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Information and communications technology (ICT) and international trade: evidence from Turkey

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Abstract This study analyzes the impacts of information and communications technology (ICT) on international trade between Turkey and its trading partners. Using an extended panel gravity model framework, it examines the effects of four ICT indices on Turkish bilateral exports and imports with static and dynamic panel data models for the period 2000–2014. The sample includes 35 countries that import Turkish goods and 34 countries that export goods to Turkey. The results indicate that ICT has positive and significant impacts on both Turkish import and export volumes. Additionally, ICT has a quantitatively larger effect on imports than on exports. These results are robust to alternative model specifications and estimation methods. Based on these results, some policy implications can be derived. For instance, Turkey may develop strategic trading partnerships with countries that have achieved high levels of ICT development, in order to increase its overall trade.

Keywords Information and communications technology · International trade · Trade costs · Gravity model · Panel data models · Turkey

JEL Classifications C33 · F10 · F14 · 030

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1 Introduction

The use of technology in our daily lives has gained much importance during the current wave of globalization. By allowing cross-border flow of ideas, knowledge, expertise, and innovations, information and communications technology (ICT), in general, and the Internet, in particular, have also contributed significantly to the globalization of the world economy (Choi 2010).[1] As a result of the revolution in the ICT sector in the 1990s, the world has witnessed some remarkable changes such as enhanced economic activity, accelerated productivity growth and rising international trade. For instance, the technological progress in telecommunications and associated decline in communication costs have frequently been cited as the leading cause of growing world trade in the last quarter of the 20th century (Fink et al. 2005).

As for the relationship between ICT and trade, the advances in ICT have made physical distance irrelevant as an impediment to trade. Thus, the discussion in the popular press of the "death of distance" has been commonplace (see Demirkan et al. 2009; Freund and Weinhold 2004b). The proximity requirement for face-to-face interaction between business partners is no longer a necessary condition because innovations in ICT such as telephone, email, and virtual conference have become substitutes for face-to-face interactions (Dettmer 2014). In particular, such ICT-enabled innovations have helped poor and developing countries with considerable geographic distances and cultural and political barriers with their trading partners in increasing trade ties by compensating for the lack of strong historical trade linkages (Freund and Weinhold 2004b).

There are several plausible mechanisms through which ICT may affect the flow of international trade (see Liu and Nath 2013). These mechanisms make markets more competitive and efficient by improving information flows and lowering transaction costs, such as fixed market entry cost, communication and information costs, and bargaining and coordination costs associated with trade (Jungmittag and Welfens 2009; Park and Koo 2005). Thus, ICT has trade-creation (trade-enhancing) effects. For instance, in respect of fixed market entry costs, through organized exchanges with several buyers and sellers over the Internet and through powerful search engines providing for sellers and buyers to find each other at a low cost, ICT has the potential to lower market-specific fixed entry costs, such as those of searching, advertising, and establishing a distribution network into a market (Freund and Weinhold 2004a; Lin 2015).

Regarding communication costs, telecommunication creates an avenue to maintain a fast and an efficient communication with trade partners to sustain business competitiveness (Bankole et al. 2015). Besides, cheaper and faster communication may boost market transactions and also enlarge the radius of international trade (Jungmittag and Welfens 2009). In case of information costs, ICT provides a low-cost channel for information gathering, processing, and

[1] ICT is a term that includes any communication device or application such as radio, television, mobile phones, computer, network hardware and software, etc., as well as the various services and applications related to them such as videoconferencing and distance learning (see http://searchcio.techtarget.com/definition/ICT-information-and-communications-technology-or-technologies).

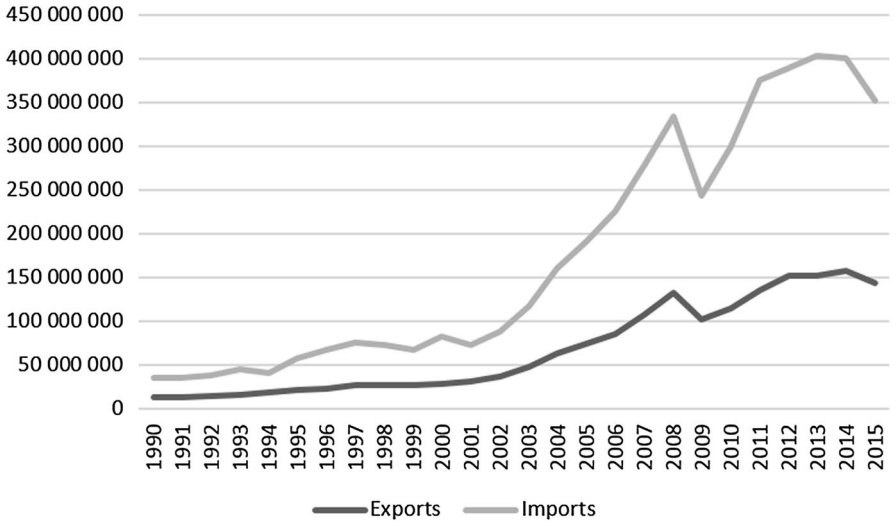

Fig. 1 The value of exports and imports of goods and services (thousands of current US dollar) Source: Turkish Statistical Institute 2016. Attained from http://www.turkstat.gov.tr

dissemination. It also leads welfare enhancement by reducing information asymmetries as all members of any given exchange share the same information (Ahmad et al. 2011; Freund and Weinhold 2004b). Furthermore, the delays in acquiring and transmitting information are reduced and planning is more efficient and accurate due to advances in ICT (Liu and Nath 2013, 2017). All these explanations indicate that there would be a positive impact of ICT on trade between countries.

Against the backdrop of the rising importance of ICT on international trade, this study aims to analyze the impact of ICT on Turkey's bilateral exports and imports for the period 2000–2014 through an augmented panel data gravity model. The Turkish economy was in disarray in the first half of the 2000s. Due to the earthquake in 1999 and the domestic financial crises in 2000–2001, the end of the 20th century and the early 2000s were drastically destructive for Turkey (Babacan 2010). However, through the enforcement of the "Transition to the Strong Economy Program" in May 2001, many structural reforms, such as market liberalization, privatization, banking system strengthening, fiscal discipline, tight monetary policy, inflation targeting, and a floating exchange rate regime, were undertaken to alleviate the impacts of these severe crises and to recover the Turkish economy. Since 2002, Turkey's imports and exports of goods and services have followed upward trends except for the world financial crisis period (2008–2009) (see Fig. 1).[2] During this period, the access, use, and skills necessary for the deployment of ICT also

[2] With respect to the shares of trading partner countries in Turkey's trade, the top 20 importers and 20 exporters of Turkey account for 68.5 and 72.9% of Turkey's exports and imports, respectively (Turkish Statistical Institute, 2016). Among them, Germany with a share of 9.3% and China with a share of 12% rank first in Turkey's exports and imports, respectively. As for country groups, European Union (EU) countries have the largest shares in both Turkish exports (44.5%) and imports (38%).

increased manifold in Turkey. For instance, the percentage of Internet users was only 3.7% in 2000 while it steadily increased to 51.04% in 2014 (ITU 2015).

To the best of our knowledge, this is the first study of this kind for Turkey. Karagoz (2007) is the only other study that analyzes the influence of ICT on Turkish exports in the literature. However, he employs a time series analysis. Additionally, the studies in the literature generally analyze the effect of ICT on trade among a group of countries, i.e. on a multilateral basis. In contrast, we consider bilateral trade. Besides, we analyze the effect of ICT on both Turkish exports and imports volumes separately, instead of Turkish total trade volume or only exports or only imports. This study also sets an example and provides policy implications for developing countries at the same development level as Turkey. Furthermore, there are only few studies (Liu and Nath 2017; Mattes et al. 2012) that consider all aspects of ICT (by computing and using ICT Development index) while examining its impact on trade. We use a comprehensive aggregate index that combines three different aspects (access, use, and skills) of ICT. Besides, we use three different sub-indices representing those three aspects separately in our regression analysis. This is another contribution of this study. Instead of utilizing only one indicator as a proxy for ICT, we represent ICT in a more comprehensive and a detailed way.

The rest of the paper is organized as follows. Section 2 briefly reviews the related empirical literature while Sect. 3 explains the model and data. The results from the empirical analyses are presented in Sect. 4. Finally, Sect. 5 concludes this study with a summary of the research findings and some important policy recommendations.

2 Literature review

After the seminal research of Freund and Weinhold (2002, 2004a), several studies have analyzed the impact of ICT on international trade. Freund and Weinhold (2002) estimate both a cross-section model and a panel data extended gravity model using data for the sample period from 1995 to 1999 to analyze the impact of the Internet on trade in 14 service industries between the US and 31 countries. The results indicate that the effect of the Internet on services trade growth is positive and significant. In another study, Freund and Weinhold (2004a) examine the impact of the Internet on bilateral merchandise trade among 56 countries from 1995 to 1999 by first using a theoretical model and then employing both a cross-section and a panel data gravity model. They find that the Internet stimulates bilateral trade between countries.[3]

The recent studies in the literature use panel data models. For instance, Vemuri and Siddiqi (2009), applying the panel gravity model framework, examine the impact of the Internet and ICT infrastructure on bilateral trade among 64 countries for the years from 1985 to 2005 and obtain a positive and significant impact of ICT infrastructure on international trade. Using a panel gravity model, Ahmad et al.

[3] To conserve space, we only mentioned about the results of panel data studies in detail. However, there are also other cross-country studies in the literature (see Clarke and Wallsten 2006; Clarke 2008; Demirkan et al. 2009; Kurihara and Fukushima 2013; Yushkova 2014).

(2011) utilize different indicators as proxies for ICT infrastructure and search for the impact of ICT on bilateral trade between Malaysia and its 36 trading partners from 1980 to 2008. The results favor the positive and significant impacts of ICT on bilateral trade. Mattes et al. (2012) analyze the impact of ICT development index on trade within the European Union (EU) and between the EU and its main trading partners for the period of 1995–2007. The results indicate that ICT has a significant impact on inter- and extra-European trade. A similar ICT development index is used by Liu and Nath (2017) as well, applying a dynamic panel data model to examine the effects of ICT on exports and imports of 10 service categories for 49 countries from 2000 to 2013. The results suggest that ICT development affects trade in only a limited number of service items. In another study, Liu and Nath (2013) estimate the effect of ICT on both exports and imports in 40 emerging markets from 1995 to 2010. Their results show that the Internet subscriptions and Internet hosts have significant positive effects on both exports and imports.

There are other panel data studies (see Choi 2010; Lin 2015; Timmis 2012) that focus only on the impact of the Internet instead of using different ICT indicators on trade. The panel study by Lin (2015) estimates the impact of the Internet users on 200 countries' bilateral trade from 1990 to 2006 in a panel gravity model. The Internet use has a positive and statistically significant effect on international trade, and its effect on export is stronger than that on import. Choi (2010) also utilizes the Internet users per 100 people to investigate the impact of ICT on service trade for 151 countries from 1990 to 2006 and finds that an increase in the Internet users promotes total service trade, as well as service export and service import. Timmis (2012) employs a panel gravity model to assess the role of the Internet adoption on trade within 34 OECD countries over the period 1990–2010. However, he finds that the Internet has a less clear-cut impact on international trade.

In the related literature, there are a few studies that use different methodologies to estimate the impact of ICT on trade (see Bankole et al. 2015; Dettmer 2014). Of them, Dettmer (2014) uses a Tobit model and Bankole et al. (2015) apply structural equation models to show that ICT has positive and significant impacts on trade. Some other studies (see Fink et al. 2005; Jungmittag and Welfens 2009; Tang 2006) examine the impact of ICT on international trade in an indirect way by searching for the effect of communication costs on bilateral trade. Furthermore, using ICT infrastructure as one of the aspects of infrastructure quality, a group of studies analyze the impact of institutions and infrastructure on international trade (see Francois and Manchin 2013; Limao and Venables 2001; Nordas and Piermartini 2004; Portugal-Perez and Wilson 2012).

3 Model and data

3.1 Model

This study utilizes an augmented version of the gravity model as a standard analytical tool for the prediction of bilateral trade flows. Tinbergen (1962) was the first to propose a gravity equation for bilateral trade as an empirical specification, of

course taking clue from Newton's universal law of gravitation. In the gravity model of international trade, bilateral trade flows between countries are positively related to the market sizes (economic masses) of the exporting and importing economies and are negatively linked to the distance between these countries. Additionally, GDP is used as a proxy for the size of the economy and expected to have positive coefficient. The distance between countries is expected to have a negative impact on bilateral trade because of lower transportation costs. The original version of the gravity model in Tinbergen's (1962) study is defined in a log–log form so that the parameters are the elasticities of trade flows with respect to the explanatory variables. Based on these explanations, we specify our model in Eq. (1) as an extended version of the original gravity equation.[4]

$$\begin{aligned}\ln Y_{ijt} = {} & \alpha_0 + \alpha_1 \ln(GDP_{it} x GDP_{jt}) + \alpha_2 \ln(Pop_{it} x Pop_{jt}) + \alpha_3 \ln(ICT_{it} x ICT_{jt}) \\ & + \alpha_4 \ln Distance_{ij} + \alpha_5 Border_{ij} + \alpha_6 Language_{ij} + \alpha_7 Colony_{ij} + \alpha_8 RTA_{ijt} \\ & + \alpha_9 Landlocked_j + \alpha_{10} Island_j + \beta_i + \gamma_t + \varepsilon_{ijt} \end{aligned} \quad (1)$$

where i and j indicate Turkey and its trading partners respectively, while t is the time period. Y_{ijt} denotes the volume of export from/import to Turkey to/from country j in period t. $\ln(GDP_{it} x GDP_{jt})$ is the GDP mass that measures the real GDP of Turkey and country j. It is expected to have positive impacts on export and import. $\ln(POP_{it} x POP_{jt})$ is the population mass that is used as a proxy for country size and measures the populations of Turkey and country j. The impact of population on export is not clear a priori (see Liu and Nath 2013). Because a growing population may raise domestic production and export by increasing labor supply; however, at the same time, by creating domestic demand, it may also reduce export. Similarly, its impact on import is also not certain. On the one hand, increasing domestic demand may raise import demand. On the other hand, country may decide to produce domestically instead of importing, resulting in decreases in import volume. $\ln(ICT_{it} x ICT_{jt})$ refers to ICT mass that measures the ICT level of the Turkey and country j, and is expected to have positive impacts on both export and import. $Distance_{ij}$ is the weighted distance between Turkey and country j that is computed by using population weights of those countries (see Dettmer 2014).

The binary dummy variables in Eq. (1) are included in the gravity model to capture the trade costs, such as transportation costs and information costs (see Nordas and Piermartini 2004). Among them, island, landlocked, and common border dummies are used to reflect shipping costs which are higher for landlocked and island countries and lower for neighboring countries. Additionally, binary dummy variables for a common language and colonial history indicate cultural proximity between countries and capture information costs that go down with sharing a common language or some colonial linkages (WTO 2012). $Border_{ij}$ is a binary dummy variable that is unity if Turkey and country j share a common border;

[4] The variables in our model are similar to those in the studies by Biswas and Kennedy (2016), Choi (2010), Freund and Weinhold (2002, 2004a). However, we could not differentiate the impacts of GDP, population and ICT variables for Turkey and its partners separately because Turkey's data are same across all trading partners. Instead of doing this, we searched for the impacts of GDP mass, population mass and ICT mass on bilateral trade between Turkey and its partner countries.

$Language_{ij}$ is a binary dummy variable that is unity if a language is spoken by at least 9% of the population in each of the two countries.[5] $Colony_{ij}$ is a binary dummy variable that takes the value 1 if Turkey and country j have been any colonial relationship; RTA_{ij} is a binary dummy variable that is unity if there is a regional trade agreement (RTA) between Turkey and country j in some periods of time; $Landlocked_j$ and $Island_j$ are binary dummy variables taking the value of unity if country j is a landlocked and an island country, respectively. Of the binary dummy variables, landlocked and island are expected to have negative coefficients while language, border, RTA, and colony variables to have positive coefficients. Additionally, β_i and γ_t are individual (country) effects and time effects and ε_{ijt} is an error term that is assumed to be normally distributed with zero mean. Time effects are included into the model to capture the effects of global events that may have impacts on trade. We estimate Eq. (1) with pooled ordinary least squares (OLS) with country fixed effects and time effects.[6]

3.2 Data

We obtain cross-country data on trade (export as well as import), ICT, and other relevant variables from 2000 to 2014. The choice of the sample period from 2000 to 2014 is dictated by the availability of ICT data. We select the most traded 40 exporting and 40 importing countries of Turkey based on data availability. However, we had to exclude the United Arab Emirates (UAE), Brazil, Vietnam, Kazakhstan, Canada and South Africa from the estimation of the import model; and Turkmenistan, Iraq, Libya, UAE, and Kazakhstan from the export model primarily due to insufficient ICT data. Thus, we are left with 35 countries that account for 73.7% of Turkey's exports and 34 countries that account for 82.7% of Turkey's imports. The countries in the sample are listed according to their trading volumes in 2014 in Table 4 (see Appendix 1). We use two separate models for exports and imports. The export model refers to Turkey's bilateral merchandise exports to its importers while the import model is used for the Turkey's bilateral merchandise imports from its exporters.

Bilateral merchandise imports and exports data are obtained from the Direction of Trade Statistics (DOTS) database of International Monetary Funds (IMF) and are measured in current US dollar (USD). We use export and import unit value indices (2005 = 100) from IMF's International Financial Statistics (IFS) to convert trade data into 2005 constant USD. GDP (constant 2005 USD) and population data are obtained from the World Development Indicators (WDI 2016) database of the World Bank. Our binary dummy variables are from CEPII GeoDist Dataset and Gravity Dataset. However, CEPII Gravity Dataset contains data for RTA only for the period 1948–2006. Therefore, this information has been supplemented by data from the World Trade Organization's (WTO) Regional Trade Agreement database for the years 2007–2014.

[5] We follow the convention of using the 9% threshold as in previous studies (e.g., Vemuri and Siddiqi 2009).

[6] Freud and Weinhold (2004a, b) use this method as well.

Data on ICT variables are obtained from the International Telecommunication Union (ITU)—World Telecommunication/ICT Indicator database (ITU 2015). Since ITU's data on the ICT development index (IDI) and the three sub-indices (ICT access, ICT use, and ICT skills) do not cover the period before 2009, we modify ITU's methodology to construct those indices for the entire sample period we consider here. Among the sub-indices, ICT access index captures ICT readiness and includes indicators that provide an indication of the available ICT infrastructure and individuals' access to basic ICTs. ICT use index measures ICT intensity and consists of three intensity and usage indicators. Finally, ICT skills index reflects capabilities or skills that are necessary for ICTs, and it includes three proxy indicators.[7] Linear interpolation is used to fill the missing values of the component variables. However, we had to exclude some variables used by ITU while constructing those indices, primarily due to a lack of data for the entire sample of countries and the sample period.[8]

In sensitivity analyses, we use some additional control variables. Of them, exchange rate data are obtained from IMF's IFS database. However, we convert exchange rate data to national currency per Turkish Lira (TL). Also, consumer price indices of Turkey and the partner countries were taken from IFS to calculate the real values of nominal exchange rates. Weighted average tariff rates data (in percentages) are extracted from the World Bank's World Integrated Trade Solution (WITS) system database. Data on goods transported by railways (million ton-km) are available from the WDI database. The voice and accountability indices from the World Governance Indicators (Kaufmann, Kraay, and Mastruzzi 2003) are obtained from the World Bank's website. We scale up this index by two so that we can take logarithmic values of this indicator as its value ranges between −1.86 and 1.81 for the countries in our sample. We include all these control variables to verify that IDI index is not picking up the effects of these variables.

4 Empirical results

4.1 Main results

The descriptive statistics (Tables 6, 7) for the variables of interest are presented in Appendix 2.

Table 1 reports the baseline model results for both export and import.[9] Column 1 in both models provides the results of model without time effects and country fixed effects. For both models, Column 2 presents the results with only time effects while

[7] Note that ITU has been publishing data on IDI index, a composite index that combines 11 indicators into one benchmark measure for countries since 2009. See http://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2015/methodology.aspx for a detailed explanations about ICT indices.

[8] See Table 5 in Appendix 1 for the variables used to construct ICT indexes.

[9] Although our time period is short, there may be concerns over the stochastic trending properties of time variant variables, such as population, GDP, export, import and ICT indices and the potential for spurious regression problem. We conduct Levin et al. (2002) panel unit root test and the results indicate that all variables are stationary in their levels. The results are available upon request from the author.

Table 1 Baseline model results for export and import

Variables	Export model			Import model		
	1	2	3	1	2	3
lnGDP	0.3859[a]	0.2782[a]	1.1651[a]	0.5608[a]	0.1250[c]	0.9665[a]
	(0.0315)	(0.0866)	(0.1905)	(0.0447)	(0.0719)	(0.3352)
lnPopulation	0.3238[a]	0.4232[a]	−0.8751[a]	0.2661[a]	0.7262[a]	−0.2529
	(0.0446)	(0.0931)	(0.2722)	(0.0399)	(0.0627)	(0.2567)
lnDistance	−0.6238[a]	−0.5950[a]	−1.5502	−0.9377[a]	−0.8098[a]	−2.5180[b]
	(0.0202)	(0.0280)	(2.2291)	(0.0510)	(0.0790)	(1.1923)
lnIDI Index	0.3904[a]	0.7752[a]	0.4720[a]	0.5057[a]	1.8738[a]	0.7515[a]
	(0.0533)	(0.2409)	(0.1246)	(0.0507)	(0.1477)	(0.1506)
Border	0.8886[a]	0.9049[a]	3.6227[a]	0.7000[a]	0.8997[a]	−2.162[c]
	(0.0829)	(0.0894)	(0.6825)	(0.0752)	(0.0660)	(1.1542)
Language	−1.4870[a]	−1.5398[a]	1.9020[a]	1.2702[a]	0.9597[a]	2.0277[a]
	(0.2707)	(0.2987)	(0.2592)	(0.2150)	(0.2393)	(0.6565)
Colony	−0.5147[a]	−0.4826[a]	−5.9624[a]	−1.5617[a]	−1.5965[a]	−5.1724[a]
	(0.0741)	(0.0553)	(0.8914)	(0.1682)	(0.1818)	(1.6683)
RTA	0.3097	0.2769[a]	0.3052[a]	−0.2884[a]	−0.2208[b]	0.44279[a]
	(0.0624)	(0.0409)	(0.0474)	(0.0833)	(0.0916)	(0.10456)
Landlocked	−0.5274[a]	−0.5283[a]	−2.1990[b]	−0.2249[b]	−0.1344	−4.5227[b]
	(0.0360)	(0.0362)	(1.0021)	(0.0999)	(0.0992)	(1.7358)
Island	−1.1145[a]	−1.0790[a]	−4.1426[a]	−0.5179[a]	−0.5487[a]	−2.1990[a]
	(0.2312)	(0.2090)	(0.7524)	(0.0627)	(0.0630)	(0.5053)
Number of country	35	35	35	34	34	34
Obs.	513	513	513	510	510	510
Time effects	No	Yes	Yes	No	Yes	Yes
Country effects	No	No	Yes	No	No	Yes
Adjusted R-square	0.7100	0.7232	0.9580	0.7673	0.8143	0.9496

Driscoll-Kray (1998) robust standard errors are reported in parentheses

[a, b, c] Indicate 1, 5 and 10% significance levels respectively. All regressions include a constant term.

Column 3 shows the estimations results with both time and country fixed effects. The F test results indicate that both time and country effects are relevant for both models.[10] Therefore, Column 3 provides us the most important results for both export and import models. As seen in Column 3 in both models, including country fixed effects along with time effects change the coefficients' signs of some variables, such as population in both export and import models, border and RTA in import model, and language in export model. Thus, country specific effects appear to have picked up some impacts of these variables.

The results from all models indicate that IDI index has a positive and significant impact on both Turkish bilateral exports and imports volumes. As provided in

[10] F tests results are available upon request from the corresponding author.

Column 3 in both models, a 1% increase in IDI index leads to about 0.4 and 0.7% rises in export and import, respectively. The positive influence of ICT may be a result of decreases in trade-related costs, such as fixed-market entry cost, communication and information costs. Turkey may have more information about foreign markets and the entry costs to those markets could have been reduced due to improvements in ICT. Suppliers in Turkey are able to advertise to numerous buyers at once. In particular, the Internet plays a pivotal role since it reduces search costs by matching buyers and sellers (Biswas and Kennedy 2016). In this case, Turkey exports more to its importers through an increase in ICT level. Besides, the more ICT connectedness between two countries, the more will be the bilateral trade between them. As stated by Freund and Weinhold (2004b), this is a gainful transaction for both sides because importing countries are able to buy goods at lower prices while exporting countries can get easy access to new markets as the fixed entry costs get reduced or removed.

Among other variables in the models, as expected, GDP has a significant and positive impact on bilateral exports and imports of Turkey in all models. Therefore, as stated in the gravity model, economic size of country pairs is a boosting factor for trade. As shown in Column 3 in both models, a 1% increase in total GDP leads to 1.1% and 0.9% rises in Turkish exports and imports, respectively. The other variable, population, as a proxy for country size, affects Turkey's exports and imports positively and significantly except for Column 3. Population growth may lead to higher domestic production and in turn higher export by increasing labor supply in Turkey. Besides, in respect of import, the growing population implies more consumers and more demand for imported goods. The distance between Turkey and its trading partners affects Turkey's export and import negatively, as expected, in most cases. The larger the distance between Turkey and its partners, the lower is the export from Turkey to those countries. Also, Turkey seems to import fewer goods from its distant exporters due to high transportation costs.

With respect to the results of the binary dummy variables, Turkey appears to trade (export as well as import) more with its neighboring countries with common border in nearly all models. However, sharing a common language has a negative and significant impact on Turkey's exports except for Column 3. This result is not odd as Turkey does not have a common language with its most importers, such as EU member countries. Contrary to the export model, sharing a common language affects Turkey's imports positively as theoretically expected.[11] The colonial heritage has adverse and significant impacts on Turkey's import and export, indicating that Turkey imports and exports less from and to its trading partners with which it shares a colonial past, such as Egypt, Bulgaria, Syria, Libya, Cyprus, and Tunisia. In gravity model, the colonial heritage is expected to have a positive and significant impact on bilateral trade. However, there are some studies that find the destructive impact of colonial past on trade. For instance, Head et al. (2010) find that, on average, trade between a colony and its colonizer declines by about 65%

[11] In our sample, Bulgaria is the only exporter of Turkey while Cyprus and Bulgaria are the only two importers of Turkey that share a common language with Turkey. The impact of language may also be biased due to this fact. We also excluded language dummy and run the regressions again; however, the results for the coefficient of ICT didn't change.

during the first 40 years of independence as the result of the deterioration of business networks or similar institutions. Further, independence may boost trade costs and lower trade between metropole and its dependencies by terminating some specific formal relationships, such as preferential trade agreements and informal connections (Lavallee and Lochard 2012).

Among other dummy variables, RTA has a positive and significant impact on Turkish exports. In particular, the Customs Union agreement, which went into force between Turkey and EU members in January 1996, has reinforced the trade linkages. EU member countries are now the largest trading partners of Turkey. However, in the import model, contrary to expectations, a negative and significant result is obtained for RTA except for Column 3. This result may have been driven by the fact that RTA has a high negative correlation with the distance variable. When we exclude the distance variable from the import model, the impact of RTA turns out to be positive and significant as expected. Thus, distance seems to have picked up some of the effects of RTA on trade.[12] Last, Turkey trades (exports as well as imports) less with its landlocked and island trading partners, as expected, due to higher transportation costs.

4.2 Sensitivity analyses

4.2.1 Additional regressions

As a part of the sensitivity analyses, we run additional regressions by using three ICT sub-indices (instead of the aggregate index as in the previous section), adding some control variables and individual time trend for each country to the baseline models, and dropping or including some specific groups of countries.[13] The results are reported in Table 2.

In the export model, ICT access and ICT skills indices have positive and significant impacts on Turkish exports, whereas ICT use index does not have any significant impact. In respect of the import model, all three sub-ICT indices have significant and positive trade effects. Besides, based on studies in the literature, we choose some control variables which are likely to affect international trade. For instance, exchange rate as an important determinant of international trade volume is used (see Ahmad et al. 2011; Freund and Weinhold 2004a; Liu and Nath 2013). Also, tariff rate is accepted as a proxy for trade cost (Clarke and Wallsten 2006; Fink et al. 2005). Due to lower tariff rates, the costs of imported goods go down, and import becomes cheaper. Thereby, as stated by Liu and Nath (2013), a country may

[12] There is a −0.6635 negative correlation between distance and RTA in the import model. In the import model, the most trading partners of Turkey are EU member countries, located in a specific region, Europe. Therefore, there is a specific physical distance between Turkey and EU economies. Also, these countries have a Customs Union agreement with Turkey. Therefore, it is reasonable to expect a high correlation between RTA and distance. When we exclude RTA from the import model, the coefficients of all variables remain unchanged and stable. We also checked the correlation between RTA and distance for the export model; however, there is relatively a smaller negative correlation of −0.1631.

[13] We did not report the results of the coefficients of control variables, goodness of fit, and observation numbers of the regressions to conserve space. However, they are available upon request from the author. Besides, tariff rates and railway data are available only for a small number of countries in both models.

Table 2 Results from additional regressions

Variables	Export model	Import model
ICT access index	0.2149[a]	0.5324[a]
	(0.0567)	(0.0528)
ICT use index	0.0004	0.3319[a]
	(0.0326)	(0.0270)
ICT skills index	0.3965[a]	0.9234[a]
	(0.0978)	(0.2500)
lnexchange rate	0.4511[a]	0.6235[a]
	(0.1568)	(0.1453)
lntariff rates	0.5563[a]	0.8629[a]
	(0.1377)	(0.1712)
lnrailway	0.6050[a]	0.5981[a]
	(0.1319)	(0.1766)
lndifference GDP per capita	0.5029[a]	0.7489[a]
	(0.1277)	(0.1527)
lnpolitical openness	0.4220[a]	1.143[a]
	(0.1228)	(0.1563)
With individual time trend for each country	0.6354[a]	0.5202[a]
	(0.2040)	(0.1618)
For developed countries	−0.3713	1.8201[a]
	(0.2891)	(0.3938)
For developing countries	0.6774[b]	−0.4679
	(0.2456)	(0.4897)
Drop EU countries	0.6371[a]	0.6725[a]
	(0.1745)	(0.0981)
Drop landlocked countries	0.3819[a]	0.6572[a]
	(0.1026)	(0.1946)
For (2009–2014)	0.13447	1.0484[a]
	(0.3810)	(0.1830)

Driscoll-Kray (1998) robust standard errors are reported in parentheses

[a, b, c] Indicate 1, 5, and 10% significance levels, respectively. Country and time fixed effects are included in all regressions; control variables are used in their natural logarithmic forms

increase imports of capital goods that enhance its ability to export. Further, railway is used as a proxy for physical infrastructure quality and the higher quality of physical infrastructure is expected to boost trade between countries (see Limao and Venables 2001; Lin 2015; Portugal-Perez and Wilson 2012). The difference between GDP per capita of Turkey and its trading partners as a proxy for similarity in lifestyles is included. By doing so, we aim to test the trade theories of Linder (1961) and Heckscher (1919) – Ohlin (H-O, 1933). Linder theory asserts that bilateral trade will only occur between two nations which have the same levels of economic development, whereas H–O theory suggests that bilateral trade takes place between two countries that have different levels of economic development.

Finally, the voice and accountability index which is a measure of political and civil rights in the country is added to the models (see Clarke and Wallsten 2006; Francois and Manchin 2013). The level of political openness of a country signals the extent of democratization that leads to more liberal trade policies and improves institutional quality. They in turn foster product quality and the reputation of a country's exports (Krenz 2016). When we add these control variables to the baseline models one by one, the estimated coefficient for the IDI index remains positive and significant in both export and import models These findings indicate that IDI index is not picking up the effects of the control variables on trade. Further, we include a time trend for each country in our model along with country and year fixed effects. In principle, there could be a different trend for each country. However, even in this case, the IDI index still retains its positive and significant effects on both imports and exports.

We also run regressions for some specific groups of countries, such as developed and developing countries, non-EU countries and non-landlocked countries separately. ICT has a positive and significant impact on export of Turkey to its developing trading partners. In contrast, ICT has a significant and positive impact on Turkey's imports from its developed trading partners.[14] As another sensitivity check, we exclude the EU member countries, the top trading partners of Turkey. There are 17 and 18 EU member economies in the import and the export model, respectively. Excluding EU countries from the sample does not lead to any significant change and the positive trade impact of IDI index remains. As yet another sensitivity check, five landlocked countries from both import and export samples are dropped. In that case, IDI index still has positive and significant coefficient.

Finally, we test the robustness of our findings for a shorter sample period: 2009–2014. This period corresponds to the aftermath of the last global financial crisis of 2008. Turkey's international trade was heavily affected in this period due to recession in EU member countries. Since then, Turkey has started looking for new trading partners, particularly from the Middle East and Africa, to prevent the destructive impacts of the crisis on its international trade and economic growth. When we re-run the regressions only for the period of 2009–2014, the IDI index keeps its positive effect on Turkish imports, whereas it loses its impact on exports. In other words, the total ICT level in Turkey and its importers was not enough to boost the Turkish exports volume in the post-crisis period. However, ICT still affects Turkish imports positively in the aftermath of the crisis due to high levels of ICT endowment in Turkey's developed exporters.

Overall, these sensitivity analyses provide clear evidence of the robustness of our results. Based on these results, it might be asserted that ICT is a leading factor that boosts bilateral trade between Turkey and its trading partners. By reducing trade-related costs, such as transportation cost, information and communication costs, ICT may foster Turkey's international trade.

[14] There are 18 developed countries in the import model and 17 developed countries in the export model based on the IMF classification.

4.2.2 System GMM estimation

To check the robustness of the results, we further apply a different estimation method, the System Generalized Method of Moments (GMM), developed by Arellano and Bover (1995). GMM is particularly useful for addressing the endogeneity problem. This problem arises because ICT and export/import might be determined simultaneously. Furthermore, the causality may run in the reverse direction. That is, export/import may stimulate ICT development, too. Besides, there may be an additional reverse causality running from other control variables such as GDP and population to export/import. Finally, changes in IDI index (and other explanatory variables) and export/import may be caused by a third factor that is not observable (Liu and Nath 2017). In the related literature, different solutions have been offered to address the endogeneity problem. For instance, Freund and Weinhold (2002) use twice-lagged internet variable as an independent variable in the regression. Clarke and Wallsten (2006) utilize the regulation of data services as an instrument for the Internet use and apply two-stage least squares. Vemuri and Siddiqi (2009) employ the instrumental variable approach of Hausman and Taylor (1981)—where lagged values of the potential endogeneous variables are used as instruments. Besides, as in this paper, GMM approach is also suggested as a solution to the endogeneity problem in other studies (see Choi 2010; Liu and Nath 2013; Lin 2015). The lagged values of potential endogenous variables are utilized as instruments in the GMM estimation. Therefore, we include 2-period lagged values of the ICT index, population and GDP as the instruments in the models. Along with the system GMM estimator, we use one-year lag of IDI index in the baseline models as another solution to the endogeneity problem. Their results are presented in Table 3.[15]

In the case of System GMM estimation, the IDI index has positive and significant impacts on both export and import. Hansen's (1982) *J* test results support the validity of instruments. The autocorrelation test results indicate the presence of the first-order autocorrelation, as expected, while there is no second-order autocorrelation. Apart from the system-GMM estimation, we also include one-year lagged IDI index as an independent variable instead of current IDI index to address simultaneity between ICT and trade. As Table 3 shows, one-year lagged IDI index also has positive and significant effects on both export and import. Overall, these findings provide evidence favoring the robustness of our results.

5 Conclusion and policy recommendations

In this study, we examine the impact of ICT on bilateral trade flows between Turkey and its trading partners based on an augmented panel gravity model. We estimate two different models for Turkish bilateral merchandise exports and imports. The export model includes top 35 importers of Turkish goods while the import model

[15] We didn't report the coefficient estimates results of other variables in the models to conserve space. However, the results are available from the author upon request.

Table 3 Results from the system GMM and the fixed effects model with one-year lagged IDI index

Panel A	System GMM estimation	
	Export model	Import model
First lag of dependent variable	0.5096[a]	0.4054[a]
	[0.0522]	[0.0994]
IDI Index	0.0909[b]	0.2147[a]
	[0.0464]	[0.0589]
AR(1)	−2.48[b]	−1.77[c]
	(0.013)	(0.077)
AR(2)	−0.80	−0.39
	(0.423)	(0.699)
Hansen's J-statistic	29.28	32.00
	(0.778)	(0.127)
Country	35	34
Obs.	478	476
Panel B	One-year lagged IDI index	
	Export model	Import model
First lag of IDI index	0.3022[b]	0.4912[b]
	[0.1269]	[0.2295]
Country	35	34
Obs.	479	476
Adjusted R-square	0.9585	0.9518

Probabilities are reported in paranthese while robust standart errors are tabulated in brackets.[a,b,c] Indicate significance levels at 1%, 5%, and 10% levels respectively. The null hypothesis of Hansen's (1982) J test is that the instruments are valid. All other control variables are also included in regressions. Robust standard errors are presented in brackets. Country and time effects are included in regressions.

includes 34 top exporters to Turkey. The sample period extends from 2000 to 2014. As a primary estimator, we use pooled OLS with time effects and country fixed effects along with GMM and conduct several sensitivity analyses to check the robustness of the results. To measure ICT, we compute four different ICT indices: a composite ICT development index (IDI) and three disaggregate indices, namely ICT access index, ICT use index, and ICT skills index. We use those three sub-ICT indices in our robustness analyses. Overall, the results indicate that ICT has positive and significant effects on both Turkish exports and imports volumes. Furthermore, ICT appears to have larger impact on Turkish imports than on Turkish exports. Besides, for the export, the high levels of ICT access and skills indices are crucial to boost export volume. However, ICT use index doesn't have any significant impact on export. In the case of import, the high levels of all ICT indices are crucial for increasing import volume.

These results indicate that by lowering trade costs, such as transportation costs, market entry costs, and communication and information costs, ICT development in

Turkey as well as in its trading partner economies may stimulate trade flows and thus may have a trade-enhancing effect. In other words, ICT provides new communication channels leading to new or improved trading stimuli (see Vemuri and Siddiqi 2009). As Freund and Weinhold (2004b) argue, due to improvements in ICTs, importing countries can buy goods at lower prices and have a lot to gain in consumer surplus while exporting countries can reduce the costs of gaining access to new markets.

Although the onus of developing ICT in trading partner countries rests on the respective countries, the results presented in this paper have some implications for policymakers in Turkey. In this regard, Turkish government should subsidize access to high-speed internet and provide tax breaks to encourage the firms or entrepreneurs that want to invest in development of ICT. The priority of policymakers should be to build the Internet infrastructure and to adopt ICT to reduce the unnecessary trade impediments (Biswas and Kennedy 2016). The policies that facilitate and encourage the adoption and the deployment of ICT will go a long way in boosting trade in Turkey. Further, Turkey should increase its trade linkages with countries that have high levels of ICT endowments. In particular, the trade relations with countries that have high levels of ICT infrastructure and access to basic ICTs will foster Turkey's bilateral export flows. Turkey has recently shifted its orientation in international trade to reduce the risk associated with trade relationships primarily with western countries in the wake of the global financial and economic crises. As it looks for new trading partners, ICT development in the potential partner countries could be an important criterion. In particular, as Turkey expands its trade with emerging markets and other developing economies, this should be of crucial importance as there are substantial variations in ICT endowments across the developing world.

As a final and closing note, we can state that further studies on the ICT-trade nexus are necessary to fill some voids in the literature. For instance, the literature does not have enough disaggregate level studies; therefore as a suggestion, future studies could expand the scope using disaggregate level data, such as agricultural products trade and manufacturing goods trade.

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Appendix 1

See Tables 4 and 5.

Table 4 The country samples in the models

Export model	Import model
Germany	Russia
United Kingdom (UK)	China
Italy	Germany
France	United States (US)
United States (US)	Italy
Russia	Iran
Spain	France
Iran	Korea Republic
Netherlands	India
Egypt	Spain
Switzerland	United Kingdom (UK)
Saudi Arabia	Switzerland
Romania	Ukraine
Israel	Greece
Belgium	Belgium
Azerbaijan	Netherlands
China	Romania
Poland	Japan
Algeria	Poland
Bulgaria	Israel
Syria	Bulgaria
Ukraine	Czech Republic
Greece	Saudi Arabia
Georgia	Indonesia
Morocco	Sweden
Sweden	Austria
Austria	Egypt
Denmark	Thailand
Tunisia	Hungary
Jordan	Malaysia
Czech Republic	Finland
Lebanon	Bangladesh
Slovenia	Mexico
Hungary	Slovakia
Cyprus	

The countries are listed in the order of their shares in Turkish exports and imports volume in 2014

Table 5 Composition of ICT development index (IDI)

Variables	Weight in sub-group (%)	Weight of sub-group (%)
ICT Access		40
Fixed telephone subscription per 100 inhabitants	25	
Mobile-cellular telephone subscriptions per 100 inhabitants	25	
International internet bandwidth(bit/s) per internet user	25	
Percentage of household with a computer	25	
ICT use		40
Percentage of individuals using the internet	50	
Fixed broadband subscriptions per 100 inhabitants	50	
ICT skills		20
Secondary gross enrolment ratio	50	
Tertiary gross enrolment ratio	50	

Source: Adapted from Measuring the Information Society Report by ITU 2015

Appendix 2

See Tables 6 and 7.

Table 6 Descriptive statistics for the variables in the import model Source: Author'sown calculation

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
lnreal import	510	21.236	1.172	17.228	23.811
lnGDP	510	53.730	1.405	50.499	57.560
lnpopulation	510	35.553	1.424	33.422	39.179
lnIDI index	510	2.848	0.732	0.691	3.968
lnICT access	510	−1.431	0.689	−3.601	−0.527
lnICT use	510	−3.692	2.033	−11.902	−1.243
lnICT skill	510	−0.755	0.409	−2.055	0.214
lndistance	510	7.885	0.790	6.568	9.359
Border	510	0.088	0.283	0	1
Language	510	0.029	0.169	0	1
Colony	510	0.088	0.283	0	1
RTA	510	0.592	0.491	0	1
Landlocked	510	0.147	0.354	0	1
Island	510	0.029	0.169	0	1
lnexchange rate	510	1.605	2.607	−1.272	9.564
lntariff rates	442	−0.037	1.608	−6.168	2.603
lnrailway	470	9.734	2.181	5.786	14.859
lnpolitical openness	476	0.778	0.627	−1.966	1.337
lndifference GDP per capita	510	0.391	1.202	−2.740	2.222

Source: Author's own calculation

Table 7 Descriptive statistics for the variables in the export model

Variables	Obs.	Mean	Std. dev.	Min.	Max.
lnreal export	520	20.677	1.340	12.196	23.217
lnGDP	518	52.992	1.803	48.896	57.560
lnpopulation	525	34.865	1.416	31.719	39.179
lnIDI index	525	2.839	0.707	0.935	3.968
lnICT access	525	−1.436	0.6737	−3.552	−0.527
lnICT use	525	−3.741	2.034	−11.150	−1.234
lnICT skill	525	−0.746	0.378	−2.151	0.214
lndistance	525	7.458	0.603	6.442	9.180
Border	525	0.171	0.377	0	1
Language	525	0.0571	0.232	0	1
Colony	525	0.171	0.377	0	1
RTA	525	0.691	0.462	0	1
Landlocked	525	0.142	0.350	0	1
Island	525	0.057	0.232	0	1
lnexchange rate	525	1.034	2.228	−1.272	9.366
lntariff rates	220	1.771	1.211	−2.525	3.842
lnrailway	458	9.392	2.210	5.288	14.859
lnpolitical openness	490	0.6345	0.736	−1.966	1.342
lndifference GDP per capita	510	0.389	1.119	−1.704	2.222

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