***	0.728**	0.637***	0.399**	0.565***
	(0.049)	(0.227)	(0.076)	(0.127)	(0.092)	(0.051)	(0.244)	(0.083)	(0.141)	(0.113)	(0.066)	(0.334)	(0.110)	(0.199)	(0.185)
mrCurrency	0.112	0.010	0.512**	-0.707***	-0.384	0.223*	0.031	0.308	0.287	-0.104	-0.013	0.019	-0.425	-0.324	0.678*
	(0.126)	(0.157)	(0.211)	(0.259)	(0.241)	(0.123)	(0.173)	(0.251)	(0.250)	(0.241)	(0.134)	(0.237)	(0.279)	(0.438)	(0.389)
mr(ln)Dist.	-1.358***	-0.767***	-1.460***	-1.318***	-1.400***	-1.311***	-1.119***	-1.333***	-1.399***	-1.604***	-1.341***	-1.540***	-1.272***	-1.272***	-1.947***
	(0.025)	(0.113)	(0.032)	(0.070)	(0.053)	(0.026)	(0.120)	(0.036)	(0.078)	(0.058)	(0.035)	(0.172)	(0.048)	(0.102)	(0.085)
mrLangua.	0.784***	-0.133	0.830***	0.204	0.500***	0.440***	-0.407*	0.508***	0.361**	0.207*	0.059	-0.722**	0.178*	0.203	0.237
	(0.052)	(0.216)	(0.064)	(0.148)	(0.106)	(0.057)	(0.234)	(0.074)	(0.163)	(0.118)	(0.071)	(0.332)	(0.095)	(0.186)	(0.180)
mrColony	0.661***	0.078	1.269***	0.891***	0.716***	0.823***	0.212	0.921***	0.892***	0.684***	1.236***	0.724**	1.505***	0.893***	1.189***
	(0.106)	(0.233)	(0.280)	(0.195)	(0.138)	(0.109)	(0.245)	(0.346)	(0.225)	(0.148)	(0.117)	(0.343)	(0.314)	(0.223)	(0.197)
mrBorder	0.568***	0.318	0.523***	0.741**	0.943***	0.558***	0.285	0.465***	1.368***	1.134***	0.506***	0.540*	0.445***	1.918***	0.823**
	(0.097)	(0.216)	(0.117)	(0.363)	(0.289)	(0.095)	(0.234)	(0.127)	(0.360)	(0.286)	(0.109)	(0.303)	(0.144)	(0.389)	(0.406)
mrLegalOrigin	0.275***	0.460***	0.239***	0.330***	0.365***	0.336***	0.643***	0.238***	0.472***	0.369***	0.359***	0.965***	0.195***	0.327***	0.491***
	(0.035)	(0.113)	(0.045)	(0.094)	(0.067)	(0.038)	(0.130)	(0.052)	(0.101)	(0.072)	(0.050)	(0.177)	(0.069)	(0.124)	(0.101)
Observations	164,788	11,368	80,977	35,565	36,878	140,359	11,365	61,332	32,240	35,422	124,082	11,224	53,442	30,347	29,069
Adj. R-sq.	0.738	0.739	0.598	0.655	0.768	0.646	0.704	0.516	0.571	0.664	0.445	0.568	0.359	0.418	0.431
Exporter	ALL	OECD	nonOECD	nonOECD	OECD	ALL	OECD	nonOECD	nonOECD	OECD	ALL	OECD	nonOECD	nonOECD	OECD
Importer	ALL	OECD	nonOECD	OECD	nonOECD	ALL	OECD	nonOECD	OECD	nonOECD	ALL	OECD	nonOECD	OECD	nonOECD
Good	Diff	Diff	Diff	Diff	Diff	Ref	Ref	Ref	Ref	Ref	Hom	Hom	Hom	Hom	Hom

Notes: Robust standard errors are clustered at the country pair level. One asterisk indicates significance at the 10 percent level, two asterisks indicate significance at the 5 percent level, and three asterisks indicate significance at the 1 percent level. A constant term as well as year dummies are included in all regressions but the coefficients are not reported. The log of bilateral trade is the dependent variable. Diff refers to differentiated goods, Ref to referenced priced and Hom to homogenous.

Table S.10: Correlation matrix

	ln(Trade)	ln(GDP_e)	ln(GDP_i)	ln($Quality_e$)	ln($Quantity_e$)	ln($Quality_i$)	ln($Quantity_i$)	Agreement	Currency	ln(Distance)	Language	Colony	Borders	LegalOrigin	ln($internetUser_e$)	ln($internetUser_i$)
ln(Trade)	1															
ln(GDP_e)	0.587	1.000														
ln(GDP_i)	0.456	-0.080	1.000													
ln($Quality_e$)	0.291	0.430	0.064	1.000												
ln($Quantity_e$)	0.268	0.414	0.008	0.584	1.000											
ln($Quality_i$)	0.231	0.062	0.438	0.504	0.399	1.000										
ln($Quantity_i$)	0.210	0.008	0.424	0.403	0.455	0.583	1.000									
Agreement	0.306	0.082	0.090	0.149	0.148	0.152	0.152	1.000								
Currency	0.091	0.000	0.003	0.030	0.020	0.031	0.021	0.236	1.000							
ln(Distance)	-0.253	0.043	0.033	-0.007	-0.029	-0.009	-0.029	-0.540	-0.209	1.000						
Language	0.035	-0.093	-0.088	-0.056	-0.068	-0.054	-0.067	0.134	0.139	-0.159	1.000					
Colony	0.155	0.079	0.081	0.023	0.028	0.025	0.029	0.038	-0.014	-0.067	0.191	1.000				
Borders	0.168	0.002	0.006	-0.017	-0.028	-0.015	-0.025	0.268	0.159	-0.390	0.149	0.112	1.000			
LegalOrigin	-0.013	-0.077	-0.082	-0.093	-0.075	-0.094	-0.079	0.047	0.089	-0.095	0.366	0.137	0.125	1.000		
ln($internetUser_e$)	0.300	0.457	-0.010	0.616	0.935	0.332	0.387	0.150	0.004	-0.013	-0.069	0.029	-0.031	-0.091	1.000	
ln($internetUser_i$)	0.227	-0.009	0.466	0.335	0.385	0.617	0.936	0.155	0.006	-0.013	-0.066	0.031	-0.027	-0.097	0.327	1.000

References

Acemoglu, D., Aghion, P., Lelarge, C., Reenen, J. V., and Zilibotti, F. (2007). Technology, Information, and the Decentralization of the Firm. *Quarterly Journal of Economics*, 122(4):1759–1799.

Ahmad, N. A., Ismail, N. W., and Hook, L. S. (2011). The Role of ICT Infrastructure on Malaysian Trade. *Journal of Economics and Management*, 5(1):140–148.

Anderson, J. E. and van Wincoop, E. (2003). Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review*, 93(1):170–192.

Baier, S. L. and Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics*, 71(1):72–95.

Baier, S. L. and Bergstrand, J. H. (2009). Bonus vetus OLS: A simple method for approximating international trade-cost effects using the gravity equation. *Journal of International Economics*, 77(1):77–85.

Baier, S. L. and Bergstrand, J. H. (2010). Approximating general equilibrium impacts of trade liberalizations using the gravity equation. In van Bergeijk, P. A. G. and Brakman, S., editors, *The Gravity Model in International Trade*, pages 88–134. Cambridge University Press. Cambridge Books Online.

Bakos, Y. (2001). The Emerging Landscape for Retail E-Commerce. *Journal of Economic Perspectives*, 15(1):69–80.

Bauer, S., Clark, D., & Lehr, W. (2010). Understanding broadband speed measurements. Presented at the *38th Research Conference on Communication, Information, and Internet Policy* (TPRC), Arlington, Virginia. Retrieved from http://people.csail.mit.edu/wlehr/Lehr-Papers_files/bauer_clark_lehr_2010.pdf Behrens, K., Ertur, C., and Koch, W. (2012). "Dual" Gravity: Using Spatial Econometrics to Control for Multilateral Resistance. *Journal of Applied Econometrics*, 27(5):773–794.

Berden, K., Bergstrand, J. H., and van Etten, E. (2014). Governance and Globalisation. *The World Economy*, 37(3):353–386.

Borenstein, S. and Saloner, G. (2001). Economics and Electronic Commerce. *Journal of Economic Perspectives*, 15(1):3–12.

Bresnahan, T. F. (1986). Measuring the Spillovers from Technical Advance: Mainframe Computers in Financial Services. *American Economic Review*, 76(4):742–55.

Brynjolfsson, E. and Hitt, L. (1995). Information technology as a factor of production: The role of differences among firms. *Economics of Innovation and New Technology*, 3(3-4):183–200.

Cairncross, F. (2001). *The death of distance: how the communications revolution is changing our lives*. Harvard Business School Press, Boston.

Campos, N. F. (2010). The impact of information technologies on economic growth in Latin America in comparative perspective. In Cimoli, M., Hofman, A. A., and Mulder, N., editors, *Innovation and Economic Development*, pages 139–158. Edward Elgar Publishing.

Carrére, C., de Melo, J., and Wilson, J. (2013). The Distance Puzzle and Low-Income Countries: An Update. *Journal of Economic Surveys*, 27(4):717–742.

Carrére, C., De Melo, J., and Wilson, J. S. (2010). Distance and the Regionalization of Trade for Low-Income Countries. Policy Research Working Paper 5214, World Bank.

Castells, M. (2009). *The Rise of the Network Society: The Information Age: Economy, Society, and Culture*, volume 1. Wiley-Blackwell, 2 edition.

Choi, C. (2010). The effect of the Internet on service trade. *Economics Letters*, 109(2), 102–104. http://doi.org/10.1016/j.econlet.2010.08.005

Clarke, G. R. G. and Wallsten, S. J. (2006). Has the Internet Increased Trade? Developed and Developing Country Evidence. *Economic Inquiry*, 44(3):465–484.

Crozet, M., Head, K., and Mayer, T. (2012). Quality Sorting and Trade: Firm-level Evidence for French Wine. *Review of Economic Studies*, 79(2):609–644.

Datta, A. and Agarwal, S. (2004). Telecommunications and economic growth: a panel data approach. *Applied Economics*, 36(15):1649–1654.

de Jong, E. and Bogmans, C. (2011). Does corruption discourage international trade? *European Journal of Political Economy*, 27(2):385–398.

de Sousa, J. (2012). The currency union effect on trade is decreasing over time. *Economics Letters*, 117(3):917–920.

Demirkan, H., Goul, M., Kauffman, R. J., and Weber, D. M. (2009). Does Distance Matter? The Influence of ICT on Bilateral Trade Flows. In *Proceedings of the Second Annual SIG GlobDev Workshop, Phoenix, USA, December 14, 2009*, volume 19.

Dimelis, S. P. and Papaioannou, S. K. (2011). ICT growth effects at the industry level: A comparison between the US and the EU. *Information Economics and Policy*, 23(1):37–50.

Duggal, V. G., Saltzman, C., and Klein, L. R. (2007). Infrastructure and productivity: An extension to private infrastructure and it productivity. *Journal of Econometrics*, 140(2):485–502.

Eaton, J. and Kortum, S. (2001). Technology, trade, and growth: A unified framework. *European Economic Review*, 45(4–6):742–755.

Eaton, J., Kortum, S. S., and Sotelo, S. (2012). International trade: Linking micro and macro. Technical report, National Bureau of Economic Research.

Egger, P. and Gassebner, M. (2014). International terrorism as a trade impediment? *Oxford Economic Papers*, 67(1):1–30.

Egger, P. and Nelson, D. (2011). How bad is antidumping? Evidence from panel data. *Review of Economics and Statistics*, 93(4):1374–1390.

Fink, C., Mattoo, A., & Neagu, I. C. (2005). Assessing the impact of communication costs on international trade. Journal of International Economics, 67(2), 428–445. http://doi.org/10.1016/j.jinteco.2004.09.006

Francois, J. and Manchin, M. (2013). Institutions, Infrastructure, and Trade. *World Development*, 46:165–175.

Francois, J. and Manchin, M. (2014). Protection and Performance. *The World Economy*, 37(4):567–578.

Frankel, J. A., Stein, E., and Wei, S.-J. (1997). *Regional Trading Blocs in the World Economic System*. Peterson Institute.

Freund, C. and Weinhold, D. (2002). The Internet and International Trade in Services. *American Economic Review*, 92(2):236–240.

Freund, C. L. and Weinhold, D. (2004). The effect of the Internet on international trade. *Journal of International Economics*, 62(1):171–189.

Gaulier, G. and Zignago, S. (2010). BACI: International Trade Database at the Product-Level. The 1994–2007 Version. Working Paper 2010-23, CEPII Research Center.

Glick, R. and Rose, A. K. (2015). Currency Unions and Trade: A Post-EMU Mea Culpa. Discussion Paper DP10615, CEPR.

Gradeva, K. and Martí-nez-Zarzoso, I. (2015). Are Trade Preferences more Effective than Aid in Supporting Exports? Evidence from the â€˜Everything But Arms Preference Scheme. *The World Economy*.

Hardy, A. P. (1980). The role of the telephone in economic development. *Telecommunications Policy*, 4(4):278–286.

Head, K. and Mayer, T. (2014). Gravity Equations: Workhorse, Toolkit, and Cookbook. *Handbook of International Economics*, 4:131–196.

Hilbert, M. (2014a). How much of the global information and communication explosion is driven by more, and how much by better technology? *Journal of the Association for Information Science and Technology*, 65(4):856–861.

Hilbert, M. (2014b). Technological information inequality as an incessantly moving target: The redistribution of information and communication capacities between 1986 and 2010. *Journal of the Association for Information Science and Technology*, 65(4):821–835.

Hilbert, M. and López, P. (2011). The World's Technological Capacity to Store, Communicate, and Compute Information. *Science*, 332(6025):60–65.

Hilbert, M. and López, P. (2012a). How to measure the world's technological capacity to communicate, store and compute information? Part I: Results and scope. *International Journal of Communication*, 6:956–979.

Hilbert, M. and López, P. (2012b). How to measure the world's technological capacity to communicate, store and compute information? Part II: Measurement unit and conclusions. *International Journal of Communication*, 6(1):936–955.

Hilbert, M., López, P., and Vásquez, C. (2010). Information Societies or 'ICT Equipment Societies?' Measuring the Digital Information-Processing Capacity of a Society in Bits and Bytes. *The Information Society*, 26(3):157–178.

Hilbert, M. (2016). The bad news is that the digital access divide is here to stay: Domestically installed bandwidths among 172 countries for 1986-2014. *Telecommunications Policy*.

Hofman, A., Aravena, C., and Aliaga, V. (2016). Information and communication technologies and their impact in the economic growth of Latin America, 1990-2013. *Telecommunications Policy*.

International Telecommunication Union (ITU) (2012). Measuring the Information Society. *International Telecommunication Union*.

International Telecommunication Union (ITU) (2014). World Telecommunication/ICT Indicators Database.

Jorgenson, D. W. and Stiroh, K. (1995). Computers And Growth. *Economics of Innovation and New Technology*, 3(3–4):295–316.

Jorgenson, D. W. and Vu, K. (2007). Information technology and the world growth resurgence. *German Economic Review*, 8(2):125–145.

Jorgenson, D. W. and Vu, K. M. (2016). The ICT revolution, world economic growth, and policy issues. *Telecommunications Policy*.

Kaufmann, D., Kraay, A., and Mastruzzi, M. (2011). The worldwide governance indicators: methodology and analytical issues. *Hague Journal on the Rule of Law*, 3(02):220–246.

Liu, L., & Nath, H. K. (2013). Information and Communications Technology and Trade in Emerging Market Economies. *Emerging Markets Finance and Trade*, 49(6), 67–87. http://doi.org/10.2753/REE1540-496X490605

Manning, W. G. and Mullahy, J. (2001). Estimating log models: to transform or not to transform? *Journal of health economics*, 20(4):461–494.

Márquez-Ramos, L. and Martínez-Zarzoso, I. (2010). The effect of technological innovation on international trade. *Economics - The Open-Access, Open-Assessment E-Journal*, 4(11):1–37.

Márquez-Ramos, L., Martínez-Zarzoso, I., and Suárez-Burguet, C. (2012). Trade Policy versus Trade Facilitation: An Application Using "Good Old" OLS. *Economics: The Open-Access, Open-Assessment E-Journal*, 6(2012-11):1–38.

Martínez-Zarzoso, I. (2013). The log of gravity revisited. *Applied Economics*, 45(3):311–327.

Mattes, A., Meinen, P., and Pavel, F. (2012). Goods follow bytes: The impact of ICT on EU trade. Discussion Paper 1182, DIW Berlin.

Mayer, T. and Zignago, S. (2011). Notes on CEPII's distances measures: The GeoDist database. Working Paper 2011-25, CEPII.

Melitz, J. and Toubal, F. (2014). Native language, spoken language, translation and trade. *Journal of International Economics*, 93(2):351–363.

Minges, M. (2005). Evaluation of e-Readiness Indices in Latin America and the Caribbean. Technical report, Santiago: CEPAL.

Oliner, S. D., Sichel, D. E., Triplett, J. E., and Gordon, R. J. (1994). Computers and output growth revisited: how big is the puzzle? *Brookings Papers on Economic Activity*, 1994(2):273–334.

Portugal-Perez, A. and Wilson, J. S. (2012). Export Performance and Trade Facilitation Reform: Hard and Soft Infrastructure. *World Development*, 40(7):1295–1307.

Rajabiun, R. and Middleton, C. (2015). Lemons on the Edge of the Internet: The Importance of Transparency for Broadband Network Quality. *Communications & Strategies*, 98(2):119–136.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, 48(1):7–35.

Roller, L.-H. and Waverman, L. (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. *American Economic Review*, 91(4):909–923.

Rosenblat, T. S. and Mobius, M. M. (2004). Getting Closer or Drifting Apart? *Quarterly Journal of Economics*, 119(3):971–1009.

Siegel, D. and Griliches, Z. (1992). Purchased Services, Outsourcing, Computers, and Productivity in Manufacturing. Nber chapters, National Bureau of Economic Research, Inc.

Spiezia, V. (2012). ICT investments and productivity: Measuring the contribution of ICTs to growth. *OECD Journal: Economic Studies*, 2012(1):199–211.

Tang, L. (2006). What accounts for the growth of trade in differentiated goods: Economic causes or technological imperatives? *Economics Letters*, 91(2):204–209.

Timmis, J. (2012). The Internet and International Trade in Goods. Technical report.

van Ark, B., O'Mahoney, M., and Timmer, M. P. (2008). The Productivity Gap between Europe and the United States: Trends and Causes. *Journal of Economic Perspectives*, 22(1):25–44.

Vemuri, V. K. and Siddiqi, S. (2009). Impact of Commercialization of the Internet on International Trade: A Panel Study Using the Extended Gravity Model. *The International Trade Journal*, 23(4):458–484.

Vu, K. M. (2011). ICT as a source of economic growth in the information age: Empirical evidence from the 1996–2005 period. *Telecommunications Policy*, 35(4):357–372.

World Trade Organization (2013). Connecting Least-Developed Countries to Value Chains.

Retrieved from https://www.wto.org/english/res_e/booksp_e/ldc_oecd_e.pdf

Yoo, C. S. (2014). U.S. vs. European Broadband Deployment: What Do the Data Say? (SSRN Scholarly Paper No. ID 2510854). Rochester, NY: *Social Science Research Network*. Retrieved from http://papers.ssrn.com/abstract=2510854

Zwart, B., Xue, F., Whitt, R. S., Ryan, P. S., Hussain, H., Croak, M., … Abraham-Igwe, N. (2015). Measuring Connectivity: A Call to Measure Internet Development with Open, Timely, and Relevant Data (SSRN Scholarly Paper No. ID 2664359). Rochester, NY: *Social Science Research Network*. Retrieved from http://papers.ssrn.com/abstract=2664359