Impact of information and communication technology (ICT) on international trade in fruit and vegetables: A gravity model approach

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Abstract:

Globalization results when markets become more integrated because of reduced transaction and transport costs. These costs have fallen because of sustained advances in transport technology and, more dramatically, in digital information and communication technology (ICT). Although communication costs tend to be a minor component of total trading costs, reductions in these costs may strongly stimulate international trade. The empirical evidence in support of this effect is, however, scant and its strength may depend on the composition of ICT and the nature of the product being traded. We test the hypothesis of an ICT effect on trade in bananas, oranges, tomatoes, and vegetables and fruit in general. We employ a gravity model of international trade between major exporting and importing countries for the period 1995 to 2009. The model explains the value of trade in terms of export and import countries' levels of internet and mobile phone penetration, and of a broad range of factors that might also affect bilateral trade. We test whether a fixed effects model or random effects model best suits the data; results suggest a fixed effects model is appropriate.

Model results suggest that mobile phone penetration significantly stimulates trade in vegetables and fruit and oranges by exporting countries. , but its impact is less than that of fixed telephone usage which has an unexpected negative influence on banana imports. Internet usage has only a positive effect on trade in imports of tomatoes. Internet usage in exporting countries for fruit and vegetables are negatively associated.

Keywords: Gravity model, information and communication technology (ICT), international trade, fruit and vegetables

Introduction

Globalisation results when markets and industries become more integrated because of lower tariffs or reduced trade costs, or both. These costs have fallen over the long term because of sustained advances in transport technology and, even more dramatically, in information and communication technology (ICT) (WDR 2009). Moreover, advances in transport technologies have significantly reduced the time trade good spend in transit (Hummels 2001). Improved transport and information technologies eventually were complemented by the modern global supply chain, an organizational innovation that leverages information and transport technology to better coordinate the activities of geographically dispersed economic agents.

Direct communication costs tend to be a minor component of total transaction costs in international trade, and their share in total trading costs of any one shipment is smaller yet. Indirect communications cost, in particular the opportunity cost of imperfect coordination due to poor communication are unknown but may be significant, particular for perishable products. Perhaps it is because of reduced loss of coordination that the diffusion of digital ICT is believed to stimulate international trade to an extent that appears to be large in proportion to the share of ICT costs in trading costs (Hummels 2007).

The purpose of our paper is to explore some of the factors that are generally believed to have contributed to the extension and intensification of international trade for vegetables and fruit, particular for bananas, oranges and tomatoes.

ICT and the impact on international trade

Digital ICT is the product of the convergence of modern telecommunication technology and digital data processing technology (Economist 2006, 2011). The telecommunication technology used by convergent technologies is the internet; the devices themselves are computers which come in various, rapidly evolving guises – PC, notebook, mobile phone, smart phone, pad, etc. The speed at which digital technology has advanced in the past is without precedent (Nordhaus, 2001). Moreover, convergent ICT is spreading much more rapidly than either conventional communication technology or the internet. Fixed-line telephone penetration in the world is nearly flat at just below 20 users per 100 inhabitants. In a much shorter time the internet has grown to about 30 users per 100 inhabitants. Mobile phones, in contrast, have spread much more rapidly than internet use and were some 5.4 billion mobile phone subscribers in the world at the end of 2010 (ITU 2011). Moreover, as UNCTAD (2006, p. 3) observed, 'Mobile phones are the only ICT in which developing countries have surpassed developed countries in terms of users.' Hence, it is safe to say that advances in convergent ICT, rather than in transportation or in conventional PC plus internet technology, will be the defining technology of the current era of globalization (Hummels 2007).

A small batch of empirical studies has investigated the impact of ICT on international trade. In an early study, Freund and Weinhold (2004) find that growth of the number of web hosts by 10 percentage points stimulates growth in a country's exports by about 0.2 percentage points. Using a model of bilateral trade, Fink et al. (2005) find that communications costs affect trade patterns significantly. Moreover, trade in differentiated goods benefits more strongly from lower communication costs than trade in homogeneous goods. Brun et al. (2005) conclude from the results of a gravity model of international trade that 'death of distance' is largely a phenomenon that can be observed in bilateral trade between rich countries whereas the poor countries become even more marginalized. Wheatley and Roe (2005) discuss the potential positive effects of the internet on U.S. trade in agricultural and horticultural products. They also present some econometric methods for measuring the effects of the internet on exports and imports. Clarke (2008), finally, investigates the question whether internet access affects the export performance of enterprises in low- and middle-income economies in Eastern Europe and Central Asia. He finds that internet access stimulates export activities by industrial and service enterprises.

We are unaware of empirical studies by others that shed light on the impact on trade of the mobile phone or its younger convergent-ICT siblings and descendants. It would, however, be surprising if the rapid diffusion of the mobile phone had no impact on trade. For one, the mobile phone has many uses (e.g. Torero and von Braun, 2006) and coordinating trade flows by means of verbal communication or short text messages is likely to be one of them. Moreover, the mobile phone is expected to reduce the costs and to increase the speed of business transactions, particularly for information-intensive transactions (UNCTAD, 2007, p. 246). For these reasons the mobile phone is expected to stimulate economic exchange and trade. We therefore study empirically the impact on trade of the internet and of mobile phones separately, something which, to our knowledge, has not yet been reported in the economics research literature on trade.

Product characteristics, transport & International trade of fruit and vegetables

Vegetables and fruits are perishable products but suitable storage and transport technologies, in particular controlled atmosphere conditions (temperature, humidity, O_2, CO_2 and ethylene content), may reduce their speed of decay. Feasible maximum storage durations differ widely among products. Yellow bananas, for instance, may be stored for one week only while green bananas may be stored without commercially significant loss of quality for up to three weeks, and oranges may be stored for up to 16 weeks (TIS 2011).

Table 1: Top 5 exporting and importing countries for vegetables and fruit, bananas, oranges and tomatoes

	Vegetables and fruit	**Bananas**	**Oranges**	**Tomatoes**
	(World market shares in parenthesis)			
Top 5 exporting countries in 2009	USA (10.1)	Ecuador (25.3)	Spain (37.2)	Netherlands (23.2)
	Spain (9.6)	Belgium (17.6)	USA (11.8)	Mexico (18.0)
	Netherlands (8.8)	Columbia (10.6)	South Africa (11.5)	Spain (16.9)
	China (7.9)	Costa Rica (5.7)	Netherlands (5.6)	Turkey (6.1)
	Belgium (5.6)	Guatemala (5.6)	Turkey (4.8)	USA (4.7)
Top 5 importing countries in 2009	USA (12.6)	USA (16.2)	Germany (10.2)	USA (21.1)
	Germany (10.7)	Belgium (13.9)	France (9.8)	Germany (17.0)
	Great Britain (6.9)	Germany (8.8)	Russia (9.6)	Russia (9.3)
	France (6.73)	Japan (8.7)	Netherlands (9.5)	Great Britain (9.1)
	Netherlands (5.3)	Great Britain (6.3)	Great Britain (5.1)	France (7.8)

Data: UN Comtrade Data

World markets for bananas, oranges and tomatoes are highly concentrated. In each market the five exporting countries with the largest value of exports jointly have a market share of about two thirds of the total value of world trade. (Note that exporting countries need not be producer countries.) Belgium, for example, is the second largest exporting country for bananas but the country is not known as banana growing country. Belgium, with its large port of Antwerp, is, however, a large entrepôt for the international banana trade. The top five exporting countries for vegetables and fruits jointly have a market share of 42 percent of total world exports.

Table 2: Development of world trade in vegetables and fruit, bananas, oranges and tomatoes, 1995-2009.

	Vegetables and fruit	Bananas	Oranges	Tomatoes
Value of world exports [in Bn US$]				
(1995)	67.6	4.1	2.1	2.8
(2009)	156.0	7.9	3.5	6.7
Annual compound growth rate (1995-2009)	5.7	4.5	3.5	6.0
Value of world imports [in Bn US$]				
(1995)	72.8	6.2	2.3	2.7
(2009)	162.3	11.7	3.9	6.9
Annual compound growth rate (1995-2009)	5.5	4.3	3.6	6.5

Data: UN Comtrade (2010)

Growth in world trade in oranges and bananas was slow compared to growth in trade in vegetables and fruit (Table 2). World trade in tomatoes experienced the highest growth rates among our four commodity groups during the period 1995 to 2009.

Growth in ICT penetration rates differ markedly between "plain old" telephones and the new digital information technologies. There was only sluggish growth in telephone penetration in exporting as well as importing countries during the period 1995 to 2009 (Tabe 3). Penetration rates for mobile phones and internet access, in contrast, exploded with annual penetration growth rates ranging from 21 percent to more than 26 percent. Moreover, whereas telephone penetration rates appear to have reached their peak far below saturation level, mobile phones penetration everywhere is beyond 100 percent penetration. For us, this suggests that all traders in the supply chains for the four commodity groups, even the smallest ones, are likely to be mobile phone users whereas we cannot be sure that this is also the case for access to fixed line telephones. Internet penetration has not yet reached mobile phone penetration levels but internet penetration rates in both exporting and importing countries for all four commodity groups are far higher than telephone penetration rates. Given the rapid fusion of internet and mobile phone technology (Economist 2011), we expect internet penetration rates to reach mobile phone penetration rates within a few years time. The is a final point we wish to point out. All three ICT penetration rates are lower in exporting than in importing countries. This reflects the fact that exporting countries of the four commodity groups most often are not highly industrialized countries where ICT penetration rates are particularly high.

Table 3: Development of ICT penetration in exporting and importing countries for vegetables and fruit, bananas, oranges and tomatoes, 1995-2009.

		Vegetables and fruit		**Bananas**		**Oranges**		**Tomatoes**	
		EX	**IM**	**EX**	**IM**	**EX**	**IM**	**EX**	**IM**
Telephone	(1995)	27.4	39.3	23.7	37.1	34.2	39.9	34.0	44.6
	(2009)	32.0	44.2	26.6	37.5	37.2	38.6	35.0	44.2
	Annual Compound Growth Rate (1995-2009)	1.0	0.8	0.8	0.1	0.6	-0.2	0.2	-0.06
Mobile phones	(1995)	3.9	6.7	3.4	6.2	4.4	7.4	3.8	7.5
	(2009)	102.9	121.3	104.6	116.9	110.3	126.6	100.1	130.1
	Annual Compound Growth Rate (1995-2009)	24.4	21.3	25.7	21.6	24.0	20.8	24.3	21.0
Internet	(1995)	1.5	2.5	1.4	2.4	1.8	2.6	2.1	3.1
	(2009)	50.1	64.6	46.3	60.1	55.6	66.0	57.0	71.9
	Annual Compound Growth Rate (1995-2009)	26.6	24.2	26.3	24.0	25.7	24.1	24.6	23.3

Data: ITU (2010)

Table 3 shows annual growth rates of ICT penetration for exporting and importing countries of vegetables and fruit, bananas, oranges and tomatoes. Fixed telephone penetration seems nearly saturated with minor growth rates. Penetration rates of all ICTs are higher in importing countries than in exporting countries but annual growth rates are bigger in exporting countries than in importing countries. Penetration rates for mobile phone subscribers are above 100 per 100 inhabitants in 2009. Internet penetration in exporting and importing countries is above 50 per 100 inhabitants and we expect a continuous growth for internet penetration. Because of shown penetration rates per 100 inhabitants, especially for digital ICT, we expect that commercial enterprises in exporting as well as in importing country use ICTs.

Modeling the impact of ICT on international trade with a gravity model

We include three ICT variables:

- telephone main lines in use per 100 inhabitants, specified in natural logarithms as $ltelX_{it}$ for exporting countries and $ltelM_{jt}$ for importing countries;
- internet users per 100 inhabitants, specified in natural logarithms as $lnetX_{it}$ for exporting countries and $lnetM_{jt}$ for importing countries; and
- mobile phone subscribers per 100 inhabitants, specified in natural logarithms as $lmobX_{it}$ for exporting countries and $lmobM_{jt}$ for importing countries.

The first of these variables is included to represent the traditional forms of telecommunication while the other two variables are included to represent modern digital ICT. All variables represent the likelihood that those involved in international trade have access to particular forms of ICT. But they are also used as proxies for the geographical spread of ICT within countries, the availability of applications associated with the technology, and the experience users would have had, and the skills they would have developed, in applying it. Finally, they are useful proxies for the costs of information and communication tools because there is a high correlation between prices and the extent of penetration of each ICT category.

Other continuous variables considered for inclusion are common to many previous models of bilateral trade flows. The natural logarithms of GDP per head in importing country *j* in year *t* ($lgdphM_{jt}$) and GDP per head in exporting country *i* in year *t* ($lgdphX_{it}$) were included. A positive sign is expected for the estimated coefficient of $lgdphM_{jt}$ and a negative sign for the estimated coefficient of $lgdphX_{it}$. The natural logarithm of population of trading partners ($lpopX_{it}$) for exporting countries and ($lpopM_{jt}$) for importing countries was also included to capture the tendency for greater trade to take place between countries with large populations.

We follow Baltagi et al. (2003) who included two main explanatory variables consistent with certain trade theories that feature gross domestic product (GDP) as a component: a similarity index of economic size between the trading partners ($lsim_{ijt}$); and the absolute difference in relative factor endowments between the trading partners in time *t* ($lrfac_{ijt}$). Egger (2000, p. 2) defined $lsim_{jt}$ as $\ln\left[1-\left(\frac{GDP_{it}}{GDP_{it}+GDP_{jt}}\right)^2-\left(\frac{GDP_{jt}}{GDP_{it}+GDP_{jt}}\right)^2\right]$. Countries with similar-sized economies are expected to trade more with each other, although this relationship is likely to be stronger at an aggregated product level than for a specific industry. $lrfac_{jt}$ is defined by Baltagi et al. (2003, p. 393) as $\left|\ln\left(\frac{GDP_{it}}{capita_{it}}\right)-\ln\left(\frac{GDP_{jt}}{capita_{jt}}\right)\right|$ where $capita_{it}$ is the population in the exporting partner country and $capita_{jt}$ is the population in the importing partner country in year *t*. Those who believe that 'New trade theory' models best depict international trade in products where scale economies prevail along with product differentiation would expect a negative sign on this variable (Baltagi et al. 2003). Adherents of the classical Heckscher-Ohlin-Samuelson theory, on the other hand, expect a positive sign: the greater the difference between countries in relative factor endowments, the more likely they are to trade with each other. While important at the macroeconomic level, the relevance of the Heckscher-Ohlin-Samuelson theory at the individual industry level is likely to be reduced.

Moreover, a sub-set of time-invariant country- and trading partner-specific variables are included: an adjacent country dummy variable (adj_{ij}) for trading partners and a variable for the use of a common language between trading countries ($lang_{ij}$) (Hutchinson 2002).

Outside financial markets, few economic transactions are executed without human intervention. The fundamental medium for human communication is speech in a particular language. Language that is not shared by the parties to an exchange introduces a barrier to trade. Research on this topos has generally shown 'that a common language results in greater trade volume between countries' (Hutchinson, 2002, p. 546). Until a future time when reliable automatic speech translation may be available, modern ICT cannot prevent language barriers from becoming trade barriers, too. In our empirical analysis, we therefore control for language commonalities, which are more basic than any ICT protocols.

Baltagi et al. (2003) point out that many country characteristics cannot be identified with specific data series. They stress the need to account for interaction effects between pairs of countries in trade flow models, to reflect the heterogeneous relationships between exporting and importing countries not captured by other country-specific variables, and to account for changes in trading relationships over time. We follow their lead by including year effects and trading partner effects in the estimated model to depict various trading partner- and year-specific factors as either fixed or random effects.

We attempt to account for the cost of international shipment by using two proxy variables that are applied to each bilateral trade transaction in each year. First, the importance of distance between two trading partners has been studied for over four decades (Egger 2008). We follow Feenstra (2004) in specifying a distance variable while controlling for the trading partner-specific fixed effects, mentioned above, to obtain a consistent estimate of the average effect of trade frictions. This variable is used in natural logarithm form ($ldist_{ij}$). Second, a continuous but trading partner-invariant variable for fuel, also in natural logarithm form ($lfuel_t$), is included to capture the effects of changes in the real fuel price on freight costs over the study period. A preferred option for transport cost would obviously have been the actual freight cost for shipping in real terms, but data on this variable are unavailable.

Because of the world financial crisis in 2008 an additional dummy variable (*dum08*) was added to capture this effect.

The model was estimated using *Stata 11.0* as a fixed-effects model and a random-effects model (Greene 2003, pp. 287-298).

The complete model specification with μ_{ijt} as error term is:

$$
\begin{aligned}
tradevalue_{ijt} = {} & ß_0\alpha + ß_1 lgdphX_{it} + ß_2 lgdphM_{jt} + ß_3 lpopX_{it} + ß_4 lpopM_{jt} + ß_5 lsim_{ijt} \\
& + ß_6 lrfac_{ijt} + ß_7 ltelX_{it} + ß_8 ltelM_{jt} + ß_9 lmobX_{it} + ß_{10} lmobM_{jt} + ß_{11} linetX_{it} \\
& + ß_{12}\mathrm{linet}M_{jt} + ß_{13} lfuel_t + ß_{14}\mathrm{dum08}_t + ß_{15}\mathrm{ldist} + ß_{16}\mathrm{adj} + ß_{17}\mathrm{lang} + \mu_{ijt}
\end{aligned}
$$

A Hausman test (Greene 2003, pp. 301-303) was conducted to decide between the fixed-effects and random-effects models.

A Poisson pseudo-maximum likelihood (PPML) estimator, recommended by Santos Silva and Tenreyro (2006), was considered the most appropriate approach among the estimators for a gravity model. Crucial statistical advantages of the PPML estimator are its linear-log linking function that avoids the under-prediction of large values or volumes of trade, and the fact that it provides a natural way to deal with the problems of zero-trade flows because of its non-linear form by using an exponential regression function (Linders et al. 2008). A detailed explanation of the Poisson specification of the gravity model trade and its attributes can be found in Santos Silva and Tenreyro (2006, 2010).

Burger et al. (2009) suggested the negative binomial pseudo-maximum likelihood (NBPML) to avoid the problem of non-equidispersion when using a PPML model. An assumption of equidispersion underlying the PPML estimator means that the conditional mean is assumed to equal the conditional variance. If this condition does not hold, under-dispersion or (much more likely) over-dispersion could result. *Stata 11.0* can be used for panel data when applying the PPML and NBPML estimators. A test was conducted for non-equidispersion when using the PPML estimator and the result was found to favor the use of the NBPML estimator because of the presence of over-dispersion.

Data on ICT, international trade of fruit and vegetables and control variables

Data on annual international trade values in nominal US dollars were obtained from UN Comtrade. The SITC codes for our product variables are SITC 05 for vegetables and fruit, SITC 0544 for fresh or chilled tomatoes, SITC 0571 for oranges, etc and SITC 05732 for bananas (including plantains), fresh or dried. Our trade data are for

the period 1995 to 2009. Nominal trade values were translated into real values using the US GDP deflator.
ITU (2010) was the source of data for the ICT variables included in the model. The specific data sources used were telephone main lines in use per 100 inhabitants (ITU/MDG [code 13130]), internet users per 100 inhabitants (ITU estimates/SYB51 [code 29969]) and mobile phone subscribers per 100 inhabitants (ITU estimates [code 13110]). The World Bank database is the source of data on population and GDP (constant 2000, in US$). The French Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) provides geographical information including distances and adjacencies between countries, and common official languages spoken in countries. The mean real annual Brent crude oil price, as reported by the U.S. Energy Information Administration (EIA) was used as a proxy for fuel prices originated by.

We estimated separately gravity models of bilateral trade for vegetables and fruit, bananas, oranges, and tomatoes, based on balanced annual data sets for the period from 1995 to 2009. Table 4 describes our data sets. Total observations vary from 4,590 for tomatoes to 16,560 data points for vegetables and fruit. Exporting and importing countries were selected for our models on the basis of their share in the total value of global trade. For each product 90 percent or more of total world trade in a given commodity are covered by the countries selected. For instance, fifteen countries cover approximately 96 percent of world tomatoes export, whereas 34 countries are needed to cover 91 percent of world exports of vegetables and fruit.
Typically, UN Comtrade data do not report trades for all years for each commodity group and pairs of exporting and importing countries. For example, data on bananas exported from Costa Rica to Austria are reported for only four years of the fifteen year period from 1995 to 2009. Missing entries occur more frequently for less aggregated commodity categories, such as bananas where close to 65 percent of all potential trades were missing, than for more aggregated categories, such as vegetables and fruit, where only about 6 percent of potential trade data were missing. We are unable to tell whether unreported trades are due to no trade having taken place or due to deficiencies in the reported statistics. If UN Comtrade does not report any trade value for a country pair during the study period, we declare them as zero-trade values.

The average traded distance between selected country pairs is similar for vegetables and fruits, bananas and oranges. Tomatoes were traded on an average distance of ca. 3,670 km.

Table 4: Descriptive Statistics of trade date used in gravity models

	Vegetables and fruit	Bananas	Oranges	Tomatoes
Total observations	16,560	11,370	8,130	4,590
No. of selected exporters	34	24	19	15
Mean share of world exports [in %] for selected exporters for the period 1995-2009	90.8	94.9	94.8	96.2
No. of selected importers	33	32	29	21
Mean share of world imports [in %] for selected importers for the period 1995-2009	90.7	94.0	90.2	93.9
No. of countries, which are exporting and importing	18	10	9	9
No. of trading partners with a common border	47	33	26	29
No. of country pairs with a common language	120	63	54	38
Trade data availability by UN Comtrade [in %]	94.1	34.5	57.7	58.9
Share of country pairs with zero-trade [in %]	0	35.5	17.8	18
Average distance* between selected country pairs [in km]	7,743	6,742	6,745	3,672

* distance calculated by Mayer and Zignago (2006) based on geographical distance between capitals and economic centers

We evaluated the quality of our trade data by comparing the frequency distribution of the first digits (d) with "Benford's Law" which holds that the relative frequencies of the first digits are given by

$$P(d) = log_{10}(1 + \frac{1}{d}), \qquad \text{with } d=1,2,\ldots,9$$

We tested for compliance with Benford's Law using a conventional chi-square test. The tests suggest that our data for vegetable and fruit comply with Benford's Law whereas the data for the remaining product categories do not. For us, this suggests that the quality of the data for the latter product groups are not beyond any doubt. The interpretation of estimates obtained from models using these data must take this concern about data quality into account.

Results

A series of hypothesis tests were conducted on the merits of various model estimates. The results of the Hausman test strongly favors a fixed effects model for all products; trading partner and year effects and estimates are reported only for this model in Table 5.
The distance, adjacent countries and language variables are excluded from Table 5 because their coefficients were reported as fixed parameters in the fixed effects model and hence no estimated coefficients were presented for them in the *Stata 11.0* output.

Table 5: Estimated model coefficients for trade of vegetables and fruit

Variable name (label)	Vegetables & fruit		Bananas		Oranges		Tomatoes	
Telephone, Export	0.072		-0.234		-0.111		0.049	
($ltelX_{it}$)	(1.49)		(-1.24)		(-0.59)		(0.24)	
Telephone, Import	-0.048		**-0.937**	***	-0.004		-0.410	
($ltelM_{it}$)	(-0.58)		**(-2.84)**		(-0.02)		(-1.68)	
Mobile phone, Export	**0.055**	***	-0.117		**0.093**	*	**-0.242**	***
($lmobX_{it}$)	**(2.87)**		(-1.54)		**(1.65)**		**(-3.00)**	
Mobile phone, Import	-0.012		-0.002		-0.127		-0.129	
($lmobM_{it}$)	(-0.46)		(-0.02)		(-1.61)		(-1.64)	
Internet, Export	**-0.051**	***	0.083		-0.086		0.087	
($lnetX_{it}$)	**(-2.94)**		(1.23)		(-1.45)		(1.03)	
Internet, Import	-0.023		0.042		0.061		**0.335**	***
($lnetM_{it}$)	(-0.94)		(0.53)		(0.74)		**(3.21)**	
GDP per capita, Export	**0.292**	***	-0.192		0.559		0.584	
($lgdphX_{it}$)	**(-3.08)**		(-0.95)		(1.56)		(1.41)	
GDP per capita, Import	**0.534**	***	**0.797**	***	0.366		0.211	
($lgdphM_{it}$)	**(5.23)**		**(4.43)**		(0.79)		(0.53)	
Population, Export	**0.358**	***	0.041		-0.143		0.490	
($lpopX_{it}$)	**(4.73)**		(0.29)		(-0.38)		(1.2)	
Population, Import	-0.044		0.026		-0.222		**-0.767**	*
($lpopM_{it}$)	(-0.53)		(0.19)		(-0.6)		**(-1.78)**	
Similarity index of economic size	**0.281**	**	-0.123		-0.070		0.883	
($lsim_{ijt}$)	**(2.20)**		(-0.45)		(-0.08)		(1.27)	
Relative factor endowments	**-0.168**	***	**-0.394**	**	-0.310		0.154	
($lrfac_{ijt}$)	**(-2.72)**		**(-2.4)**		(-1.58)		(0.58)	
Fuel price	**0.250**	***	0.039		0.025		**0.264**	***
($lfuel_t$)	**(12.65)**		(0.47)		(0.44)		**(4.98)**	
dummy year 2008	**0.082**	***	0.011		**0.144**	***	-0.031	
(dum08)	**(8.5)**		(0.22)		**(4.11)**		(-1.08)	
Constant	**-10.694**	***	-1.791		0.574		1.208	
(α)	**(-6.15)**		(-0.63)		(0.09)		(0.20)	
No. of observations	16,560		11,370		8,130		4,590	

Notes: z-Values in parenthesis;
***, **, * denote statistical significance at the 1%, 5%, and 10% significance level

Discussion of ICT results

Our results may be approached either from ICT or from a commodity perspective. Our interpretation of results from a commodity perspective should keep the results of the Benford-Law-tests in mind: only the quality of the data for vegetables and fruit is beyond doubt. Given the long history of fixed line telephony, we are not surprised that telephone penetration rates have, by now, no impact on exports and imports of fruit and vegetables. Moreover, we willingly accept the result that mobile phones encourage exports of vegetables and fruit as well as of oranges. We have, however, no ready explanation for the negative impact of internet penetration rates on imports of vegetables and fruit. Given the questionable quality of trade data for bananas and tomatoes, we are not overly disturbed by our model results which suggest a negative impact of telephone penetration rates on banana imports, and of a negative impact of mobile phone penetration on exports of tomatoes.
From the point of view of the ICTs, it is obvious that fixed line telephone penetration rates have had no significant impact on either exports or imports during the past decade. In contrast, penetration rates by mobile phones and internet have had some limited and sometimes unexpected impact on international trade.
As expected, mobile phones have stimulated exports of fruit and vegetables and of oranges. Contrary to our expectations, mobile phone penetration has, however, decreased exports of tomatoes. Moreover, mobile phone penetration has had no discernible impact on imports. This may be due to the high level of telecom infrastructure development in the importing countries.
The impact of internet penetration is also mixed. The positive impact of internet penetration on imports of vegetable and fruits corroborates our expectations but the negative impact of exports of the same commodity group is counter to our expectations.

Neither of the ICT variables have a strong positive impact on exports and imports of the selected goods. The results nevertheless support the proposition that recent developments in the internet and mobile telephony have had a significant impact on the pattern of trade for selected products, albeit at small magnitudes.

We make two observations with regard to the non-ICT variables in our gravity models. In the gravity model explaining bilateral trade of vegetables and fruit, with one exception, all variables that are usually included in gravity models, are statistically significant and have the expected sign. The exception is population in importing countries (Table 5). We therefore have reason to believe that we have chosen an adequate set of control variables for our gravity models. The fact, that most of the same variables are statistically insignificant in the models for the less aggregated commodity groups may seem to undermine our confidence. Given the doubtful quality of the trade data for these commodity categories, we are, however, inclined to attribute the poor performance of the gravity-variables in the models explaining trade in bananas, oranges, and tomatoes to deficiencies in data quality.

Closing remarks

We employed gravity models of international trade for several product categories of vegetables and fruit. The models cover the period from 1995, when the World Wide Web and mobile phone technology were in their infancy, until 2009 when both technologies were available globally. The gravity model explains the value of trade between two countries in terms of the level of internet, fixed telephone line and mobile phone diffusion, and a broad range of factors that might also affect bilateral trade. A fixed effects model using a negative binomial panel estimator was found to be appropriate for estimation purposes.

Results from tests of ICT effects on international trade provide findings, which vary between exporting and importing countries. Neither of the ICT variables in exporting and importing countries have a strong positive impact on trade for selected goods. The results nevertheless support the proposition that recent developments in the internet and mobile telephony have had a significant impact on the pattern of trade for selected products, albeit at small magnitudes.

These results provide modest support for the proposition that recent developments in internet and mobile telephony have had a positive impact on the pattern of trade during the study period and raises questions why producers and exporters are not making more effective commercial use of ICT.

Finally, results from a Benford-Law-test suggest that some of our trade data, which all came from highly regarded sources, may not be of the highest quality and model estimates ought to be interpretate with due restraint.

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