The impact of ICT on EU trade

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Abstract

EU trade has increased significantly during the last 15 years. At the same time many countries experienced rapid developments of ICT infrastructure. Theoretically, ICT development enhances trade by reducing transactions costs. Due to the network characteristic of ICT, this is true when both trading partners have advanced ICT developments. This theoretical argument is analysed empirically in the present study. A gravity model is applied to assess the impact of ICT development on EU trade. Therefore, an ICT indicator is constructed in accordance with the ICT Development Index of the International Telecommunication Union. Two estimation approaches are applied in order assess the robustness of the results. Both approaches are based on a recent academic discussion about the appropriate estimation approach for the gravity model. The results reveal that ICT does have a significant positive impact on EU trade. In particular, if both trading partners have good ICT development, trade is enhanced. This finding resembles the network characteristic of trade and is thus consistent with economic theory.

1. Introduction

The growth of international trade is nowadays a well documented fact. For instance, intra-EU trade and extra-EU trade vis à vis five major non-EU trading partners more than tripled between 1995 and 2007[1]. During the same time, Information and Telecommunication Technologies (ICT) have developed rapidly facilitating the global exchange of information. This is particularly true for the last 10 years when broadband technologies were implemented around the world.

These concurrent growth trends might suggest a relationship between ICT and international trade. Theoretically, ICT should enhance trade as it reduces information costs across international borders. Economic literature commonly suggests that ICT markets are strongly influenced by positive network effects (Wendt and von Westarp 2000). Those effects constitute of two aspects: the requirement of compatible products to exchange data or information (direct network effects) and the requirement of complementary products and services (indirect network effects) (Wendt and von Westarp 2000, Katz and Shapiro 1985). Thus, due to the network characteristics, economic theory would suggest that ICT enhances trade if both trading partners have a good level of ICT development.

Despite this theoretical argument, to the knowledge of the authors, no general empirical assessment regarding the impact of ICT on trade has been published. There are, however, papers which analyse the impact of ICT on growth and consumer welfare. Such papers are published in light of the new growth theory focussing on the endogeneity of the growth process (Romer 1986). Röller and Waverman (2001) estimate a model which endogenizes telecommunication investments and find a significant positive effect on growth. In particular, when a critical mass of telecommunication infrastructure is reached, the causal link is confirmed. In line with these findings, Greenstein and Spiller (1996) find that investments in telecommunication infrastructure significantly increased consumer surplus and business revenues in the US between 1988 and 1992. Such findings are a further motivation for an empirical analysis of the impact of ICT on trade.

In the present study such an empirical assessment is conducted by applying the gravity model. The gravity model is an econometric model commonly applied in order to analyse trade related issues such as determining the trade potential of a country or evaluating the

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[1] Numbers are calculated from IMF Direction of Trade Statistics. “Intra-EU” trade refers to trade between the EU-27 countries except for Malta, Luxemburg, and Cyprus. “Extra-EU” trade refers to trade of the EU countries with five non-EU countries (USA, Canada, South Korea, Japan, and Australia) and trade among those non-EU countries.

effect of certain policy variables on trade. Such policy variables may be the membership in a free trade agreement (FTA) or the quality of transportation infrastructure.

Studies which assess the impact of transportation infrastructure on trade generally find a positive effect (e.g. Bougheas et al. 1999, Limao and Venables 2001, and Nordas and Piermartini 2004). In light of these findings, the present analysis utilizes two indicators in order to control for the effect of transportation infrastructure and isolate the true effect of ICT on trade in one regression model specification. The construction of both indicators - one for the quality of transportation infrastructure and a second indicating the extent of ICT development - is based on findings from existing studies.

In the course of the analysis two estimation approaches are applied to ensure the robustness of the regression results: an OLS estimator and a within-group fixed-effects estimator. These estimators are applied to a variety of model specifications. The model specification process and the choice of estimator are based on a rather recent academic discussion about the appropriate estimation method for the gravity model. This discussion has revealed the importance of controlling for as much heterogeneity as possible in order to obtain unbiased estimation results of the policy variable. The findings of both estimation approaches applied in this paper suggest that good ICT development does have a significant and positive effect on the trade of the EU. This is particularly true when both trading partners have good ICT development levels. This result is consistent with positive network effects of ICT as suggested by economic theory.

The rest of the paper proceeds as follows. First, the gravity model, which is the basis of the analysis, is explained. This includes a description of the econometric specification and a discussion of the preferable estimation approach. Second, the modelling of ICT in the gravity framework is explained. Subsequently, the applied data and their sources are described. Fourth, the estimation results are presented and, finally, a conclusion summarizes the main findings.

2. The gravity model

The gravity model draws upon the Newtonian theory of gravitation (Newton’s law). The theory states that the force of gravity between two bodies is positively related to the mass of the attracting bodies and negatively related to the square of their distance (Piermartini and The 2005). In the gravity model trade flows between any country pair is explained by the size (mass) of the two countries (usually measured by GDP) and the trade costs between the countries (Piermartini and The 2005). Trade costs, which are assumed to deter trade, are proxied by several variables in the gravity model. First, bilateral distance as well as dummies for island, landlocked and common border capture transportation costs. A larger distance between two countries and status as an island or as landlocked is assumed to increase transportation costs. Second, dummies for common language and common colonial history capture information costs, which are important components of trade costs. Information or search costs are assumed to be lower if two countries speak the same language or have a common historical and cultural link. Third, dummies for free trade areas (FTA) capture tariff barriers.[2] If two countries are members of the same FTA, their trade is assumed to be positively affected.

The gravity model has been applied in trade related analyses for several decades (see Tinbergen 1962 for the first application) and has usually produced a high explanatory fit. While a good fit would suggest the gravity model's appropriateness, some researchers point out that a high explanatory value by itself does not provide a basis for an empirical model. For instance, Anderson and van Wincoop (2003) argue that a structural interpretation of regression coefficients requires a structurally consistent approach to estimation. Similarly, Piermartini and The (2005) find that a lack of a theoretical underpinning for the model significantly weakens its credibility due to the consequent subjectivity in the interpretation of the regression coefficients. Thus although the gravity model generally has high explanatory power, one must ensure that the model is also consistent with the prevailing economic theories of trade. A variety of studies have found the gravity model to be consistent with major theories (Piermartini and The 2005).

As mentioned, knowledge of the economic models behind the econometric gravity model is important in order to ensure proper inferences from estimations. Moreover, these theoretical economic models are important in order to derive the correct model specification. In particular, the rather recent work of Anderson and van Wincoop (2003) led to gravity model specification considerations. These authors show that trade does not only depend on absolute trade costs between a country pair but also on relative trade costs. Relative trade costs refer to multilateral resistance. Multilateral resistance implies that bilateral trade between two countries depends on bilateral trade barriers between them relative to the average trade barriers that the two countries face with all their trading partners. For instance, bilateral trade decreases when bilateral trade barriers between two countries are greater than the average trade barriers that each face with all their trading partners. Anderson and van Wincoop highlight that omitting controls for multilateral resistance in the econometric

[2] Bilateral tariff data cannot be used in this context due to endogeneity problems.

gravity model biases the estimation results. This finding has led to a discussion about the appropriate estimation approach for the gravity model, which we take into account for the present study.

2.1 Basic econometric specification of the gravity model

The standard gravity equation is usually specified in the following log-linear form and looks as follows (time subscripts omitted):

$$\ln(E_{ij}) = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(DIST_{ij}) + \beta_4 (F_{ij}) + \varepsilon_{ij}, \tag{1}$$

where $\ln(E_{ij})$ represents the log of real exports from country *i* to country *j*, $\ln(GDP_i)$ and $\ln(GDP_j)$ correspond to the logs of the real GDP of country *i* and country *j*, $\ln(DIST_{ij})$ refers to the log of distance between countries *i* and *j*, F_{ij} stands for a set of dummy variables such as landlocked, common border or membership of a FTA, and, finally, ε_{ij} is the error term. This study uses equation (1) as the basis for the various specifications estimated, as will be explained in subsequent sections.

2.2 Estimation approach for the gravity model

The choice of the correct estimation approach is very important in order to obtain consistent and unbiased results. Since the work of Anderson and van Wincoop (2003), many papers have emerged that discuss the proper estimation method and model specification for the gravity model. While most of those deal with cross-sectional analysis, more recent papers assess the correct estimation approach for panel data. In particular, controlling for multilateral resistance in a panel framework has been highlighted as the “biggest challenge” in estimating the gravity equation by Fratianni and Oh (2008). The present paper modifies the aforementioned gravity equation (1) and applies the appropriate techniques in order to adequately control for multilateral resistance effects.

Anderson and van Wincoop (2003) estimate a simultaneous system of equations with non-linear least squares in order to control for multilateral resistance. However, this approach is very complicated and is rarely applied in other papers. As an alternative, Anderson and van Wincoop (2003) suggest adding country dummies to the basic gravity model regression equation. Feenstra (2003) suggests a similar approach for controlling for multilateral resistance, utilizing dummies that represent source (exporter) and destination (importer) countries. Feenstra (2003) postulates that since multilateral resistance terms are unobservable, they can be measured as the coefficients of source and destination country specific fixed effects. Piermartini and The (2005, p. 45) support this by stating that gravity models with country fixed effects (importer and exporter dummies) “are among the most credible”.

Though easily applicable and therefore seemingly attractive, adding importer and exporter dummies to the regression is not sufficient for the present study. Importer and exporter dummies only control for the cross-sectional variation of multilateral resistance terms without allowing these effects to vary over time. Baldwin and Taglioni (2006) therefore suggest adding time varying importer and exporter dummies. This approach is implemented through interaction terms between time and exporter dummies as well as beween time and importer dummies. This approach has frequently been applied in order to control for multilateral resistance in a panel framework (e.g. Fratianni 2007, Baier and Bergstrand 2007, and Baier et al. 2008).

The first estimation approach applied in this study is based on the reasoning of Baldwin and Taglioni (2006). The regression equation is an augmented version of the above presented standard gravity model in (1) (time subscripts omitted):

$$\begin{aligned} \ln(E_{ij}) = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(DIST_{ij}) + \beta_4 (F_{ij}) + \\ \delta_i + \mu_j + \theta + (\delta * \theta)_i + (\mu * \theta)_j + \varepsilon_{ij}, \end{aligned} \quad (2)$$

where the terms δ_i, μ_j, θ, $(\delta * \theta)_i$, and $(\mu * \theta)_j$ are added to the regression equation. δ_i, μ_j, and θ are fixed exporter specific, importer specific and time effects, which constitute the main effects. $(\delta * \theta)_i$ and $(\mu * \theta)_j$ are the interaction effects. $(\delta * \theta)_i$ captures all time-variant exporter specific effects, which also include multilateral resistance. Correspondingly, $(\mu * \theta)_j$ captures all time-variant importer specific effects. Thus, this specification of the gravity model readily controls for multilateral resistance through the inclusion of time-variant exporter and importer dummies. This model specification can be estimated using ordinary least-squares (OLS)[3].

[3] Note that Baldwin and Taglioni do not keep the main effects in the regression. However, Baltagi et al. (2003) underline the importance of controlling for as much heterogeneity as possible so that the main effects are kept in the regression.

The subsequent estimation approach applied in this study takes advantage of the panel data characteristics of the data. Baltagi (2001) points out that using panel data allows for more variation in the data, which implies possible efficiency gains and a reduction of multicollinearity. Panel data also allows controlling for all time-invariant unobserved effects through the inclusion of country-pair fixed effects in the regression and the application of the within-group fixed effects estimation method (Wooldridge 2008).

Controlling for time-invariant unobserved effects is important when estimating the impact of a certain policy variable on trade and is supported by the literature. Baltagi et al. (2003) highlight the importance of controlling for as much heterogeneity as possible in order to prevent an omitted variable bias. They suggest adding country-pair fixed effects to equation (2). Similarly, Baldwin and Taglioni (2006) suggest that an estimation approach which controls for country-pair fixed effects and includes time-varying exporter and importer dummies is the best choice to estimate the gravity model when panel data are used. Such an estimation method takes advantage of the fixed effects estimator and adequately controls for multilateral resistance. Baier et al. (2007) show that such an estimation approach is also theoretically founded. They extend the theoretical cross-section based model of Anderson and van Wincoop (2003) to a panel framework concluding with an econometric specification of the gravity model similar to equation (3) below[4]. Moreover, they show that policy variables, such as dummies for membership of a FTA, likely suffer from a bias if less exhaustive estimation methods are applied.

While Baldwin and Taglioni (2006) and Baier et al. (2007) do not include the main effects of time in the regression, Baltagi et al. (2003) keep time main effects. The inclusion of time effects is supported by the recent paper of Stack (2009) who estimates the gravity model by controlling for varying degrees of heterogeneity. She finds that a fixed effects estimation in combination with time fixed effects as well as exporter and importer time-varying effects is most reliable.

Building on these conclusions, the second estimation equation applied in the present study is as follows (time subscripts omitted):

$$\ln(E_{ij}) = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(DIST_{ij}) + \beta_4 (F_{ij}) + \alpha_{ij} + \theta + (\delta * \theta)_i + (\mu * \theta)_j + \varepsilon_{ij}, \quad (3)$$

[4] Note that Baier et al. (2007) restrict the coefficients of GDP to unity. This aspect is discussed in chapter 5.

where all variables are known from equation (2) except for α_{ij}, which corresponds to the country-pair fixed effect. Note that the individual exporter and importer specific effects (δ_i and μ_j) are dropped from the regression. They are controlled for by the country-pair fixed effects α_{ij}.

One drawback of the fixed-effects estimation approach is that it is no longer possible to estimate the time-invariant effects on trade included in the basic gravity model (1) such as the distance between countries. The fixed effect estimator uses the within-group variation (over time) to form the estimator[5]. Because time-invariant effects are also of interest in the present paper, we employ both the OLS and the fixed-effects estimator. Each estimation approach implies a different modelling of ICT in the gravity framework, providing important insights into the real impact of ICT on trade. Furthermore, the application of different estimation approaches allows a better evaluation of the robustness of the estimation results.

In sum, two estimation approaches are applied where each has certain advantages and certain drawbacks. The OLS approach applied to (2) controls for multilateral resistance but may still suffer from an omitted variable bias as it does not control for country-pair fixed effects. On the other hand, OLS allows us to asses the impact of time-invariant variables on trade, which the fixed effects estimation method applied to (3) does not allow. Instead, the fixed effects estimator spans the whole vector space of possible treatments in explaining variations in bilateral trade and is therefore least likely to suffer from an omitted variable bias (Stack 2009).

3. ICT in the gravity framework

After explaining the gravity model and the appropriate estimation approaches, attention turns to the appropriate modelling of ICT impact in the gravity framework.

It should be noted that including variables for ICT in the econometric gravity model does not alter the structural interpretation of the gravity model. ICT can simply be integrated as reducing trade costs due to lower transaction costs. ICT likely reduces search costs across international borders enabling consumers to easily search for a specific good and compare prices in countries all over the world. The same is true for businesses, which can benefit from

[5] Note that a random effects model would allow estimating the impact of time-invariant variables on trade. However, as argued by Egger (2000), the random effects estimator is hardly suitable in the gravity framework.

ICT by optimizing their value chain in terms of supply as well as distribution channels. In particular, the presence of the European Single Market, which ensures frictionless trade, in combination with yearly improving ICT deployment in Europe, should positively affect intra-European trade.

The network characteristics of ICT further imply that both trading partners need good ICT deployment in order to support trade. When a technology such as ICT exhibits network characteristics, the benefits incurred from the application in one country depend on the total number of users of ICT in other countries (Katz and Shapiro 1985). Thus ICT will enhance international trade when both trading partners have good ICT deployment.

In order to measure the impact of ICT on trade, an ICT indicator is constructed. The ICT indicator applied in the present study is constructed in accordance with the ICT Development INDEX (IDI) which is published by the International Telecommunication Union. This indicator was recently developed in response to complaints from the international community about the presence of several ICT indicators that essentially measure the same aspects (ITU 2009)[6]. This indicator can be interpreted as most comprehensive as it is built upon experience from several earlier indicators. Experts from different countries participated in the construction of the indicator and a principal component analysis helped to identify the most relevant factors. The indicator aims to measure the information society by giving "an indication of the extent to which countries have advanced in the area of ICT" (ITU 2009, p. 12).

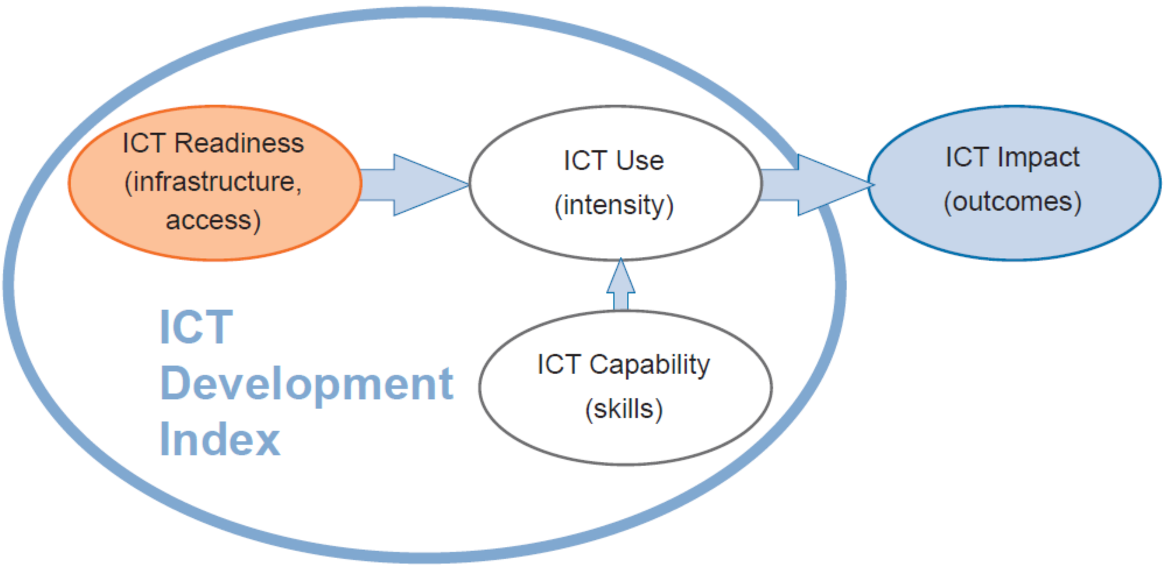
The IDI is constructed from a three-stage model (ITU 2009), which has usually been applied for measuring the information society (e.g. OECD 2005). The three stages are ICT readiness, ICT intensity, and ICT impact. Due to a lack of data for the third stage, only indicators from the first two stages are included in the overall IDI indicator.

The first stage, ICT readiness, refers to infrastructure and access while the second stage, ICT intensity, refers to use and intensity of use. The evolution towards an information society and the reaching of the final state (ICT impact) depends on a third component, ICT capability or skills. All three components - access, use, and skills - are closely linked. Access to ICT infrastructure is a prerequisite for its use. ICT use indicates the extent of absorption of the technologies which largely depends on ICT skills. As there does not exist a single indicator

[6] The two main alternative indicators which were basically merged to the IDI had a correlation coefficient of 0,94 (ITU 2009).

for all three components, it is necessary to develop a composite indicator. Figure 1 illustrates the rationale behind the three-stage model.

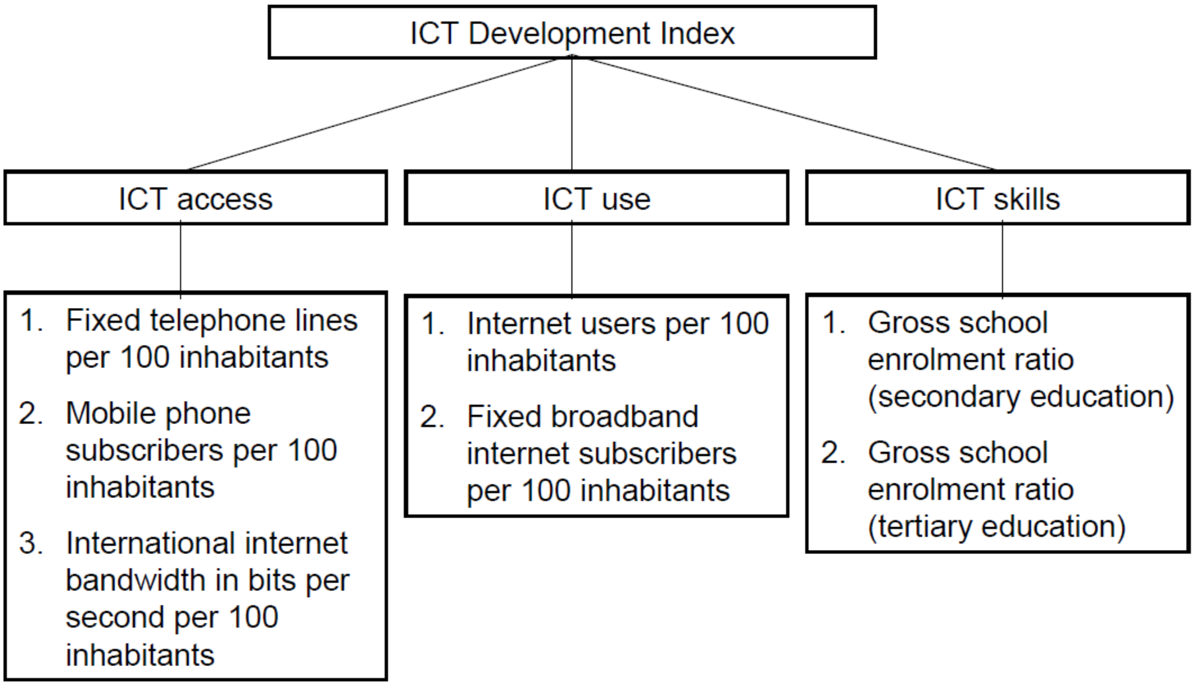
Figure 1: Three stages in the evolution towards an information society



Source: ITU 2009.

ITU (2009) suggests a set of sub-indicators to measure each of the three components. Figure 2 displays how the overall indicator is constructed. ICT infrastructure and access is measured by fixed telephone lines per 100 inhabitants, mobile cellular subscriptions per 100 inhabitants, and international internet bandwidth in bits per person. ITU (2009) suggests also including the proportion of households with a computer and the proportion of households with internet access at home. However, the data for the last two indicators are not available for the required time period and countries and thus are omitted from the present study. ICT use and intensity of use are measured by internet users per 100 inhabitants and fixed broadband internet subscribers per 100 inhabitants. ITU (2009) further includes mobile broadband subscribers per 100 inhabitants to this sub-indicator. However, the data is again not available for many countries and, in particular, not for the required time period. ICT skills and the capacity to use ICT effectively are measured through secondary and tertiary gross school enrolment ratios. These ratios indicate the educational level of a country. Additionally, ITU (2009) includes adult literacy rate to this sub-indicator. Since all of the considered countries have literacy rates close to 100%, this element could be omitted from the present study. The data for the individual indicators is sourced from the World Bank (World Development Indicators).

Figure 2: Composition of the ICT Development Index



The individual indicators are aggregated to the sub-indicators ICT access, use, and skills. As a first step, each indicator is rescaled to take on values between 1 and 5 in order to make them comparable. This is done for each year separately. In a second step, the indicators are aggregated by taking the weighted average of the indicators, where the weights correspond to the variances for each indicator in each year. Thus, indicators with higher variances obtain larger weights to reflect the differences in the data. Such an approach is less arbitrary compared to an expert guess regarding the correct weighting scheme. Next, the sub-indicators are aggregated to one overall indicator applying the same aggregation method.

4. Data

The following estimations are based on a 13 year time period ranging from 1995 to 2007. The choice of the time period is grounded on data availability, as for most Eastern European countries the data quality is rather poor prior to 1995. Except for Malta, Luxemburg, and Cyprus, all EU-27 countries are included in the analysis. Malta, Luxemburg, and Cyprus are excluded due to lack of data for certain variables. Furthermore, USA, Canada, Australia, South Korea and Japan are included in the study. The choice of the countries stems from the importance of these give countries to extra-EU trade, as defined in the introduction. The non-EU countries are generally known for good ICT quality and which have good data for the required time period. The sample selection implies that the findings of the analysis are specific to intra-EU trade and extra-EU trade with the five non-EU countries. In total, the analysis covers trade flows of 29 countries over a period of 13 years which leads to a balanced panel of 10556 observations[7].

The applied data stem from different sources[8]. Trade data are collected from IMF Direction of Trade Statistics (DOTS) and deflated to real values by applying the US price index (2000 as numéaire) from IMF World Economic Outlook Database (WOE). GDP data at 2000 constant prices are taken from the World Development Indicators. Distance data as well as data for the dummies of common border and common language stem from CEPII. As mentioned above, the data for the ICT indicator stem from World Development Indicators.

Another data-related issue regards the choice between using import and export data. The decision differs among studies. Import data have traditionally been preferred by trade economists due to the fact that countries are more concerned to measure imports in order to avoid tariff fraud. However, as Baldwin and Taglioni (2006) point out, this aspect has been reversed for the European Union since 1993 as trade data haven been collected from VAT statistics since then. As the present study focuses on European countries, export data seem the best choice for modelling trade. Furthermore, it is important to note that trade data is not averaged in the present study. Some researchers average trade data such that exports from France to Germany and exports from Germany to France are considered as one observational unit. However, there is no theoretical argument for taking the average (Baldwin and Taglioni 2006). Furthermore, Baldwin and Taglioni (2006) point out that the gravity equation is a modified expenditure function. This means that it explains the amount spent by one country on goods produced by another country. Therefore, the gravity equation explains uni-directional trade. Referring to the previous example, exports from France to Germany and exports from Germany to France are considered as two observations.

5. Estimation results

As described in chapter 2, two estimation approaches are applied in this study. In the following, the two approaches are again shortly explained and the estimation results are presented.

[7] As countries do not trade with each other, the number of observations equals 28 x 29 x 13.
[8] Note that in case of missing values the data has been interpolated.

5.1 Estimation approach 1

The first estimation approach implies an augmentation of the standard gravity equation (1) by several dummy variables. In particular, time, importer, and exporter dummies are included as well as interactions of time and country dummies in order to control for multilateral resistance. As the sample contains 29 countries and 13 time periods, this implies that 754 time-varying dummy variables are constructed. Due to the size of the sample, there should not be any problems with the number of degrees of freedom[9].

When importer and exporter dummies are included in a regression, it is no longer possible to estimate the effects of variables that vary across countries, but not bilaterally (Piermartini and The 2005). That is why it is not possible to just include the ICT indicators for exporting and importing countries when the first estimation approach is applied. Instead, a bilaterally varying variable has to be constructed.

The use of bilaterally varying indicators is supported in Nordas and Piermartini (2004). The authors estimate the effect of transportation infrastructure on trade on cross-section data applying the gravity model. They add importer and exporter dummies in order to control for multilateral resistance, which precludes the inclusion of variables that vary across countries. They construct a bilaterally varying variable in form of a dummy that takes on unity if both countries (exporter and importer) have above average quality of infrastructure and zero otherwise. This particular dummy variable construction is appropriate for the present analysis as it models the network characteristics of ICT, in which ICT likely supports trade only if both trading partners have good ICT development,.

The paper of Nordas and Piermartini (2004) also influences the present study through its finding that transportation infrastructure generally enhances trade. This finding is supported by other studies that also rely on the gravity model (e.g. Bougheas et al. 1999, Limao and Venables 2001). As far as the present study is concerned, if countries with good transportation infrastructure also have good ICT development, our ICT development indicator may partly capture the effect of good transportation infrastructure.

This problem can be solved by constructing an additional variable which controls for transportation infrastructure. Such a variable allows us to control for the effects of ICT and transportation infrastructure on trade separately. In particular, in combination with the

[9] Baldwin and Taglioni (2006) point out that 2NT dummies have to be constructed, where N is number of countries and T is time. With a squared panel there are 2N(N-1)T observations so that there will be many degrees of freedom left if T and N are large.

construction of an aggregated indicator of ICT and transportation infrastructure, this approach helps to identify the true effect of ICT on trade. First, the use of two indicators in separate estimations allows us to compare the coefficients of the two individual indicators. Second, inclusion of the aggregate indicator in an estimation can confirm the appropriateness of the two individual indicators, assuming that the aggregated indicator has a larger effect on trade than each of the individual indicators. Third, both individual indicators can be added simultaneously to the regression. However, this last point only works if the two indicators are not highly collinear.

Transportation infrastructure can be measured by different indicators. Information about road and rail networks seems to be most obvious for use as indicators. The problem with such indicators is that they are measured by the kilometres of roads or rails over the square kilometres of a country so that countries with a large surface (e.g. USA, Canada, Germany, Sweden, and Finland) are assigned rather poor values even though their infrastructure is actually good (and vice versa; small countries may get high values despite poor infrastructure). This is particularly worrisome for the present study because of the construction of the indicator for the first estimation approach: the dummy takes on unity if both countries have above average infrastructure. Large countries are biased below average and receive a zero indicating poor quality of transportation infrastructure. In fact, this reasoning is supported by results from Nordas and Piermartini (2004) who partly find a negative impact of good transportation infrastructure on trade. Interestingly, these authors find a positive effect of transportation infrastructure when indicators are applied that stem from survey questions (Global Competitiveness Report) in which business owners are asked about the quality of infrastructure. Such indicators based on survey questions rather than structural data seem to more adequately capture the quality of infrastructure.

In light of Nordas and Piermartini (2004)'s results, the transportation infrastructure indicator applied in this study is constructed from such survey questions. The data is sourced from the IMD World Competitiveness Yearbook, and two different indicators are constructed[10]. The first indicator captures the efficiency of the basic distribution infrastructure of goods and services[11]. A second indicator measures adequacy regarding the planning and financing of the maintenance and development of basic infrastructure. The two individual indicators are

[10] Note that the data for the transportation infrastructure variable is poor for a few countries. To keep all countries in the sample, the development of the infrastructure of countries with poor data was assumed to be comparable to countries with similar geographic conditions and GDP. For instance, the development of transportation infrastructure is assumed to be comparable in all three Baltic countries. It has been decided that this approach is preferred over reducing the sample as the ICT variable is in the focus of the analysis and the data for this variable was available.

[11] Basic implies that transportation infrastructure as well as energy supply are considered.

aggregated to one overall indicator using the same aggregation method as used for the ICT indicator.

5.1.1 Regression specifications

The following four regression equations are estimated using estimation approach 1:

$$\ln(E_{ij}) = \beta_0 + \beta_1 \ln(DIST_{ij}) + \beta_2(Language_{ij}) + \beta_3(Border_{ij}) + \beta_4(EU_{ij}) + \beta_5(TRA_{ij}) + \delta_i + \mu_j + \theta + (\delta * \theta)_i + (\mu * \theta)_j + \varepsilon_{ij}, \quad (4)$$

where most variables of equation (4) are known from equation (2). Note that the GDP variables are dropped from the regression equation as suggested by Nordas and Piermartini (2004)[12]. Language, border and EU are dummy variables. Language takes on unity if both trading partners have a common language and is expected to have a positive sign. Similarly, border takes on unity if both trading partners share a common border and is thus also expected to have a positive effect. EU takes on unity if both countries are members of the EU. As membership of the EU is expected to enhance trade, the coefficient is also expected to be positive. Finally, TRA_{ij} is a dummy variable that takes on unity if both trading partners have above average quality of transportation infrastructure.

$$\ln(E_{ij}) = \beta_0 + \beta_1 \ln(DIST_{ij}) + \beta_2(Language_{ij}) + \beta_3(Border_{ij}) + \beta_4(EU_{ij}) + \beta_5(ICT_{ij}) + \delta_i + \mu_j + \theta + (\delta * \theta)_i + (\mu * \theta)_j + \varepsilon_{ij}, \quad (5)$$

Equation (5) resembles equation (4) except for the dummy variable ICT_{ij} which captures the quality of ICT instead of transportation infrastructure.

$$\ln(E_{ij}) = \beta_0 + \beta_1 \ln(DIST_{ij}) + \beta_2(Language_{ij}) + \beta_3(Border_{ij}) + \beta_4(EU_{ij}) + \beta_5(AGGR_{ij}) + \delta_i + \mu_j + \theta + (\delta * \theta)_i + (\mu * \theta)_j + \varepsilon_{ij}, \quad (6)$$

Equation (6) is again similar to equation (4), only that now an aggregated indicator (AGGR) is included in the regression. This indicator aggregates the two individual indicators of transportation infrastructure and ICT development. This equation allows to evaluate whether the two individual indicators actually proxy for the intended aspects. Specifically, the aggregated indicator is expected to have a larger coefficient than the individual indicators.

[12] Note that estimations with controls for GDP included lead to very similar results.

$$\ln(E_{ij}) = \beta_0 + \beta_1 \ln(DIST_{ij}) + \beta_2(Language_{ij}) + \beta_3(Border_{ij}) + \beta_4(EU_{ij}) + \beta_5(TRA_{ij}) + \beta_6(ICT_{ij}) + \delta_i + \mu_j + \theta + (\delta * \theta)_i + (\mu * \theta)_j + \varepsilon_{ij}, \quad (7)$$

Finally, equation (7) contains both individual indicators (TRA) and (ICT).

5.1.2 Estimation results

The results from the first estimation approach are presented in Table 1[13]. Column 1 presents OLS estimation results where no controls for any kind of fixed effects are included. Columns 2-6 present OLS estimation results where controls for time, importer specific and exporter specifc fixed effects, and interactions of time and country fixed effects are included.

Table 1: Results from estimation approach 1

	Pooled OLS	Exporter and importer specific fixed effects, time fixed effects, and time varying importer and exporter dummies				EU-15
Column	1	2	3	4	5	6
lnGDPi	0.921*					
lnGDPj	0.837*					
lnDISTij	-1.108*	-1.404*	-1.395*	-1.399*	-1.394*	-0.765*
Language	0.448**	0.19	0.198	0.167	0.175	0.32**
Border	0.51**	0.316**	0.331**	0.315**	0.314**	0.37**
EU	0.377*	-0.145	-0.115	-0.146	-0.137	1.388*
TRA Dummy		0.385*			0.287*	
ICT Dummy			0.384*		0.283*	
AGGR Dummy				0.437*		
Constant	-31.146*	15.808*	16.393*	19.057*	12.789*	12.783*
Observations	10556	10556	10556	10556	10556	4940
R-squared	0.847	0.916	0.916	0.916	0.917	0.928
RMSE	0.937	0.721	0.721	0.719	0.718	0.562
Note: *, **, and *** denote signficance at 1%, 5% and 10% levels.						

Note that *, **, and *** denote significance at 1%, 5%, and 10% levels.

The results in column 1 indicate that all variables behave as expected, being highly significant. Moreover, the magnitudes of the coefficients are within the common range. These

[13] Note that all estimations are conducted with cluster-robust standard errors. This is because a Breush-Pagan/Cook-Weisberg test indicates a heteroskedastic error variance. Further note that country and time fixed effects as well as their interactions are not included in the regression output table. As mentioned in the text, all sets of dummy variables are jointly highly significant.

results are included in order to show the importance of adequately controlling for multilateral resistance in order to prevent an omitted variable bias. The effect of omitted variable bias can be seen in the difference in magnitude and significance of the coefficients in columns 2 to 5 in comparison with those in column 1. This point is supported by several statistical tests. Exporter, importer and time dummies, as well as their interactions, are generally individually significant and always jointly highly significant. As confirmation, a likelihood ratio test clearly supports the inclusion of all fixed effects and their interactions[14]. Further note the high R-squared in all columns of Table 1, which reveals the high explanatory fit of the gravity model.

In columns 2 to 6, exporter and importer specific fixed effects, time fixed effects, and time-varying exporter and importer dummies are included as controls in the regression. Before analysing the coefficients of interest, i.e. transport and ICT variables, the results of the other coefficients are shortly discussed.

The distance variable has a negative sign and is highly significant, as usually found in gravity models. The size of the coefficient is also within the common range. The border dummy also has the expected positive and significant impact. The common language dummy has the expected positive sign but is insignificant.

The only variable that does not behave as expected is the dummy variable that controls for membership of the European Union. This variable has a negative and insignificant coefficient. The result is surprising and seems counterintuitive at the first glance, but it can be explained by our regression method and data selection choices. First, the literature specific to our regression method does not offer conflicting results. There are other studies that control for many effects through various dummy variables and their interactions and use comparable estimation techniques similarly find no significant effect of EU membership on trade (e.g. Stack 2009, Baldwin and Taglioni 2006, Brussière et al. 2005). In fact, some of those studies also find a negative and insignificant impact (Brussière et al. 2005). Secondly, our sample selection method may help explain the EU dummy coefficient. Due to data availability, the EU-27 countries (except Cyprus, Luxembourg, and Malta) plus five other non-EU countries are included in the sample. The five non-EU countries belong to the most important non-EU trading partners of the former EU-15 countries. At the same time, many of the Eastern European countries included in the study trade less compared to the non-EU countries. The EU countries included in our sample exhibit a bias toward lower trade in

[14] The likelihood ratio test compares an unrestricted model to a restricted model. The unrestricted model is the regression equation applied as first estimation approach which is compared to models with less exhaustive controls for fixed effects and their interactions. The log-likelihood test reveals that the unrestricted model is always clearly superior.

comparison to the non-EU countries included in our sample, which would naturally lead to a dummy for EU membership that is insignificant and even negative. This reasoning is supported by the fact that estimations on a smaller sample, which only contains data of EU-15 countries plus the five non-EU countries, lead to a large, positive and highly significant coefficient of the EU-dummy variable as displayed in column 6 of Table 1.

Turning now to the variables that are in the focus of this analysis, we first observe that good transportation infrastructure of both trading partners significantly enhances trade (column 2). In particular, if both trading partners have good transportation infrastructure, trade between these two countries is about 1,47 times (or 47%) larger compared to the case where one country (or both countries) have poor infrastructure quality[15]. According to the construction of the transportation indicator, good transportation infrastructure implies that a country has a quality of transportation infrastructure which is above the average of the sample. Second, column 3 of Table 1 shows that the effect of both trading partners having good ICT quality is of comparable magnitude to that of both trading partners having good transportation. If both trading partners have good ICT development, trade increases by 47% holding all other variables constant.

These results suggest that good ICT development of both trading partners is as important for international trade as the good transportation infrastructure of both countries. This finding might lead to doubts about the adequacy of the chosen indicators, suggesting that both indicators actually control for the same effects. However, column 4 of Table 1 indicates that such concerns are unfounded. This column contains the estimation results when the aggregated indicator is included in the regression. The aggregated indicator accounts for both transportation infrastructure and ICT development. The coefficient is larger compared to the results from column 1 and 2, implying that the individual ICT and transportation indicators do not account for the same effects. The estimation implies that trading partners that have both good quality transportation infrastructure and good quality ICT will trade about 55% more than a country pair in which one or both countries have poor transportation infrastructure and ICT quality.

The results presented in column 5 of Table 1 also support the adequacy of the proxies. In this column, both individual indicators are added simultaneously to the regression. Both variables remain highly significant and are not highly collinear, supporting our conclusion that the two variables do control for the intended separate aspects. The magnitudes of the

[15] Note that the effect of a dummy variable on a log-transformed dependent variable is attained by taking the exponential of the regression coefficient. As an example, a regression coefficient of 0,385 implies an impact on trade of exp(0,385) = 1,47.

coefficients of both variables are also of comparable size, which is in line with the findings from columns 2 and 3 where both variables where included separately in the regressions.

In sum, the results of the first estimation approach clearly indicate the importance of ICT for international trade within the European Union and with respect to its main trading partners. In particular, when controlling for good transportation infrastructure, ICT increases trade by around 33% if both countries have good ICT development. Moreover, the results suggest that having good ICT infrastructure in both trading partners is as important for bilateral trade as having good transportation infrastructure in both countries.

5.2 Estimation approach 2

The results of the second estimation approach are presented in the following section. As explained in 1.1.3, several researchers suggest controlling for as much heterogeneity as possible in the gravity model in order to prevent an omitted variable bias. A fixed effects estimator is most appropriate for that purpose, as it controls for all time-invariant effects. In the following approach, this estimator is combined with controls for time fixed effects and time-varying importer and exporter dummies in order to control for multilateral resistance. Statistical tests again justify our method; F-tests for joint significance of all sets of dummy variables (time-varying exporter and importer dummies as well as the fixed effects) indicate high joint significance. A likelihood ratio test confirms significance by indicating that the applied model is preferred to models with less exhaustive controls.

While the fixed effects estimator prevents a bias from omitting time-constant variables, its drawback is that only time-varying variables can be included in the regression. This characteristic has an important implication for the modelling of ICT development in the context of the second estimation approach. The dummy variables applied in the first estimation approach, which indicate whether both countries have above average quality ICT developments, are very constant over time and thus are not suitable for this estimation method. However, in contrast to the first estimation approach, the application of fixed effects estimation does not preclude the inclusion of variables that vary across countries. Therefore, it is possible to include the measures of ICT development for exporter and importer countries. This approach also allows testing the assumption that ICT enhances trade when both countries have good ICT development by interacting the measures of ICT development of both countries. A positive and significant interaction term would indicate that trade is particularly supported if both trading partners have good ICT developments.

5.2.1 Regression specifications

In this section the impact of ICT on European trade is analysed without consideration of . transportation infrastructure. This restriction is based on several observations. First and most importantly, the estimation results of the previous section showed the adequacy of the chosen ICT development indicator[16]. Second, the effect of ICT on trade constitutes the main interest of this paper, such that estimating the effect of transportation infrastructure separately is not necessary. Third, the use of an interaction term in this section's model specifications complicates the interpretation of the results, as described further in section below so that a restriction to the ICT indicator seem appropriate.

As mentioned, ICT is not modelled via dummy a variable in this section due to the application of the fixed effects estimator. The application of the fixed effects estimator leads to further considerations regarding model specification in this section. As the fixed effects estimator controls for all time-invariant effects, the impacts of distance[17] and of the time-invariant dummy variables language and border cannot be estimated separately any more [18]. On the other hand, the GDP variables from our basic gravity model (1) in section 2.1 may now be included in the regression. According to the theoretical deviation of the gravity model in the panel framework (Baier and Bergstrand 2007), GDP should be forced to unity. Thus Baier and Bergstrand (2007) and Baier et al. (2008) exclude GDP variables from their regressions, while Baltagi et al. (2003), Baldwin and Taglioni (2006), and Stack (2009) keep the variables. In the present study both approaches are tested. A final concern regarding model specification for the second estimation approach regards the EU dummy. The EU dummy is omitted from the specifications in this section because the dummy remains insignificant in this estimation approach (when included).
Thus, the following two regression equations are estimated in this section:

$$\ln(E_{ij}) = \beta_0 + \beta_1 \ln(ICT_i) + \beta_2 \ln(ICT_j) + \beta_3(\ln(ICT_i) * \ln(ICT_j)) + \alpha_{ij} + \theta + (\delta * \theta)_i + (\mu * \theta)_j + \varepsilon_{ij}, \tag{8}$$

[16] Further note that it is not possible to include the transportation infrastructure and ICT indicators simultaneously in the regression when the second estimation approach is applied due to multicollinearity problems.
[17] Note that Stack (2009) considers this characteristic of the fixed effects estimator as desirable due to shortcomings of distance as a measure of transport and information costs. She points out that distance implicitly assumes that overland transport costs are equivalent to overseas transport costs.
[18] Note that a random effects model would allow estimating the effects of time-invariant variables on trade. However, a Hausman test clearly rejects the random effects model compared to the fixed effects model. Congruently, Egger (2000) points out that the random effects model would also be difficult to justify theoretically.

where most variables are known from before. α_{ij} refers to country pair fixed effects. $\ln(ICT_i)$ and $\ln(ICT_j)$ are the logs of ICT developments of country *i* and country *j*, respectively. $\ln(ICT_i)*\ln(ICT_j)$ is an interaction term between $\ln(ICT_i)$ and $\ln(ICT_j)$ which accounts for a possible interaction effect of both variables. As mentioned, a positive and significant interaction term indicates that trade is particularly supported if both countries have good ICT development.

$$\begin{aligned}\ln(E_{ij}) = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(ICT_i) + \beta_4 \ln(ICT_j) + \\ \beta_5(\ln(ICT_i)*\ln(ICT_j)) + \alpha_{ij} + \theta + (\delta*\theta)_i + (\mu*\theta)_j + \varepsilon_{ij},\end{aligned} \tag{9}$$

Equation (9) resembles equation (8) except that GDP variables are included in the regression.

5.2.2 Estimation results

Before discussing the estimation results, some considerations regarding the interaction effect must be observed. Particular books that exclusively deal with interaction effects in multiple regression models (e.g. Aiken and West 1991) and recent papers from the political science literature (e.g. Braumoeller 2004, Brambor et al. 2005) have pointed out common mistakes in the presence of interaction terms. Thus, care has to be taken to draw correct inferences. First of all, it is important to understand that in the presence of an interaction term, the marginal effect of e.g. $\ln(ICT_i)$ in equation (9) is calculated by $\beta_3 + \beta_5 * \ln(ICT_j)$ (Aiken and West 1991). Thus the marginal effect of $\ln(ICT_i)$ must be evaluated at appropriate values of $\ln(ICT_j)$ in order to make inferences. The interpretation of the marginal effect of $\ln(ICT_i)$ becomes the effect of home country *i*'s ICT development on its exports for given levels of the destination country *j*'s ICT development. The same procedure is followed in order to calculate the marginal effect of $\ln(ICT_j)$. Notably, this model specification is perfectly suited to test for network characteristic.

Besides calculating magnitude of the marginal effect, it is also important to test whether the entire effect is significant. Thus, whenever the effect of $\ln(ICT_i)$ on trade is evaluated at levels of $\ln(ICT_j)$, the corresponding t-statistics have to be calculated through a separate process (Aiken and West 1991). This also implies that in the presence of a significant interaction term, insignificant coefficients of the main effects $\ln(ICT_i)$ and $\ln(ICT_j)$ do not imply that the home country's ICT development is statistically irrelevant for trade.

In the following analysis the effect of home country's ICT developments on its exports is evaluated at applicable values of the importing country's ICT development and vice versa. Researchers tend to suggest a graphical presentation as the most easily interpretable when interactions are included in the regression (e.g. Kohler 2008, Brambor et al. 2005). Thus, the discussion of the estimation results is based on a graphical presentation. Table 2 displays the regression results for both model specifications (equations 8 and 9) as a first step.[19]

Table 2: Results from estimation approach 2

Fixed effects estimation with time fixed effects and time-varying exporter and importer dummies		
	1	2
lnGDPi		1.037*
lnGDPj		0.962**
lnICTi	0.522**	0.093
lnICTj	-0.056	-0.166
ICT_int	0.346**	0.346**
Constant	4.99*	-46.074*
Observations	10556	10556
Within R^2	0.81	0.81
Between R^2	0.034	0.567
Overall R^2	0.089	0.579
Note: *, **, and *** denote signficance at 1%, 5% and 10% levels.		

Note that *, **, and *** denote significance at 1%, 5%, and 10% levels.

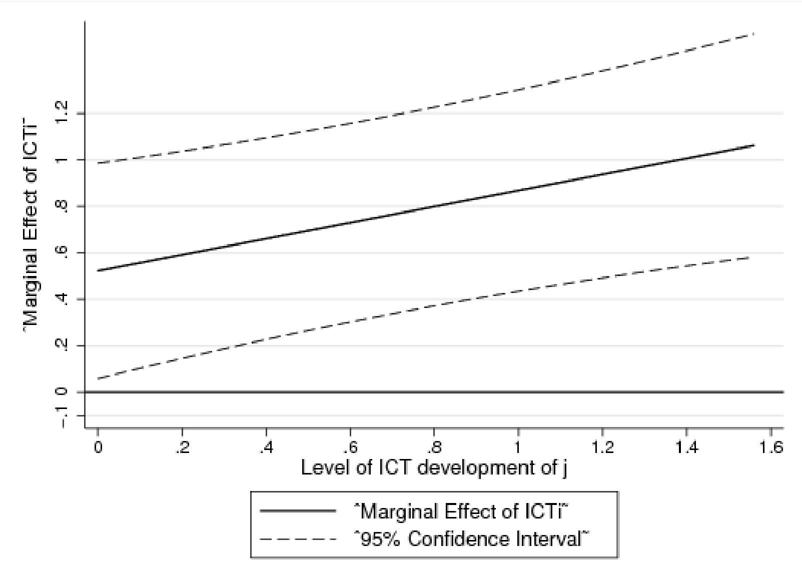
Table 2 indicates that the interaction term is significant and of similar magnitude for both model specifications. This suggests that trade is enhanced when both trading partners dispose of good ICT development, confirming the network characteristics of ICT. Further note that a within R-squared of 0.81 indicates a high explanatory fit of the model.

As mentioned, a discussion of the estimation results is facilitated by a graphical presentation. Brambor et al. (2005) suggest using a graph similar to Figure 3 below. This figure shows how

[19] Note that the models are estimated with cluster-robust standard errors due to the presence of heteroskedasticity as suggested by Stock and Watson (2006). Moreover, the time varying country dummies and the time fixed effects are again not included in the regression output table. As mentioned in the text, all sets of dummy variables are jointly highly significant.

the marginal effect of home country's (*i*) ICT development on its exports changes with different levels of destination country's (*j*) ICT development. The figure refers to column 1 of table 2; i.e. GDP is excluded from the regression. The solid sloping curve displays how the marginal effect of the source country's ICT development changes with the level of ICT development in the destination country. The two dashed lines represent the 95% confidence interval for the estimation. Whenever both lines are above or below the zero line, the effect of ICT on trade is significant.

Figure 3: The impact of an exporting country's (*i*) ICT development on its exports for different levels of destination country's (*j*) ICT development (figure refers to equation 8)[20]

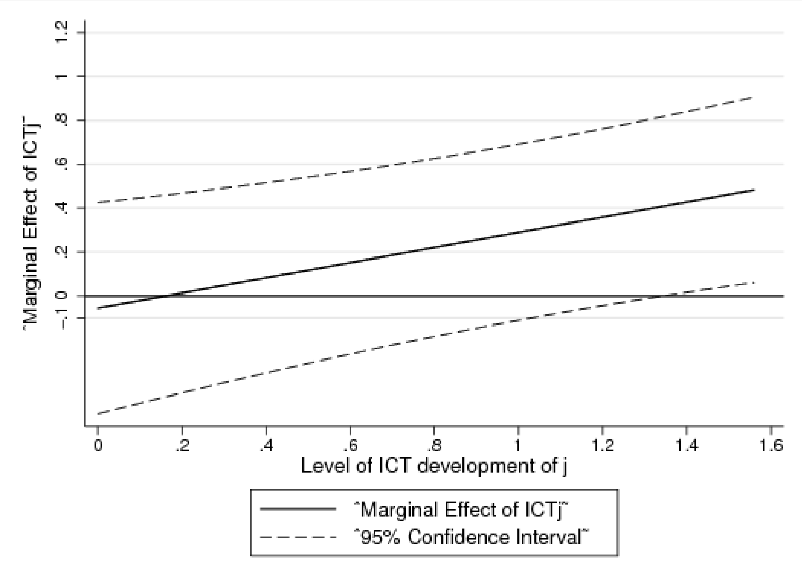


The upward sloping solid curve indicates the network characteristic of ICT development, i.e. the impact on home country's exports is larger when the level of ICT development in the destination country is higher. In Figure 3 the upper and lower bounds of the confidence intervals always lie above the zero line. Hence, the home country's ICT development significantly affects its exports even when the destination country disposes of poor ICT development.

Figure 4 displays the marginal effect of the destination country's (*j*) ICT development on its imports for changing values of the exporting country's (*i*) ICT development (again referring to column 1 of table 2). The network characteristic is again supported by the data. In contrast to the previous findings, when the importing country is considered, ICT development only enhances trade for high levels of ICT implementation of the exporting country.

[20] Note that due to the log-transformation of the ICT indicator, the level ranges from 0 to 1.5.

Figure 4: The impact of an importing country's (*j*) ICT development on its imports for different levels of exporting country's (*i*) ICT development (figure refers to equation 8)



These two figures allow for some conclusions. First, the network characteristic of ICT is confirmed by the data for both exporters and importers. Second, the results support the findings from the first estimation approach that ICT development has a positive and significant impact on European trade. Third, the cut-off value for ICT to enhance exports is considerably lower compared to the cut-off value for enhancing imports. In fact, exports from the source country are enhanced even when the importing country disposes of poor ICT development. The theoretical reason for this finding may be that for exporters it is particularly important to be visible over the internet, while visibility requires good ICT development. Thus, exporting country's ICT development is very important to ensure visibility, while even lower levels of destination country's ICT development are sufficient to notice the potential exporter abroad. In contrast, from an importing country's perspective, good ICT development of potential exporting countries is a prerequisite for finding potential trading partners.

The results of the alternative model specification from column 2 of Table 2 (with GDP included in the regression) are presented in Figure 5 and Figure 6. According to Figure 5, in order to enhance exports for a given country, moderately high levels of the importing country's ICT development are required. Thus, this figure confirms the network characteristics of ICT and its positive impact on trade given good quality ICT in the destination country. However, Figure 5 does not confirm that even low levels of ICT development of the importing country are sufficient to enhance exports. Furthermore, Figure 6 suggests that the level of ICT in the exporting country does not significantly enhance imports of a given destination country. Overall, these results mirror the findings from before in an attenuated way. In particular, the results confirm that ICT development of the exporting country seems to be specifically important in order to enhance trade.

Figure 5: The impact of an exporting country's (*i*) ICT development on its exports for different levels of destination country's (*j*) ICT development (figure refers to equation 9)

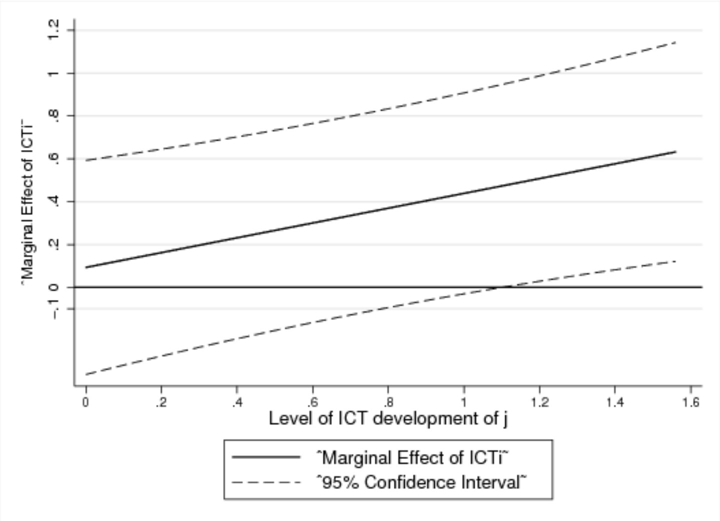
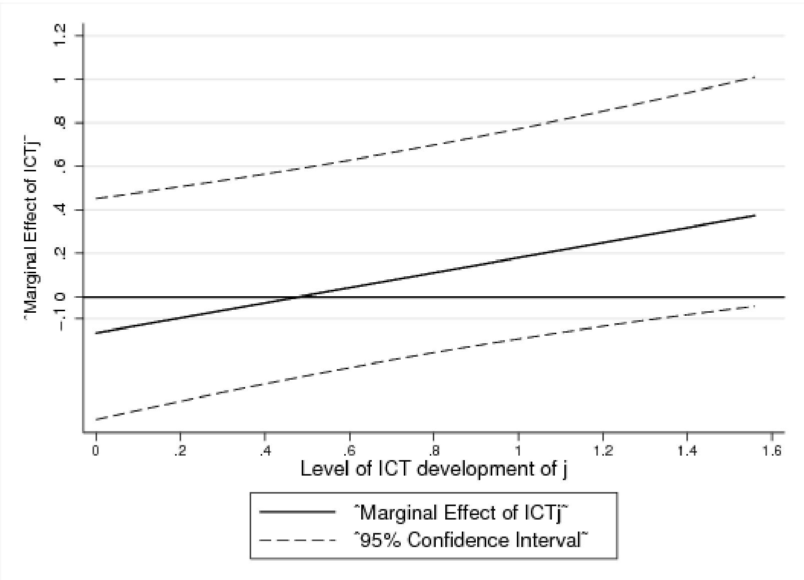


Figure 6: The impact of an importing country's (*j*) ICT development on its imports for different levels of exporting country's (*i*) ICT development (figure refers to equation 9)



The statistically and economically smaller impact of ICT on trade in the second model specification, where the effect of GDP on exports is controlled for, may have different explanations. One explanation may be that the first model specification suffers from an omitted variable bias despite its basis on the theoretical model of Baier and Bergstrand

(2007). This reasoning is supported by the fact that both GDP variables are significant in column 2 of table 2. Another reason for the different impact of ICT development in the two model specifications may be that the inclusion of GDP leads to multicollinearity problems that inflate error variances, reducing the significance of the effect of ICT. But despite these minor concerns, the second estimation approach confirms the conclusions from the first estimation approach. ICT is subject to network effects and it enhances exports when both trading partners dispose of good ICT development.

6. Conclusion

This paper has analysed the impact of ICT on EU trade through the application of the gravity model, which is frequently applied in trade-related research and has proven to be a reliable model. A rather recent discussion about the correct estimation approach has led to new considerations regarding model specification and estimation method. The chosen estimation approaches for the present study are directly based on that discussion. Two estimation approaches are applied in order to assess the robustness of the estimation results.

In order to ensure a correct modelling of ICT development in the gravity framework, an indicator has been developed based on the ICT Development Index of the International Telecommunication Union. This indicator is an internationally-acknowledged measure of ICT development. The estimation results conclude that our indicator is soundly-constructed and an appropriate proxy for the level of ICT in our analyzed countries.

The estimation results indicate that ICT development has a significant positive impact on European trade. In particular, the results suggest that ICT enhances trade when both trading partners have good ICT implementation. This finding is in line with economic theory which characterizes ICT as a network technology. The first estimation approach suggests that - after adequately controlling for transportation infrastructure - two countries with good ICT development trade about 33% more than a country pair where one country or both countries have poor ICT development. The second estimation approach supports the relevance of ICT development for European trade. The results suggest that the exporting country's ICT development is particularly important in order to enhance trade between a given pair of countries.

These findings may be interpreted as justifying common European as well as country specific efforts of ICT development in order to support the European Single Market and to foster the further economic integration of the region.

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