ICT and Trade Performances of Central and Eastern European Countries

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Abstract

The paper examines the effects of Information Communications Technology (ICT) and general technological environment expressed in knowledge economy on trade performances of Central and Eastern European Countries (CEEC). The analysis explicitly studies ICT effects on both exports and imports of CEEC and distinguishes among the different income countries across their trading partners. Empirical results derived from the pseudo Poisson Maximum Likelihood (PPML) estimator find that relative differences in the factor endowments explain well the patterns and destinations of the CEEC exports and imports. Including the ICT variables and proxies for the knowledge economy in the model further strengthens the effects and outlines that the higher ICT use, stronger ICT infrastructure and well developed knowledge economy increase exports of CEEC. The ICT effects are less robust on the CEEC imports, which so far are mostly explained by the differences in the factor endowments and income levels of the trade partners.

Keywords: ICT, Central and Eastern Europe, international trade, technological progress, knowledge economy

JEL codes: F12, F14, F15, J24, O33, O52

1. Introduction

In the recent century, information technology revolution and the Internet together with the fast pace of globalization gave birth to digital economy that created new opportunities to produce, deliver, trade and consume goods and services all over the world. Consequently, global economy as well as international trade is broadly affected by the recent waves of digitization. In this context, deployment of Information Communications Technology (ICT) gets the vital sense, since it is ICT that enables using recent technological advancements and reaping benefits of digitization. As it is reported by the International Telecommunication Union (ITU), ICT development can be reflected in the following factors: in ICT infrastructure that provides readiness for employing ICT; in ICT use, since the contribution of ICT does not exist unless ICT is not deployed; and in skills (human capital) that enables usage of ICT (ICT Development INDEX (IDI), ITU 2009).

While US and other large economies as well as western European countries are broadly covered in scientific analysis, the literature on the ICT effects on trade performance of Central and Eastern European Countries (CEEC) is quite scarce. To fill the gap in the literature, the goal of the paper is to analyze ICT effects on trade of CEEC. In particular, I examine the effects of ICT infrastructure, ICT use and ICT network effects on both exports and imports of CEEC. Moreover, the paper elaborates the impact of general technological environment to assess implications of the knowledge economy on trade performances of CEEC. Finally, for concrete empirical insights, the analysis distinguishes between income levels of the trade partners and tracks the magnitude of ICT effects on trade with low and high-income countries.

To conduct empirical analysis, I augment the structural gravity equation proposed by Cieślik (2009) with ICT variables, such as ICT use, ICT infrastructure and ICT network effects, human capital and knowledge economy. Empirical results derived from the pseudo Poisson Maximum Likelihood (PPML) estimator find that relative differences in the factor endowments explain well the patterns and destinations of the CEEC exports and imports. Including the ICT variables and proxies for the knowledge economy in the model further strengthens the effects and outlines that the higher ICT use, stronger ICT infrastructure and well developed knowledge economy increase exports of CEEC. The ICT effects are less robust on the CEEC imports, which so far are mostly explained by the differences in the factor endowments and income levels of the trade partners.

The rest of the paper is organised as follows: section 2 reviews the literature around the ICT and trade, section 3 presents the empirical framework, variables and data used in the analysis followed by estimation results in section 4. Finally section 5 concludes.

2. Literature review

The literature on ICT and trade starts from the early 2000s and outlines that ICT has positive effects on trade performances by reducing trade costs. Freund and Weinhold (2002, 2004), were one of the very first scholars who examined the impact of the Internet and ICT infrastructure on trade. Authors analysed US trade in services and found that an increase in the number of web hosts by 10 percentage points is associated with the increase in exports by about 0.2 percentage points.

The positive impact of ICT infrastructure on export performances was also supported by study of Portugal-Perez and Wilson (2010). Authors outlined that together with "hard infrastructure", ICT infrastructure enhances trade. Furthermore, while analysing impact of "soft infrastructure" on trade of Asian countries, Ismail and Mahyideen (2015) found that a 10% increase in the number of fixed and mobile phone subscribers in both exporter and importer countries increases trade by 2.6% and 2.2%, respectively. Given its importance, authors concluded that together with hard infrastructure, effects of soft infrastructure should also be examined systematically for different country groups.

Additionally, studies illustrate that the trade-enhancing effect of ICT may not depend solely on

ICT infrastructure or ICT capability per se, but on its use. Namely, Liu and Nath (2013) employed panel data for forty emerging market economies from 1995 to 2010 and found that Internet subscriptions and Internet hosts have significant positive effects on both exports and imports in the emerging countries. Impact of broadband use on trade development in Middle East and North Africa is studied by Gelvanovska, Rogy and Rossotto (2014). As authors outlined, broadband contributes in trade in this region. The study found that one percentage point increase in the number of Internet uses increases exports by 4.3 % points.

Positive impact of ICT use is furthermore outlined for trade in fruits and vegetables by Thiemann, Flemming and Mueller (2012). Authors proxy ICT use by the data on telephone main lines, Internet usage and mobile phone subscribers and found that mobile phone penetration significantly stimulates trade in vegetables and fruit. The role of ICT use for different Spanish industries is studied by Bernal-Jurado and Moral-Pajares (2010). The paper found that the largest exporting and importing industries are the ones that are more engaged in electronic commerce through different communication channels, such as EDI, Minitel or Internet.

Furthermore, there is an empirical evidence on direction of causality between Internet penetration and exports. This issue was quite controversial for the last decade, since mid 1990s and early 2000s was characterized by drastic increase in both world exports and Internet hosts. As summarized by Clarke and Wallstein (2004), world exports increased from 20% of gross world product in 1994 to 24% in 2002. At the same time the number of Internet hosts rose from 17 per 10,000 people in 1994 to 231 in 2001. Authors argued that on the one hand boom in world exports since 1990s could stimulate deployment of ICT, and on the other hand, rapid growth in ICT use could boost exports (alternatively, this could just be a coincidence). By using instrumental variable approach for macro-level analysis, the paper found that causality runs from ICT to exports.

This finding was further confirmed by Kneller and Timmis (2016) who conducted analysis on the effects of broadband use on the firm-extensive margin of UK service exports. To deal with possible endogeneity, authors built an instrument that exploited exogenous variation in access to broadband technologies owing to the historic telephone network. Empirical findings indicated that the causal effect runs from the Internet to trade in business services.

ICT effects via trade costs is analyzed by Keita (2015). Estimations of gravity model outline that the elasticity of trade costs to distance decreases as the level of ICT increases. The hypothesis that ICT use creates network effects is supported by Mattes, Meinen, and Pavel (2012). Authors analyze the EU trade and show that ICT yields positive and significant impact on trade especially if both trading partners reveal advanced ICT endowments. This finding supports existence of ICT network effects.

Furthermore, a number of studies suggest that the ICT effects could substantially depend on the level of intangible capital in a given country. Such intangible capital may refer to organizational changes and firms' own experiments to adopt new technologies in practice. However, as argued in the study, processes related to "co-invention" in firms takes longer time than modernization of technologies, therefore effects of ICT could show up after some time (Crafts, 2008 cited in Akhvlediani, 2016). This intuition is embodied in the idea of classifying

ICT as a General Purpose Technology (GPT). This implies that all the advantages related to a new GPT might be fully utilized through complementary investment in both tangible and intangible assets (Bresnahan and Trajtenberg,1995). Here investment in tangible assets refer to investments in ICT equipment and software, while organizational changes in firms represent investment in intangible assets (Brynjolfsson and Hitt, 2000, 2003; Basu et al., 2003; Lechman, 2016).

Classification of ICT as GPT underlines importance of human capital and digital literacy in ICT uptake. As underlined by the International Telecommunication Union (ITU), ICT development can be reflected in the following factors: in ICT infrastructure that provides readiness for employing ICT; in ICT use, since the contribution of ICT does not exist unless ICT is not deployed; and in skills (human capital) that enables usage of ICT (ITU, 2009).

Furthermore, importance of high-quality university system and widespread of digital skills is highlighted by Renda (2016). As the author states, in the age of digitalisation one of the scarcest resource in ICT ecosystem is human capital since the latter presents a fundamental driver of ICT uptake. Therefore, according to Renda (2016) development of high-quality university system and widespread of e-skills and digital literacy should be one of the main targets of policies aiming at improving economic performance, competitiveness and innovation.

As for the CEEC, the literature on ICT and trade performance is rather scarce. Some general evidence is found by Lechman (2016) who finds that during 1995-2015 exports of CEEC countries were strongly oriented towards the high-tech and ICT manufactures.

To sum up, the literature on international trade and ICT shows that ICT has positive effects on trade performances via putting forward better infrastructure for quick exchange of goods and services, reducing trade costs and creating network effects. The latter implies that ICT benefits to its users increases when ICT is intensively used in both trading countries. Additional factors which should enable ICT to generate its widespread effects are human capital and investments in intangible capital, both contributing in building knowledge economy. While studies are mostly done for the US economies and the EU countries in general, the literature on the ICF effects for the CEEC economies is quite scarce.

To fill the gap in the literature, this paper studies the ICT effects on the trade of CEEC. I examine exports and imports of CEEC separately and furthermore disaggregate their trade partners into low, middle and high-income countries. This approach allows outlining the ICT effects on exports and imports separately and delivers some insights on these effects for the different income countries.

3. Empirical framework and data description

To conduct the empirical analysis, this paper relies on the structural gravity equation suggested by Cieślik (2009). Although the gravity model proposed by Jan Tinbergen (1962) is broadly employed in empirical trade analysis for over five decades, the model is often criticized for lacking the micro foundations. Among many efforts that have been gone to derive gravity equation from the theory, the framework proposed by Cieślik (2009) departs from the assumption of the complete specialization and allows the incomplete specialization of the trading partners. The latter is quite important feature as it implies that countries differ in factor endowments which is quite realistic assumption. As an extension of the initial specification by Cieślik (2009) together with capital-labour ratios, I include human capital endowments in the model. This approach, on the one hand, complements initial model and on the other hand, introduces the needed channels for tracking the impact of ICT which depends on the level of human capital and knowledge economy. These two factors should account for the general technological environment in the trading countries.

Empirical equation extending the initial specification proposed by Cieślik (2009) could be specified as follows:

$$\begin{aligned} \mathrm{X_{ijt}} = {} & \beta_0 + \beta_1 \ln(K_{it}/L_{it} - K_{jt}/L_{jt}) + \beta_2 \ln(K_{it}/L_{it} + K_{jt}/L_{jt}) + \beta_3 \ln(H_{it}/L_{it} - H_{jt}/L_{jt}) \\ & + \beta_4 \ln(H_{it}/L_{it} + H_{jt}/L_{jt}) + \beta_5 \ln\left(1 - s_{it}{}^2 - \mathrm{s_{jt}}{}^2\right) + \beta_6 \ln\left(\mathrm{GDP_{it}} + \mathrm{GDP_{jt}}\right) \\ & + \beta_7 \ln(\mathrm{ICT\_infr_{it}}) + \beta_8 \ln\left(\mathrm{ICT\_infr_{jt}}\right) + \beta_9 (\mathrm{ICT\_use_{it}}) + \beta_{10}\left(\mathrm{ICT\_use_{jt}}\right) \\ & + \beta_{11}\left(\mathrm{ICT_{use_{it}}} * \mathrm{ICT_{use_{jt}}}\right) + \beta_{12} \ln(\mathrm{Kn\_Ec_{it}}) + \beta_{13} \ln\left(\mathrm{Z_{ij}}\right) + \beta_{14} \mathrm{D'_{ij}} + \mu_i + \varphi_j \\ & + \lambda_t + \mu_i * \lambda_t + \varphi_j * \lambda_t + \varepsilon_{ijt} \end{aligned}$$

where $\mathrm{X_{ijt}}$ is the export or import flow from country *i* to country *j* at time *t*; K_{it}/L_{it} and K_{jt}/L_{jt} stand for the capital-labour ratio of trade partners, likewise, H_{it}/L_{it} and H_{jt}/L_{jt} stand for human capital-labour ratio of trade partners; $1 - s_{it}{}^2 - \mathrm{s_{jt}}{}^2$ presents similarity index proposed by Helpman (1987); $\mathrm{GDP_{it}}$ and $\mathrm{GDP_{jt}}$ represent the current GDPs of the trade partners at time *t*, *ICT_infr* and *ICT_use* stand for the ICT infrastructure and ICT use in trade partners at time *t*, while $\mathrm{ICT_{use_{it}}} * \mathrm{ICT_{use_{jt}}}$ proxies network effects of ICT usage; finally *Kn_Ec* stands for knowledge economy of the CEEC countries at time *t*. Geographical variables are presented by $\mathrm{Z_{ij}}$, which is the non-binary but time invariant information such as distance between the exporter and importer countries, common language and common colonial ties; $\mathrm{D'_{ij}}$ which stands for contiguity and equals one when the trade partners share the common border and zero otherwise; μ_i and φ_j represent country effects, λ_t presents time dummies, $\mu_i * \lambda_t$ and $\varphi_j * \lambda_t$ present country-time effects, and ε_{ijt} is the error term that does not have to be homoscedastic.

Based on the literature review, to reflect all possible effects of ICT, the analysis controls for ICT infrastructure, ICT use, possible network effects created by ICT use and knowledge economy as the proxy of the technological environment for the ICT effects. ICT infrastructure is proxied by fixed telephone lines subscribers per 100 inhabitants and ICT use by Internet users as % of the population (this variables is taken as fraction and therefore is not put into the logarithm). Network effects, as discussed by Mattes, Meinen, and Pavel (2012) are presented as the product of the ICT use in both trade partners. Following Von Ark and O'Mahony (2008), knowledge economy is calculated as sum of human capital, capital services and total factor productivity.

The data on the export flows in millions of Euros are taken from WITS. Following Head and Mayer (2015) the trade flows are not deflated as the gravity equation presents an expenditure function of nominal GDPs and nominal trade flows. The data of the current GDP levels are extracted from the World Development Indicators database complied by the World Bank. Data on factor endowments such as capital and human capital[1] labour ratios will be included from the newest version of Penn World Tables (PWT 9.0). The data on ICT infrastructure and ICT use are included from the ITU database. Knowledge economy of CEEC will are calculated based on the variables sourced from the PWT (9.0).[2] The data for the other variables such as distance, contiguity and other cultural and historical ties are extracted from the CEPII database. The information about regional trade agreements (RTAs) are derived from the WTO agreement database.

According to the time span of different databases, the sample will cover the period from 2000 to 2018. The division of the trade partners into low, middle and high income countries is done based on the World Bank classification of the countries. The considered group of countries consists of CEEC countries as importers/exporters and all the countries from the rest of the world as their trading partners.

To estimate structural gravity equation augmented with human capital and ICT variables, the paper employs the seminal findings of Silva and Tenreyro (2006). Authors argue, that the multiplicative trade models with multiplicative error terms do not satisfy the assumption of the homoscedasticity of the error term since there is dependency between the error term of transformed log-linear model and the regressors, which finally causes inconsistency of the ordinary least squares estimator or the random and fixed effects estimator. As an alternative, authors propose the estimation of the gravity model in levels using the PPML estimator. Besides tackling with the problem of heteroscedasticity of the error term, the estimator deals with the zero value observations in trade flows. Additionally, unlike to the standard Poison approach, PPML does not require the data to be Poison type, in other words, it does not require the dependent variable to be an integer. Finally, PPML allows identifying effects of time invariant factors.

To control for the multilateral resistance term (MRT) discussed by Rose and van Wincoop, (2001); Anderson and van Wincoop (2003); Feenstra, (2004), the estimation equation includes country and time fixed effects (see Head and Mayer, 2015). Here time effects account for cyclicality of economies involved. Additionally, the estimation equation also controls for the dynamic MRT by including country-time effects, to control the changes in MRT, as the period of analysis is long and covers more than a decade, (see Baldwin and Taglioni, 2006). The country pair-time effects are not included as the model controls for several country-pair information such as contiguity, distance, common language, common colonial ties and regional trade agreements (RTAs). Therefore country-pair-time effects could be correlated by other country-pair controls that might make estimations biased.

[1] Human capital endowment is proxied by human capital-labour ratios calculated based on the human capital index subtracted from PWT 9.0.
[2] The analysis could also employ the data extracted from the EUklems database. Yet, this database does not offer up-to-date time series on needed variables and would considerably limit the time span of the regression analysis.

4. Estimation results

Estimation results on export and import flows of the CEEC are reported in Tables 1 and 2, respectively. columns 1-6 in each table present the estimations run for the sample of all the trade partners of the CEEC, while columns 7-12 report the estimations for the sub-samples of the high, middle and low income countries. First I start with the regressions on standard gravity variables and then I augment the model with ICT variables. Due to the high correlation between ICT use and ICT network effects,[3] these variables are always included separately in all specifications.

In all estimations on export flows (see Table 1) coefficients on standard gravity variables, such as GDPs, similarity index, contiguity, common language, common colonial ties, and distance turn out statistically significant and yield expected signs. Yet, it is noteworthy that in all specifications the coefficient on distance has very small magnitude, close to zero. This suggests that factor proportions, ICT variables and the other factors such as ICT network effects, knowledge economies and country and time heterogenous effects explain bilateral exports better than physical distance between the trade partners. This finding is in line with the results of Keita (2015) who finds the elasticity of trade costs to distance decreases as the level of ICT increases.

Factor proportions, namely, difference in capital-labour ratios and sum of human capital indices yield statistically significant and positive signs in most of the estimations on export flows. Yet, coefficients on capital-labour ratios are not robust to the inclusion of additional variables standing for knowledge economy and ICT networks and take negative and statistically significant values. Although, this can be explained by the fact that the regressions provided in columns 1-6 of Table 1 are done for the sample of all the trade partners without discriminating among different income countries. As outlined by Cieślik (2009) the effects of factor proportions need to be interpreted in sub-samples of the trade partners in order to account for the relative factor endowments. Namely, the theoretical model proposed by Cieślik (2009) predicts that when a country is relatively capital abundant compared to its trading partner then an increase in the capital-labour ratio in this country leads to a higher absolute value of the capital-labour difference and translates into an increased volume of bilateral trade. This is well demonstrated in the estimation results which distinguish between different income countries as reported in columns 7-12 of Table 1. As predicted by the model, exports of the CEEC with low-income countries increase with the difference in capital-labour ratios, because the CEEC are more capital abundant than low-income countries. The opposite holds for the CEEC exports to the high and middle-income countries, suggesting that higher difference in factor proportions decreases exports of the CEEC as they are relatively less capital abundant (more labour abundant) than their trading partners. The difference in human capital endowment turns out significant only for exports with low-income countries highlighting that exports of the CEEC increase when the CEEC are more human capital-abundant than their trade partners. Overall, estimations suggest that there is an incomplete specialization in production of the CEEC, favouring the Heckscher-Ohlin-Samuelson (HOS) model assuming inter-industry trade patterns where trade is explained by factor-endowment differences.

[3] Correlation between ICT network variables and ICT use in the reporter and partner countries stands around 70% and 90%, respectively.

When it comes to the ICT variables, ICT use in the CEEC countries yields positive coefficients in all estimations run for the whole as well as for the sub-samples of different income countries. Yet, the effect is not robust to the inclusion of the other variables in the model. ICT use in the partner countries turns out negative and statistically significant in all estimations for the whole sample. When I distinguish between the high, middle and low income countries, the effect is strongest for the middle-income countries. This implies that exports increase with ICT use in the CEEC yet decrease with the countries which have higher ICT use, strengthening the effects of the relative differences in factor endowments. ICT infrastructure yields more robust coefficients and shows that stronger ICT infrastructure in the CEEC leads to higher exports, particularly with the high-income countries, while the opposite holds for the low-income countries. This suggests that the CEEC exports to the high-income countries increase with strengthening ICT infrastructure. Whereas the low-income countries which increase their ICT infrastructure tend to decrease their imports from the CEEC. As the ICT infrastructure is closely associated with the overall economic growth, this hints that emerging developing economies diversify their imports which could lead to decreased imports from the CEEC.

ICT network effects turn out significant and negative but with miniscule magnitudes. This could be explained by the empirical results on ICT use: CEEC exports increase with the higher ICT use at home but decrease with the higher ICT use in the partner countries. This would cancel out the overall network effects.

Finally, knowledge economy yields positive and statistically significant effects on exports in most of the estimations run for the whole sample as well as for the sub-samples of different income countries. This implies that improving knowledge economy in both the CEEC and their partner countries positively affects export flows, particularly with middle-income countries (see columns 7-12 of Table 1).

Estimations on import flows of CEEC bring similar results (See Table 2). In all estimations the coefficients on standard gravity variables, such as GDPs, contiguity, common language and distance turn out statistically significant and yield expected signs. However, the coefficients on similarity index and common colonial ties yield negative signs. This points that imports of the CEEC countries increase with the countries with different cultural ties and economic sizes. Similar to the estimations on exports, empirical results on import flows also find the negative effects of distance yet with minor magnitude, close to zero. This suggests that factor proportions, ICT variables and other factors such as ICT network effects, knowledge economies and country and time heterogenous effects explain bilateral imports better than physical distance between the trade partners.

Factor proportions, namely, differences and sums of capital-labour ratios turn out positive for low-income countries and negative for middle-income countries. This suggests that CEEC imports are of intra-industry nature with low-income countries and of inter-industry nature with middle-income countries. The effects are not robust for the high-income countries. Differences in human capital endowments seems to increase imports with all groups of countries except with low-income countries. With the latter not the difference but the sum of human capital endowment yields positive effects with a high magnitude. This implies that the CEEC imports from the low-income countries increases with the human capital accumulation in the partner countries. Overall, estimations suggest that there is an incomplete specialization in production of the CEEC, favouring the Heckscher-Ohlin-Samuelson (HOS) model assuming inter-industry trade patterns where trade is explained by factor-endowment differences.

When it comes to the ICT variables, ICT use in both the CEEC and their partners yield negative and statistically significant coefficients for the whole sample, as well as for the different income countries. The magnitude is strongest on imports with the low-income countries. The same holds for the coefficients standing for the ICT infrastructure in partner countries. Yet, ICT infrastructure in the CEEC countries does not seem to yield any statistically significant impact on the import flows. Moreover, none of these coefficients are robust to the inclusion of the variables on knowledge economy. The latter yields positive and statistically significant effects on imports when the estimations are run for the whole sample. Yet, when the countries are disaggregated into different income-groups, knowledge economy yields negative impact on imports with high-income countries. This suggests that the CEEC imports increase with the higher knowledge economy in the low and middle-income countries and decrease with higher knowledge economy in the high-income countries. This hints that the CEEC might struggle to afford imports from the high-income countries which have better developed knowledge economies.

ICT networks yield significant and negative effects on imports of CEEC, but the magnitudes are very small, close to zero, similar to the estimations on export flows. This is in line with the empirical results on ICT use which gained negative, miniscule effects on imports. This suggests that neither ICT use and nor network effects explain imports of CEEC.

Standard errors in parentheses

Table 1. Estimation Results on export flows

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			Total sample				High	Middle	Low	High	Middle	Low
lΔKL	0.013^{***}	0.014^{***}	0.014^{***}	0.024^{***}	0.015^{***}	0.025^{***}	0.024^{***}	0.021^{**}	0.154	0.023^{***}	0.024^{***}	0.178
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.009)	(0.118)	(0.004)	(0.009)	(0.118)
lΣKL	-0.119^{***}	-0.129^{***}	-0.127^{***}	-0.308^{***}	-0.158^{***}	-0.331^{***}	-0.370^{***}	-0.368^{***}	-0.973^{**}	-0.347^{***}	-0.387^{***}	-0.811^{**}
	(0.021)	(0.022)	(0.023)	(0.033)	(0.023)	(0.033)	(0.061)	(0.097)	(0.396)	(0.061)	(0.097)	(0.392)
lΔHC	-0.005	-0.005	-0.005	0.003	-0.006	0.002	0.003	-0.005	0.093	0.004	-0.013	0.089
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.015)	(0.062)	(0.005)	(0.015)	(0.063)
lΣHC	1.592^{***}	1.714^{***}	1.733^{***}	1.242^{***}	1.561^{***}	1.105^{***}	1.493^{***}	0.934^{**}	-0.535	1.465^{***}	0.928^{**}	-0.097
	(0.193)	(0.199)	(0.203)	(0.219)	(0.204)	(0.219)	(0.330)	(0.465)	(2.350)	(0.330)	(0.460)	(2.252)
lGDP	0.377^{***}	0.381^{***}	0.381^{***}	0.313^{***}	0.359^{***}	0.294^{***}	0.389^{***}	0.185^{***}	-0.384^{*}	0.390^{***}	0.177^{***}	-0.418^{**}
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.023)	(0.026)	(0.206)	(0.023)	(0.026)	(0.210)
Sim	0.471^{***}	0.484^{***}	0.487^{***}	0.456^{***}	0.440^{***}	0.415^{***}	0.729^{***}	0.532^{***}	0.052	0.732^{***}	0.520^{***}	0.030
	(0.040)	(0.040)	(0.040)	(0.042)	(0.041)	(0.042)	(0.057)	(0.078)	(0.578)	(0.057)	(0.078)	(0.575)
contig	0.181^{***}	0.180^{***}	0.179^{***}	0.182^{***}	0.176^{***}	0.179^{***}	0.185^{***}	0.174^{***}		0.185^{***}	0.166^{***}	
	(0.018)	(0.018)	(0.018)	(0.017)	(0.018)	(0.017)	(0.016)	(0.049)		(0.016)	(0.049)	
comlang_eth	0.086^{***}	0.081^{***}	0.081^{***}	0.080^{***}	0.083^{***}	0.082^{***}	0.006	0.327^{***}		0.007	0.343^{***}	
	(0.022)	(0.021)	(0.022)	(0.021)	(0.022)	(0.021)	(0.021)	(0.046)		(0.021)	(0.048)	
colony	0.042^{*}	0.045^{*}	0.045^{*}	0.058^{**}	0.045^{*}	0.057^{**}	0.071^{***}	0.417^{***}		0.070^{***}	0.432^{***}	
	(0.025)	(0.024)	(0.024)	(0.023)	(0.024)	(0.023)	(0.019)	(0.077)		(0.019)	(0.074)	
distcap	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000^{***}	-0.000	-0.000^{***}	-0.000^{***}	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ICT_use		0.098	0.081	0.137^{*}			-0.039	0.194	1.261			
		(0.078)	(0.077)	(0.080)			(0.094)	(0.171)	(1.021)			
ICT_useP		-0.331^{***}	-0.333^{***}	-0.317^{***}			-0.007	-0.808^{***}	0.809			
		(0.038)	(0.038)	(0.039)			(0.059)	(0.095)	(1.781)			
ICT_infr			-0.013	-0.047^{*}	-0.027	-0.062^{**}	-0.035	-0.136^{**}	-0.320	-0.028	-0.152^{***}	-0.346
			(0.022)	(0.025)	(0.022)	(0.025)	(0.030)	(0.055)	(0.240)	(0.030)	(0.056)	(0.242)
ICT_infrP			0.043^{***}	0.054^{***}	0.037^{***}	0.046^{***}	0.055^{**}	-0.015	-0.188^{**}	0.057^{**}	-0.019	-0.189^{**}
			(0.012)	(0.013)	(0.012)	(0.013)	(0.023)	(0.028)	(0.078)	(0.022)	(0.028)	(0.078)
know_ec				0.239^{***}		0.226^{***}	0.209^{***}	0.452^{***}	1.172	0.214^{***}	0.411^{***}	0.973
				(0.038)		(0.038)	(0.046)	(0.097)	(0.752)	(0.045)	(0.097)	(0.734)

know_ecP				0.168^{***}		0.155^{***}	0.231^{***}	0.088^{**}	0.500^{**}	0.217^{***}	0.085^{**}	0.418^{**}
				(0.020)		(0.020)	(0.039)	(0.043)	(0.218)	(0.037)	(0.043)	(0.212)
networks					-0.000^{***}	-0.000^{***}				0.000^{**}	-0.000^{***}	0.000
					(0.000)	(0.000)				(0.000)	(0.000)	(0.000)
Constant	-4.593^{***}	-4.952^{***}	-5.116^{***}	-6.086^{***}	-4.082^{***}	-4.995^{***}	-7.618^{***}	-5.312^{***}	-4.451	-7.716^{***}	-4.460^{***}	-3.464
	(0.383)	(0.421)	(0.426)	(0.461)	(0.453)	(0.486)	(0.806)	(0.902)	(5.171)	(0.789)	(0.906)	(5.075)
N	21668	20621	20488	16375	20488	16375	5764	4269	1460	5764	4269	1460
adj. R^2												

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2. Estimation Results on import flows

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Total sample						High	Middle	Low	High	Middle	Low
lΔKL	0.011***	0.014***	0.014***	0.026***	0.014***	0.026***	0.022***	-0.006	1.115***	0.022***	-0.008	0.958***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.005)	(0.009)	(0.271)	(0.005)	(0.009)	(0.263)
lΣKL	-0.121***	-0.125***	-0.124***	-0.365***	-0.137***	-0.366***	-0.397***	-0.185*	0.073	-0.387***	-0.243**	-0.454
	(0.024)	(0.024)	(0.026)	(0.038)	(0.026)	(0.038)	(0.080)	(0.108)	(0.699)	(0.080)	(0.109)	(0.677)
lΔHC	0.028***	0.028***	0.028***	0.022***	0.028***	0.023***	-0.008*	0.079***	0.073	-0.009*	0.079***	0.049
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.019)	(0.103)	(0.005)	(0.020)	(0.099)
lΣHC	0.267	0.217	0.179	-0.121	0.010	-0.183	1.263***	-0.293	13.958***	1.292***	-0.521	12.563***
	(0.211)	(0.215)	(0.219)	(0.227)	(0.221)	(0.229)	(0.353)	(0.495)	(3.230)	(0.360)	(0.493)	(3.200)
lGDP	0.330***	0.317***	0.314***	0.207***	0.309***	0.211***	0.334***	0.162***	-0.947**	0.343***	0.160***	-0.876**
	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)	(0.016)	(0.025)	(0.026)	(0.423)	(0.025)	(0.027)	(0.442)
Sim	0.079*	0.079*	0.075	-0.116**	0.064	-0.108**	0.249***	-0.194**	1.411	0.265***	-0.196**	1.813*
	(0.045)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.066)	(0.078)	(0.967)	(0.066)	(0.078)	(0.968)
contig	0.247***	0.252***	0.252***	0.249***	0.252***	0.249***	0.232***	0.124**		0.233***	0.116**	
	(0.021)	(0.021)	(0.021)	(0.020)	(0.021)	(0.020)	(0.020)	(0.059)		(0.020)	(0.058)	
comlang_eth	0.171***	0.173***	0.172***	0.153***	0.172***	0.153***	0.066***	0.400***		0.067***	0.415***	
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.023)	(0.055)		(0.023)	(0.054)	
colony	-0.062***	-0.061***	-0.061***	-0.049**	-0.060***	-0.048**	0.007	0.175**		0.008	0.195**	
	(0.023)	(0.023)	(0.023)	(0.022)	(0.023)	(0.022)	(0.017)	(0.077)		(0.017)	(0.077)	
distcap	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000	-0.000***	-0.000***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ICT_use		-0.428***	-0.432***	-0.293***			-0.082	-0.848***	0.128			
		(0.083)	(0.086)	(0.086)			(0.102)	(0.177)	(1.336)			
ICT_useP		-0.026	-0.033	0.074			0.347***	-0.364***	-10.592***			
		(0.044)	(0.044)	(0.046)			(0.074)	(0.107)	(2.143)			
ICT_infr			-0.008	-0.017	0.018	-0.000	-0.035	-0.082	-0.399	-0.025	-0.041	-0.419
			(0.026)	(0.028)	(0.025)	(0.028)	(0.035)	(0.058)	(0.329)	(0.034)	(0.057)	(0.312)
ICT_infrP			0.028**	-0.030*	0.025*	-0.029*	-0.020	-0.037	-0.094	0.006	-0.040	-0.098
			(0.014)	(0.016)	(0.014)	(0.016)	(0.025)	(0.035)	(0.110)	(0.023)	(0.035)	(0.111)

know_ec				0.253^{***}		0.266^{***}	0.313^{***}	0.001	-0.732	0.321^{***}	0.052	-0.254
				(0.040)		(0.039)	(0.049)	(0.102)	(1.198)	(0.048)	(0.102)	(1.150)
know_ecP				0.181^{***}		0.180^{***}	0.212^{***}	0.050	1.532^{***}	0.256^{***}	0.060	1.748^{***}
				(0.024)		(0.024)	(0.056)	(0.049)	(0.256)	(0.056)	(0.049)	(0.243)
networks					-0.000^{**}	0.000				0.000	-0.000^{***}	-0.002^{***}
					(0.000)	(0.000)				(0.000)	(0.000)	(0.000)
Constant	-1.622^{***}	-1.373^{***}	-2.073^{***}	-1.918^{***}	-1.568^{***}	-2.002^{***}	-6.422^{***}	1.919	-28.186^{***}	-7.210^{***}	2.088^{*}	-28.089^{***}
	(0.425)	(0.435)	(0.457)	(0.497)	(0.491)	(0.534)	(0.807)	(1.187)	(6.923)	(0.820)	(1.216)	(6.798)
N	21304	20164	20048	15958	20048	15958	5673	4151	1277	5673	4151	1277

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusions

The paper examined the effects of ICT and general technological environment expressed in knowledge economy on trade performances of CEEC. The empirical framework augmented the structural gravity equation proposed by Cieslik (2009) with ICT variables, such as ICT use, ICT infrastructure and ICT network effects, human capital and knowledge economy. The analysis explicitly studied the ICT effects on both exports and imports of CEEC and allowed distinguishing among the different income countries across the trading partners of CEEC.

Empirical results derived from the PPML estimator are in line with the literature on the standard gravity variables. Yet, the effects of distance seems to yield minor explaining power on the CEEC exports and imports once controlled for the factor proportions, ICT variables, knowledge economies and country and time heterogenous effects. Estimations on both exports and imports hint at the incomplete specialization in production of the CEEC, favouring the Heckscher-Ohlin-Samuelson model assuming inter-industry trade patterns where trade is explained by factor-endowment differences.

Empirical results outline that exports of the CEEC increase with the higher ICT use and stronger ICT infrastructure at home while decrease with the higher ICT use and stronger ICT infrastructure at the partner countries. This strengthens the effects of the relative differences in factor endowment and cancels out expected ICT network effects. Finally, improving knowledge economy in both the CEEC and their partner countries positively affects export flows, particularly with middle-income countries

However, estimations do not find robust effects of ICT variables on CEEC imports. Although, in most of the estimations, the impact of knowledge economy turns out statistically significant. In particular, the CEEC imports increase with the higher knowledge economy in the low and middle-income countries and decrease with higher knowledge economy in the high-income countries. This hints that the CEEC might struggle to afford imports from the high-income countries which have better developed knowledge economies.

Overall, the paper demonstrates that controlling for the relative differences in the factor endowments explains well the patterns and destinations of the CEEC exports and imports. Including the ICT variables and proxies for the knowledge economy in the model further strengthens the effects of the relative differences in the factor endowments. Distinguishing among the high and low income countries makes the interpretation of the results more straightforward. In particular, higher ICT use, stronger ICT infrastructure and well developed knowledge economy increases exports of the CEEC. The ICT effects, however, seem less robust on the CEEC imports, which so far are mostly explained by the differences in the factor endowments and income levels of the trade partners.

Regressions results also find some controversial findings on the similarity index, hinting that the proposed empirical framework might have some limitations to study the effects of ICT variables and knowledge economies on imports of the CEEC. While this paper gave a try to shed some light on the effects of the ICT and knowledge economy on the CEEC trade, more systemic research should be done to put forward the proper empirical framework to study these effects.

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