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An Empirical Investigation into the Role of Technology Gap in the Trade Relations of the EU Member States

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A B S T R A C T

Objective: The objective of this article is the assessment of the role of technology gap in explaining the intensity of trade relations among the EU28 member states over the period of 1995-2015.

Research Design & Methods: We constructed a basic trade model in a gravity framework and further augmented it by incorporating various measures of technology gap. We verified the robustness of the results by re-estimating the model for subgroups depicting the south-south, south-north & north-north trade.

Findings: We have found that the technology gap plays a substantial role in determining the intensity of present trade relations of the EU28 Member States. We tested the robustness of the results and have found that the impact of technology gap varies with respect to different groups of reporters and partners depending on their level of technological sophistication. The results are in line with the postulates of trade theory.

Implications & Recommendations: Technology gap plays an important role in determining the intensity of trade within the group of the EU28. The gradual convergence in incomes and TFP levels is likely to modify its role, with more effort directed at horizontal differentiation which in turn could lead to the intensification of the IIT.

Contribution & Value Added: We tested various standard and non-orthodox measures of technological gap. The semi-mixed effects panel data model was estimated with the use of PPML – a new and superior approach.

Article type: research paper
Keywords: technology gap; gravity model; panel data; semi-mixed effects; PPML
JEL codes: F10, F14, C23

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INTRODUCTION

The levels of technological sophistication differ significantly between countries and between sectors. In addition, the recent micro-level evidence proves that they vary greatly between firms within the same sector located in the same country (e.g. Bernard, Jensen, & Lawrence, 1995), which is reflected in highly right skewed productivity distribution at the core of the heterogeneous firms' theory.

Taking the above into account, the gap in technological sophistication could be one of the most important determinants of bilateral trade between any two countries, even if they are the same level of technological sophistication (north-north or south-south trade) or we deal with trade between a leader and a follower (north-south trade). To our surprise, with some exceptions, relatively little attention has been given to the empirical investigation of the role of the technology or innovation gap in determining the intensity of trade flows with the use of the very popular and clearly robust gravity approach.

The objective of the present article is the assessment of the role of technology gap in determining the aggregate intensity of bilateral trade within the group of the EU28 Member States over the period of 1995-2015 utilising the panel data approach. We constructed a basic gravity model of bilateral trade with exports as the chosen dependent variable and then further augmented it by introducing various measures of bilateral technological gap or technological distance. From this perspective, the present article can be considered an extension of the studies of Brodzicki and Śledziewska (2016) and Brodzicki (2016) on the role of technology in the trade relations of Poland allowing more general conclusions to be drawn. Based on the prior results as well as theoretical postulates, we expected technology gap to play a significant role in determining the intensity of trade relations. For the time being, the lack of suitable sectoral data does not allow us to test the technology gap hypothesis on a global panel of countries at more disaggregated, adequate sectoral or even product level. We thus consider the present analysis as a step towards the comprehensive verification of technology gap trade as proposed by Soete (1981).

We would like to acknowledge that the linkage between technology and trade is multifaceted and has been investigated since the earliest contributions to economics. Technology differentials of exogenous nature, for instance, are the basis of Smith's absolute advantage trade model as well as Ricardian comparative advantage model. Eaton and Kortum (2002) build an interesting modern extension of the Ricardian model with heterogeneous technology allowing both geographic barriers (not only distance) as well as technology to determine international specialisation. A thorough review of the role of technology gap in economic growth and trade has been recently conducted by Kubielas (2011). According to Kubielas, technology gap can play a role of both a barrier as well as an incentive to trade and furthermore effective catching-up process (structural convergence).

However, as noticed by Lall (1992), economic literature neglected the mechanisms for technology creation, assuming only static effects of technology and thus adopted exogenous technological change. Simplified neoclassical models assumed equal access to technology at both macroeconomic and microeconomic levels with perfect knowledge diffusion. The initial endowment in production factors determined the factor price ratios which corresponded to a certain level of physical capital per worker or the K/L intensity. Furthermore, all companies were assumed to share the same production function and barriers to technology diffusion were zero. In that setting, a purposeful innovative activity by a given company did not result in any advantage for the firm or economy in general over its competitors. There was no rational justification for R&D spending.

The dominant framework was questioned in the 1960s by the emergence of the technology gap theory by Posner (1961) or Freeman (1963) who in their stylised models described an advantage enjoyed by a country introducing a new good into a market, thus gaining the first-mover advantage due to technological lead (supremacy) that led to gaining an initial exporter status. The initial importers could potentially become exporters after gaining the necessary knowledge. It required a certain lag due to the imperfect character of knowledge diffusion.

It is also worth stressing that Vernon (1966) and Hirsch (1974) developed the theory of trade with product life cycles. The theory was elaborated by Krugman (1979) in his general-equilibrium model of bilateral trade between industrialised north and underdeveloped south with a product life cycle. Krugman's model assumed that innovating North enjoyed an initial advantage in the production of innovative goods thus becoming their exporter. However, the non-innovating South can eliminate the North's initial advantage thanks to 'technology borrowing' or technology imitation. In order to retain the leadership, the Northern economy is forced to innovate repetitively. The technology gap can be partially reduced by prior imports or FDI inflows (e.g. Coe & Helpman, 1995) – major channels of international R&D spillovers and technology transfer (Kwiatkowski, 2015). Thus, we have to acknowledge that trade and technology gap could be endogenous at least to some extent.

In contrast to the theoretical literature, the results of the initial empirical analyses on the technology gap based trade are mixed. In his influential paper, Soete (1981) performed a static cross-sectional analysis of OECD trade at the disaggregated sectoral level, and the results strongly supported the theoretical postulates. The international trade performance of innovative sectors in the OECD countries was found to be a function of sectors' relative technological performance as measured by technology-output indicators.

A more elaborated analysis by Cotsomitis, DeBresson, & Kwan, (1991) exposed, however, that the technology gap theory was unable to properly predict the directions of high technology trade between OECD economies. The authors linked it to inadequate theoretical formulation of the theory. Specifically, it is based on the overall technology leadership and does not allow for variation at the level of product.

However, more recent studies are clearly in favour of technology gap based trade. In her work Wakelin (1998) analysed the role of innovations in trade performance of the OECD countries disaggregated for 22 industries over the period of 1980-1988 and concluded that at the aggregate level and in the case of the majority of sectors innovative activity played a significant role. Moreover, she suggested that innovations impacted trade performance to a greater extent in sectors that created technology ('net producers') than in sectors utilising the technology ('net users'). The result was is in line with the classic work by Dosi and Soete (1983). Similar results were obtained by Kerr (2017), who proved that Ricardian technology differences had a significant impact on bilateral trade among 88 countries disaggregated into 26 industries in the period of 1980-1999.

The remainder of the paper is as follows. Section 2 presents a review of empirical studies on the role of technology gap applied in the gravity setting; Section 3 presents the methods utilised, the empirical model and data source, and considers the measurement of the technology gap. Section 4 presents and discusses the results of the estimation on the general sample, as well as trade between the groups depending on their level of technological sophistication. The final section concludes.

LITERATURE REVIEW

The utilisation of the gravity framework in modelling trade intensity since the early contribution by Tinbergen (1962) has been extensive and successful. The later seminal contributions include, for instance, the works by Bergstrand (1985), Anderson and van Wincoop (2003) or Anderson (2011). The gravity model is one of the most successful empirical models in which bilateral trade between any two trade partners is modelled as inversely proportional to the distance between them and proportional to their sizes. This basic framework is regularly extended to incorporate variables in line with the hypotheses tested in a given study that could potentially affect mutual trade intensity. The quick review of contemporary studies shows that researchers are rather flexible in the selection of explanatory variables based on the context or aim of their particular analysis (Kepaptsoglou, Karlaftis, & Tsamboulas, 2010). Head and Mayer (2014), in turn, critically review the methodological foundations of the gravity equation and empirical methods utilised.

Despite its robustness, new methods of analysis are being developed and applied, leading to more precise results. Egger (2000) points to the need of a proper econometric specification of the gravity equation in order to obtain unbiased estimates.

In the most typical usage, the empirical model is log-linearised and estimated with the use of country-pair dummies (in order to account for the problem of trade persistence - Anderson and van Wincoop [2003]) Log-linearisation leads to a number of problems, such as the presence of zero-trade flows typically solved by zero-adjustment, etc. Furthermore, the introduction of fixed-effects in the two way setting could lead to neglecting time-invariant variables and therefore requires the use of more elaborate methods such as of the Hausman-Taylor estimator, for instance.

In contrast to the usual approach, Santos Silva and Tenreyro (2006) stressed that the logarithmic transformation of the model was not an appropriate approach to estimate elasticities in gravity equation. As an alternative, they proposed the use of the Poisson pseudo-maximum likelihood estimator (PPML). Recently, Proenca, Sperlich and Savaşcı, (2015) recommended the use of a semi-mixed effects method which relaxed the very strict assumptions of random errors model but kept more restrictions than the fixed effect model. This approach was successfully utilised in Brodzicki (2016) and in Brodzicki and Śledziewska (2015) and is going to apply in the present study as well.

As it has been already mentioned, despite the significance of technological sophistication and the role of technology gap as postulated by theoretical literature, only a limited number of empirical studies tested for the role of technology gap or technological distance in explaining bilateral trade flows within the gravity framework.

Martinez-Zarzoso and Ramos (2005) utilised a composite index capturing technology and human knowledge gaps in an augmented gravity framework in a cross-sectional study on 62 developed and developing countries in 1999. The model for exports was estimated with the standard OLS on a standard double log specification. The authors utilised a composite Technology Achievement Index (TAI) developed by the United Nations. The index composed of eight distinct achievement indicators (Desai *et al.* 2002) captured the efficiency in the creation and diffusion of new as well as existing technologies and in building the human skill base for technology creation. TAI indices for exporters and importers were introduced separately to test their significance in subsamples of wealthy and poor exporters. Martinez-Zarzoso and Ramos (2005) included a standard set of conditioning variables controlling in addition to infrastructure endowment. The impact of exporters' TAI on the value of exports was found to be statistically significant and positive for both developed and developing countries. However, it was statistically significant for importers' TAI only in the case of developing countries.

Filippini and Molini (2003) included technological distance measured by an indicator proposed by Lall (1992) in an extended panel model to examine the relevance of technology gap in the trade flows between East Asian industrialising countries and selected developed countries over a period of 30 years. They split the sample into developed and developing countries and furthermore decomposed the trade flows into manufacturing and non-manufacturing goods. Filippini and Molini (2003) applied the fixed effects estimator and were able to positively verify the hypothesis that bilateral trade tends to increase in technological similarity between countries.

In the study by Wang, Wei and Liu (2010) for 19 OECD countries over the period of 1980-1998, R&D stock, similarities in the domestic R&D stock, market sizes as well as inward FDI stock were found to play a major role in determining the value of exports. At the same time, domestic R&D stock was found to play a bigger role than GDP and FDI in promoting bilateral trade. A 1 percent increase in total domestic R&D stock increased bilateral trade by up to 1 percent, and a 1 percent increase in the R&D similarity between trade partners raised trade by around 0.4 percent. R&D was furthermore observed to be the second most important variable in explaining trade flows within the group of the OECD countries just after the geographical distance. The results by Wang *et al.* (2010) are in line with the postulates of the new growth theories (e.g. Romer, 1990; Grossman & Helpman, 1991; Aghion & Howitt, 1998).

Brodzicki and Śledziewska (2016) estimated a panel model of trade relations of Poland with its 234 trade partners over the period of 1999-2013. The technology gap was measured by TFP and relative patenting performance controlling for the quality of institutions as well as technology and innovation indices of the Global Competitiveness Report (Schwab, 2010) published by the World Economic Forum on a yearly basis. They applied the PPML estimators. The technology gap was proven to play a statistically significant role, however, the elasticity of trade on the technology gap differ significantly between groups of trade partners classified by the level of income and the level of their technological sophistication.

Brodzicki (2016) performed a linked analysis on the Polish trade with all possible trade partners over the period of 1999-2011 using similarly to the present study a semi-mixed effects model using PPML estimator as suggested by Proenca *et al.* (2015). In measuring the technology he utilised several approaches taking into account differences in TFP, GERD (technology-input), patenting and citation in scientific journals (technology-outputs), while controlling for differences in human capital. The major result was that Poland exported more to countries at the similar level of technological sophistication. The results were checked on sub-groups of countries based on their GERD intensity levels. It was found to be evident that the results varied depending mostly on whether Poland enjoyed leadership, followership or was a peer vis-à-vis a given group of partners. The present study extends the analysis to numerous reporting countries, therefore, allowing for more general conclusions to be drawn.

MATERIAL AND METHODS

Our empirical panel data model for total exports of reporting country i to partner country j in the year t took the following form:

$$\text{export}_{ijt} = \exp\big(\ln \alpha_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln d_{ij} + \gamma \ln X_{ijt} + \rho \ln Tech.Gap_{ijt} + \nu_t + \eta_i\big)\varepsilon_{it} \quad (1)$$

where:

Y_{it} - size of the reporting country;

Y_{jt} - size of the partner country;

d_{ij} - distance in kilometres between reporter's and partner's capital cities;

X_{ijt} - conditioning set of standard gravity variables describing bilateral trade relations;

$Tech.Gap_{ijt}$ - measure of the technological gap of direct interest to us.

The form of the empirical model allowed to interpret the coefficients on the key variables as elasticities.

In contrast to the traditional approach, the dependent variable entered the equation in levels and not in logs. In addition, we estimated the model for total bilateral trade (total trade) as well as imports (import) separately. We expected the coefficients on it to be statistically significant.

The explained variable (exports) was the value of exports from a given reporting EU 28 members state to a given EU 28 partner in millions USD in a given year. All values were converted to constant 2005 USD in order to obtain coherence with the data from the PWT 9.0 database.

In contrast to previous analyses by Brodzicki (2016) and Brodzicki and Śledziewska (2016) conducted for Poland and its trade partners, we dealt with a matrix of 784 trade flows on a bilateral basis observed over a period of 21 years (1995-2015), thus allowing for more universal conclusions.

The trade data for the EU28 countries were retrieved from COMEXT database (http://epp.eurostat.ec.europa.eu/newxtweb/). The data were converted from EUR to USD and deflated in order to guarantee their coherence with the explanatory data retrieved from the PWT 9.0.

Table 1 contains a description of the utilised variables, their source and basic statistical properties. The membership in the EU28 was utilised as a clustering variable (eu) in our semi-mixed effect model. It was a dummy variable which was time variant.

The basic specification of the gravity model includes standard variables such as the sizes of reporter and partner as measured by the log of their real GDP (real GDP) and the log of distance between trade partners (distance). The distance is measured by the 'as the crow flies method' between the capital cities of reporter and trade partner. In accordance with the postulates of the gravity theory, the coefficients on real GDP of partner and reporter should be positive and negative in the distance.

Economic theory postulates that trade between two countries at the similar level of development is more intense. In order to account for this, we adopted natural log of absolute difference in real GDP per capita as a measure of the gap in the level of development (rld) and expected the coefficient on it to be statistically significant and negative. We would like to stress furthermore that we chose to apply the above mathematical transformation (that is the natural log of absolute difference) to all variables depicting the technology gap in order to ease the interpretation of the obtained results. At the same time, other alternatives were checked – such as e.g. the log of the ratio of key variables between reporters and trade partners. It proved not to have a major impact on the results once we allowed the different interpretation of coefficients on technology gap variables.

We utilised COMEXT dataset as a principal source of trade data. For the set of explanatory variables, we utilised first of all the Penn World Tables 9.0 (Feenstra *et al*., 2015). The dataset provided information on real GDP, capital, labour and human capital endowments, import and export shares as well as TFP of all countries considered. Most of the remaining data come from the World Bank's World Development Indicators Database.

In their seminal article, Dosi and Soete (1983) postulated that technological gap should be preferably measured by the difference in patenting performance vis-à-vis the US. The US was chosen as a benchmark country located on the global technology frontier (GTF). Dosi and Soete (1983) approximated the difference by the technology-output or R&D efficiency indicator. Other approaches utilised in the empirical literature on the subject include for instance the share of high technology or medium-high technology goods or sectors in exports or total production. On the other hand, the use of technology-input indicators is also popular. The most popular include R&D spending intensity as proxied by General Expenditures on R&D (GERD) or some measure of R&D sector's size, such as the number of employees involved in R&D.

Acknowledging the complex nature of technology and its diffusion channels, as well as the importance of both technology-inputs and technology-outputs, many researchers try to build composite technology or innovation indicators. The example, being the TAI or the Summary Innovation Index (SII) utilised in the European Innovation Scoreboards (European Commission, 2015). The use of this kind of variables is however debatable. At most, their direct interpretation is difficult if not impossible. On a more serious note, Grupp and Mogee (2004) show that the use of composite measures led to purposeful manipulation, which obviously should be prevented as it could result in false policy recommendations or policy decisions. Therefore, we eliminate this possibility from our analysis.

Bearing the above in mind, in the present article we introduce several measures of a technological gap not favouring any of the utilised approaches driven by the review of the theoretical literature. Both technology-input and technology-output proxies technology gap are utilised.

Economic growth theory postulates that technological sophistication can be proxied foremost by total factor productivity (TFP). Our preferred measure of the technological gap was, therefore, the difference in TFP levels as measured by a natural log of the absolute difference in TFP levels between a given reporting and partner country a given year (diff_ctfp). The TFP levels come from the PWT 9.0 dataset.

Soete (1981) attributed technological gap to differences in relative factor endowments of physical capital in relation to labour. We thus introduced a relative difference in K/L ratios between the reporting and partner country as one of the options considered.

Some authors (e.g. Comin & Mestieri, 2013) utilise electric power consumption in kWh per capita as a proxy for the level of technological sophistication. We thus used it as an alternative proxy (diff_epc). The data for this and the following variables come to form the World Bank Development (WDI) Indicators database. Relative technological readiness (diff_techred) is typically measured by the difference in the individual usage of the Internet given in the percentage of total population of a given state. We treated it as another alternative.

As a proxy for technology gap from the technology-input perspective, we utilised first of all the difference in R&D intensity – General Expenditures on Research and Development as a share of to GDP (dif_gerd).

As technology is said to be skilled-biased (Acemoglu, 1998; Acemoglu, Gancia, & Zilibotti, 2012; Gancia, Müller, & Zilibotti, 2011), we furthermore took into account the gap in human capital endowments (diff_hc). For human capital, we utilised PWT 9.0 measure – an index of human capital per person based on average years of schooling and returns to education.

Taking into account specific skills of research & development activity, we also controlled for the differences in the size of employment in the R&D per 1 million inhabitants (diff_emp_rd) from the WDI.

In turn, as a proxy for technology gap from a technology-output perspective we utilised the difference in total patenting activity in the United States Patent & Trademark Office (USPTO) in total (diff_uspto) as well in per 1 million inhabitants (diff_uspto_pc) in order to better account for differences in potential. The USPTO was selected on purpose as an illustration of the ability to patent at the global technological frontier.

As a secondary measure of technology-output, we took a total number of scientific journal articles (diff_jrn) and scientific journal articles per capita (diff_jrn_pc). The data once again came from the WDI database.

For the robustness analysis purposes we analysed in detail the global distribution of real GDP per capita and TFP levels from PWT 9.0 in 2004 – the year a significant number of countries in our sample joined the EU. After a careful examination, we chose the third quartile of the global distribution of the two key parameters and applied it throughout the panel in order to classify the analysed trade flows into three subgroups: south-south, south-north and north-north trade (6740, 6792 and 3716 observations respectively for TFP). In the present article, we have decided to present the robustness estimates for the groups delimited by the level of TFP only (the estimates for the real GDP per capita based groups are available upon request).

In order to eliminate a potential bias, we calculated the correlation measures and constructed correlation matrix for our technology gap proxies (Table 2). The analysis shows that at least several variables should not enter the same regression. Finally, we decided that various measures of technology gap would enter our empirical model separately. A similar analysis was conducted with the measures of technology gap and of similarity in the level of development (rld) showing that the correlation in most cases was weak or only moderate.

RESULTS AND DISCUSSION

The analysis was carried out for all possible trade flows between the Member States of the European Union present in the COMEXT dataset over the period of 1995-2014. The panel is unbalanced, in particular the specification of the model due to data restrictions in the PWT 9.0.

The explained variable is the value of exports or the value of total trade in millions USD (constant USD from 2005). The preferred explained variable in the present article is the value of exports, however due to the article size restrictions (the results for total trade can be made available upon request, they do not differ significantly from the presented results).

We built a semi-mixed effects empirical panel model and estimated it with the use of Poisson Pseudo Maximum Likelihood (PPML) estimator. The EU membership (eu) played the role of a clustering variable in our empirical analysis.

Our empirical strategy was as follows. We first estimated the augmented gravity model with standard gravity variables and various measures of the technology gap entering the model separately for the general sample. In the next stage, as it has already been stressed, we split the sample into three – the trade between south-south, south-north (or north-south) and north-north for reporting and partner countries respectively. The results for the broad sample of trade partners are provided in Table 3. The estimates for split samples are presented in Tables 4, 5 and 6.

We would like to notice that the obtained results proved not to be sensitive to the inclusion of time fixed-effects. We therefore decided to exclude them from the analysis.

In all analysed specifications of the models for both the general as well as subgroups, the overall fit of the model is high – explaining around two-thirds of the variation in the exports between the reporter and partner country. The fit of the model is the highest in the case of north-north trade.

In all analysed specifications the coefficients on distance are statistically significant at 1 percent and negative as it could be expected. The magnitude of the effect in most cases is below of 0.9, it is above of 1 in several specifications in the case of the south-south trade group. The intensity of bilateral trade increases in the proximity of trade partners.

The size of trade partner as well as of reporter as measured by the log of real GDP has a statistically significant (at 1 percent level) and positive impact on exports. The elasticity is below of 1 in most cases. The elasticities are the lowest on average in the case of north-north trade and the highest in the south-south trade. The choice of the log of the total population as a measure of size does not affect the outcomes (not shown in the tables with estimates).

The impact of the membership in the EU (eu) is positive and statistically significant in all analysed specifications. The effect is particularly strong in the case of north-north trade. Nonetheless, the membership of a trade partner in the EU28 significantly intensifies mutual trade.

Last but not least, the impact of the gap in the level of development as indicated by rld is statistically significant and negative, therefore the closer two trade partners in the EU28 are in terms of the level of development, the greater the intensity of exports is.

Furthermore, we would like to stress that the inclusion of additional variables such as adjutancy or integration linkages among states did not modify the key results.

In interpreting the results, we obviously focused on the variables of interest of the present article related to the impact of technology gap on the intensity of exports within the analysed groups of countries.

A careful analysis of the estimation results for the general sample (Table 3) and the following estimates for subsamples: south-south trade (Table 4), south-north trade (Table 5) and north-north trade (Table 6) shows that the significance of the effect of the gap on exports and its direction to a large extent depends on the type of the utilised proxy.

In the general sample, including all possible trade partners within the EU28 group, the impact of the gap in TFP, K/L ratios, GERD, technological readiness and journal articles per capita is statistically significant and negative. The impact of the gap in human capital, the number of patents in the USPTO in general and per capita is statistically significant and positive. The impact of the gap in employment in R&D and electricity consumption per capita is statistically insignificant. This applies to all types of models in the case of R&D employment, an important technology-input variable, which could indicate for instance problems with its measurement or relatively small differences in the analysed group of countries. The EPC is statistically significant only in the case of south-south trade (SS6) with a negative impact on the explained variable.

As it could be expected, the impact of the technology gap is not robust to changes in the sample. The level of sophistication of both the reporter and the partner matters. Here we only report the results which are statistically significant on at least 5 percent level. The difference measured by human capital is positive in the case of south-north trade (SN2) and is not significant in the case of south-south and north-north trade. Thus, in the case of south-north trade the greater the gap in human capital endowment, the more intense the exports.

The impact of the gap in TFP considered in the literature of the subject as the best measure of the level of technological sophistication has a negative impact in the case of SS and SN trade (SS3 & SN3). It is irrelevant in the case of NN trade. The similar pattern holds for the gap in K/L ratios with greater similarity increasing exports in the case of south-south and south-north trade. Nonetheless, we have to note here that some authors perceive the difference in K/L ratios to represent the difference in endowments in physical capital and labour and not in the level of technology per se.

The gap measured by the difference in GERD is of great significance as probably the most important technology-input indicator. The result is statistically significant and negative only in the case of south-north and north-north trade. It is irrelevant for south-south (SS5) trade probably due to small differences in generally small expenditure on R&D in these countries. Thus, the result seems to be rational.

The gap measured by technological readiness (the Internet usage) is only to have a negative and statistically significant impact throughout. It is the opposite for the gap in the major technology-output indicator, that is the number of patents in the USPTO (SS8-NN8). The greater the difference, the greater the intensity of exports. This holds for a number of patents per capita in the case of south-south and south-north trade (SS9, SN9), and is statistically insignificant in the case of the north-north trade so within the most technology-intensive group of countries (NN9).

As to journal articles, the results for the two variables (jrn, jrn_pc) are statistically significant, however, the direction of their impact differs between the analysed subsamples. In the case of a total number of scientific journal articles the impact is negative in the case of south-south trade (SS10), and positive in the remaining cases (SN10, NN10). If we control for the population size, however, the result becomes negative in the case of south-south (SS11) and north-north (NN11) trade and positive in the case of south-north trade (SN11).

The obtained results are in line with the principal theoretical postulates of the technology gap based theory, as well as postulates of the new growth theory. The technology gap has a statistically significant impact on the intensity of exports between trade partners. In the case of the principal measures of the technology gap, such as based on differences in TFP or GERD, the mutual trade increases in technological similarity. This is in line with Filippini and Molini (2003). Nonetheless, not all measures of technology gap are robust and the results are more nuanced. Furthermore, the results differ between the analysed subgroups similarly to Martinez-Zarzoso and Ramos (2005), Brodzicki (2016) or Brodzicki and Śledziewska (2016). The differences between south-south, south-north and north-north trade do not contradict the logic of the theory itself.

CONCLUSIONS

The major objective of this empirical article was to investigate the role of technology gap in explaining the intensity of trade at the country level and thus to verify the postulates of the technology gap based trade. We utilised the trade gravity approach further augmenting it with technology gap measures.

The analysis was conducted for a panel of trade flows between 28 EU member states observed over the period of 1995-2015. To obtain unbiased results, we utilised the semi-mixed effects model estimated with the PPML estimator as suggested in the most recent methodological and empirical literature (Proença, Sperlich, & Savaşcı, 2015). The advantages of the approach comprise the possibility to include all possible trade flows including zero-trade flows without the need for log-linearisation. Nonetheless, we would like to stress that the major results hold even if the analysis is conducted with other empirical strategies present in the literature of the subject.

The gravity framework can be successfully applied to determine the intensity of exports between the EU28 states with more than two-thirds of variation explained. The gravity holds clearly – with the reporters and partners sizes having a positive impact and the distance between them having a clearly negative impact. The proximity in the level of development within the analysed group clearly boosts bilateral exports. Furthermore, the membership in the EU28 of the partner clearly brings positive benefits.

In measuring the technology gap, we have utilised several approaches taking into account differences in TFP, GERD, human capital and R&D employment (technology-inputs), patenting at the global technology frontier in the USPTO & scientific journals articles (technology-outputs). We also controlled for K/L ratios and non-standard measures, such as technological readiness (internet usage) or electrical power consumption.

The results vary between the indicators and the analysed subgroups of trade relations constructed in accordance with the economic logic – south-south, south-north (& north-south), as well as north-north trade. The most popular indicators that are TFP and GERD point to the negative impact of the gap on the intensity of exports. Countries seem to export more to countries at the similar level of technological sophistication. Nonetheless, the observed differences can be rationally explained despite being more nuanced. The results support the postulates of the technology gap based trade. The role of technology gap is likely to remain important or even increase in significance as the role of technology is ever increasing

Table 1. The description of key variables

Variable	Full description	Obs	Mean	Std. Dev.	Min	Max	Data source
import	Value of imports, M of constant 2011 USD	13 525	4403.696	14647.840	0.000	195050.20	Eurostat COMEXT
export	Value of exports, M of constant 2011 USD	13 522	4539.961	14932.990	0.000	188440.40	Eurostat COMEXT
total trade	Total trade, M of constant 2011 USD	13 522	8944.634	29126.080	0.000	353316.90	Eurostat COMEXT
ln_gdp_rep	Real GDP of reporter, M of constant 2011 USD, ln	15 680	12.2076	1.504	8.755	15.126	PWT 9.0
ln_gdp_par	Real GDP of partner, M of constant 2011 USD, ln	15 680	12.2076	1.504	8.755	15.126	PWT 9.0
ln_pop_rep	Population of reporter, M, ln	15 680	2.038	1.418	-0.988	4.407	PWT 9.0
ln_pop_par	Population of partner, M, ln	15 680	2.038	1.418	-0.988	4.407	PWT 9.0
rld	Difference in the level of development	15 120	9.047	1.188	1.164	11.261	PWT 9.0
ln_distance	Distance between capitals, ln**	16 632	7.175	0.769	4.087	8.857	Own elaboration
eu	EU membership	17 248	0.786	0.410	0.000	1.000	Own elaboration
diff_hc	Relative human capital level	15 120	-1.497	1.093	-8.751	0.353	PWT 9.0
diff_ctfp	Relative total factor productivity	15 120	-1.877	1.091	-9.486	-0.027	PWT 9.0
diff_k_l	Relative capital/labour endowment ratio	15 120	11.104	1.153	0.426	13.0450	PWT 9.0
diff_gerd	Relative general expenditures on R&D, percent of GDP	12 956	-0.486	1.180	-9.028	1.302	World Bank WDI
diff_epc	Relative electric power consumption, kWh per capita	15 120	7.585	1.238	-1.519	9.600	World Bank WDI
diff_techred	Relative individuals using Internet, percent of population	16 111	1.984	1.807	-12.477	4.252	World Bank WDI
diff_uspto	Relative no. of utility patents granted by the USPTO	15 502	5.573	2.317	0.000	8.808	USPTO
diff_uspto_pc	Relative no. of utility patents granted by the USPTO per capita	15 100	2.907	1.866	-7.750	5.785	USPTO
diff_jrn	Relative scientific and technical journal articles published	10 584	9.152	1.565	0.916	11.528	World Bank WDI
diff_jrn_pc	Relative scientific and technical journal articles published per capita	10 584	5.860	1.092	-3.660	7.523	World Bank WDI
diff_emp_rd	Relative no. of researchers in R&D per 1 M people	13 120	6.925	1.193	-2.081	8.899	World Bank WDI

*rld was calculated as natural logarithm of absolute value of difference between reporter's and partner's GDP. All other variables approximating technology gap were calculated accordingly. **(DISTANCE:=6371*2*ATAN2((SQRT(1-(SIN(ABS(LATITUDE_2-LATITUDE_1)*PI()/180/2)^2+COS(LATITUDE_1*PI()/180)*COS(LATITUDE_2*PI()/180)*SIN(ABS(LONGITUDE_2-LONGITUDE_1)*PI()/180/2)^2)));SQRT((SIN(ABS(LATITUDE_2-LATITUDE_1)*PI()/180/2)^2+COS(LATITUDE_1*PI()/180)*COS(LATITUDE_2*PI()/180)*SIN(ABS(LONGITUDE_2-LONGITUDE_1)*PI()/180/2)^2)))

Source: own study.

Table 2. Correlation matrix between technological gap indicators in our dataset

Variable	diff_hc	diff_ctfp	diff_k_l	diff_gerd	diff_epc	diff_techred	diff_uspto	diff_uspto_pc	diff_jrn	diff_jrn_pc	diff_emp_rd
diff_hc	1.0000										
diff_ctfp	-0.0989	1.0000									
diff_k_l	-0.0719	0.1277	1.0000								
diff_gerd	0.0086	0.2077	0.0935	1.0000							
diff_epc	-0.0439	0.1548	0.1126	0.4531	1.0000						
diff_techred	0.0646	0.1435	0.0820	0.2932	0.2814	1.0000					
diff_uspto	0.0060	0.2732	-0.0119	0.4010	0.1873	0.1903	1.0000				
diff_uspto_pc	-0.0705	0.3125	0.0595	0.5500	0.4546	0.3448	0.6855	1.0000			
diff_jrn	0.0808	0.0761	0.0099	0.1197	-0.0424	0.0175	0.7150	0.2772	1.0000		
diff_jrn_pc	0.0205	0.1520	0.1792	0.4714	0.3369	0.2858	0.2974	0.4172	0.1158	1.0000	
diff_emp_rd	0.0026	0.1309	0.0853	0.5467	0.4386	0.3654	0.2593	0.4786	0.0161	0.3777	1.0000

Note: Estimated in STATA 14.

Source: own study.

Table 3. Technological gap in the exports within the EU28 – semi-mixed effects model estimated with the PPML

Variables	(G1)	(G2)	(G3)	(G4)	(G5)	(G6)	(G7)	(G8)	(G9)	(G10)	(G11)	(G12)
ln_gdp_par	0.710***	0.708***	0.705***	0.705***	0.725***	0.706***	0.714***	0.727***	0.715***	0.757***	0.747***	0.726***
	(0.0125)	(0.0124)	(0.0128)	(0.0125)	(0.0127)	(0.0133)	(0.0126)	(0.0127)	(0.0121)	(0.0118)	(0.0125)	(0.0131)
ln_gdp_rep	0.802***	0.799***	0.799***	0.799***	0.811***	0.797***	0.800***	0.807***	0.807***	0.848***	0.845***	0.807***
	(0.0139)	(0.0137)	(0.0141)	(0.0141)	(0.0140)	(0.0147)	(0.0139)	(0.0148)	(0.0139)	(0.0132)	(0.0134)	(0.0144)
ln_distance	-0.859***	-0.861***	-0.858***	-0.841***	-0.840***	-0.852***	-0.827***	-0.870***	-0.883***	-0.886***	-0.893***	-0.878***
	(0.0208)	(0.0207)	(0.0207)	(0.0214)	(0.0211)	(0.0212)	(0.0223)	(0.0205)	(0.0210)	(0.0215)	(0.0216)	(0.0237)
rld	-0.138***	-0.137***	-0.128***	-0.135***	-0.119***	-0.139***	-0.116***	-0.139***	-0.153***	-0.0502***	-0.0293**	-0.124***
	(0.0136)	(0.0137)	(0.0145)	(0.0135)	(0.0144)	(0.0135)	(0.0133)	(0.0138)	(0.0130)	(0.0136)	(0.0138)	(0.0142)
eu	1.785***	1.783***	1.767***	1.764***	1.755***	1.786***	1.790***	1.697***	1.743***	1.704***	1.768***	1.736***
	(0.0706)	(0.0705)	(0.0701)	(0.0712)	(0.0728)	(0.0707)	(0.0707)	(0.0715)	(0.0713)	(0.0660)	(0.0659)	(0.0746)
diff_hc		0.0281**										
		(0.0137)										
diff_ctfp			-0.0486***									
			(0.0149)									
diff_k_l				-0.0660***								
				(0.0132)								
diff_gerd					-0.0744***							
					(0.0144)							
diff_epc						-0.0196						
						(0.0133)						
diff_techred							-0.117***					
							(0.0149)					

diff_uspto								0.108***				
								(0.0133)				
diff_uspto_pc									0.0594***			
									(0.0170)			
diff_jrn										0.0957***		
										(0.0117)		
diff_jrn_pc											-0.0932***	
											(0.0147)	
diff_emp_rd												0.0200
												(0.0152)
Constant	-6.144***	-6.038***	-6.223***	-5.458***	-6.801***	-5.927***	-6.328***	-7.025***	-6.147***	-9.113***	-7.659***	-6.541***
	(0.353)	(0.352)	(0.354)	(0.371)	(0.356)	(0.401)	(0.365)	(0.358)	(0.353)	(0.375)	(0.351)	(0.383)
No of observations	13,522	13,522	13,522	13,522	12,308	13,522	13,518	13,244	13,520	10,581	10,581	11,776
R-squared	0.639	0.639	0.647	0.642	0.657	0.643	0.652	0.649	0.657	0.752	0.748	0.659
No of parameters	6	7	7	7	7	7	7	7	7	7	7	7
Log-likelihood	-1.910e+07	-1.900e+07	-1.900e+07	-1.890e+07	-1.690e+07	-1.900e+07	-1.840e+07	-1.790e+07	-1.890e+07	-8.878e+06	-8.904e+06	-1.620e+07
AIC	3.810e+07	3.810e+07	3.790e+07	3.780e+07	3.370e+07	3.810e+07	3.680e+07	3.580e+07	3.780e+07	1.780e+07	1.780e+07	3.230e+07
BIC	3.790e+07	3.780e+07	3.770e+07	3.750e+07	3.350e+07	3.790e+07	3.660e+07	3.550e+07	3.760e+07	1.760e+07	1.760e+07	3.210e+07

Note: All regressions carried out using semi-mixed effect ppml with the EU28 as a clustering variable. Robust standard errors in parentheses. *significant at 10 percent; **significant at 5 percent; ***significant at 1 percent. Estimated in STATA 14. Dependent variable – bilateral exports in millions USD.

Source: own study.

Table 4. Technological gap in the exports within the EU28 – semi-mixed effects model estimated with the PPML - south-south (SS) trade

Variables	(SS1)	(SS2)	(SS3)	(SS4)	(SS5)	(SS6)	(SS7)	(SS8)	(SS9)	(SS10)	(SS11)	(SS12)
ln_gdp_par	0.753***	0.753***	0.740***	0.767***	0.779***	0.771***	0.756***	0.635***	0.738***	0.794***	0.779***	0.790***
	(0.0267)	(0.0274)	(0.0263)	(0.0257)	(0.0246)	(0.0291)	(0.0225)	(0.0257)	(0.0286)	(0.0190)	(0.0175)	(0.0217)
ln_gdp_rep	0.954***	0.954***	0.944***	0.968***	0.933***	0.972***	0.941***	0.810***	0.939***	0.938***	0.915***	0.937***
	(0.0324)	(0.0325)	(0.0312)	(0.0312)	(0.0290)	(0.0339)	(0.0267)	(0.0325)	(0.0343)	(0.0221)	(0.0187)	(0.0246)
ln_distance	-1.024***	-1.024***	-1.026***	-1.023***	-1.020***	-1.020***	-0.938***	-0.934***	-1.021***	-0.995***	-0.988***	-1.028***
	(0.0377)	(0.0374)	(0.0368)	(0.0342)	(0.0371)	(0.0367)	(0.0323)	(0.0320)	(0.0396)	(0.0343)	(0.0325)	(0.0396)
rld	-0.211***	-0.211***	-0.197***	-0.153***	-0.170***	-0.231***	-0.189***	-0.251***	-0.233***	-0.109***	-0.103***	-0.129***
	(0.0342)	(0.0343)	(0.0328)	(0.0335)	(0.0357)	(0.0294)	(0.0313)	(0.0402)	(0.0351)	(0.0232)	(0.0235)	(0.0260)
eu	1.493***	1.493***	1.528***	1.552***	1.368***	1.455***	1.574***	1.322***	1.414***	1.485***	1.490***	1.284***
	(0.108)	(0.108)	(0.110)	(0.112)	(0.107)	(0.114)	(0.111)	(0.106)	(0.108)	(0.0996)	(0.101)	(0.107)
diff_hc		-1.80e-05										
		(0.0283)										
diff_ctfp			-0.0497**									
			(0.0233)									
diff_k_l				-0.172***								
				(0.0231)								
diff_gerd					0.0221							
					(0.0233)							
diff_epc						0.0559*						
						(0.0323)						
diff_techred							-0.157***					
							(0.0247)					

diff_uspto								0.141***				
								(0.0237)				
diff_uspto_pc									0.0565***			
									(0.0191)			
diff_jrn										-0.0461**		
										(0.0215)		
diff_jrn_pc											-0.0510**	
											(0.0237)	
diff_emp_rd												0.0264
												(0.0199)
Constant	-7.088***	-7.089***	-7.045***	-6.078***	-7.482***	-7.761***	-7.510***	-4.655***	-6.612***	-8.237***	-8.019***	-8.135***
	(0.497)	(0.556)	(0.498)	(0.528)	(0.481)	(0.726)	(0.462)	(0.692)	(0.564)	(0.447)	(0.445)	(0.437)
No of observations	5,482	5,482	5,482	5,482	5,142	5,482	5,482	5,378	5,480	4,391	4,391	4,949
R-squared	0.664	0.664	0.676	0.702	0.679	0.672	0.746	0.533	0.652	0.751	0.764	0.753
No of parameters	6	7	7	7	7	7	7	7	7	7	7	7
Log-likelihood	-2.829e+06	-2.829e+06	-2.819e+06	-2.745e+06	-2.234e+06	-2.809e+06	-2.652e+06	-2.648e+06	-2.813e+06	-1.434e+06	-1.431e+06	-1.895e+06
AIC	5658597	5658599	5637498	5489168	4467757	5618154	5303705	5296303	5627012	2868106	2862701	3789189
BIC	5.578e+06	5.578e+06	5.557e+06	5.409e+06	4.393e+06	5.538e+06	5.223e+06	5.217e+06	5.546e+06	2.805e+06	2.800e+06	3.717e+06

Note: All regressions carried out using semi-mixed effect ppml with the EU28 as a clustering variable. Robust standard errors in parentheses. *significant at 10 percent; **significant at 5 percent; ***significant at 1 percent. Estimated in STATA 14. Dependent variable – bilateral exports in millions USD.

Source: own study.

Table 5. Technological gap in the exports within the EU28 – semi-mixed effects model estimated with the PPML - south-north (SN) trade

Variables	(SN1)	(SN2)	(SN3)	(SN4)	(SN5)	(SN6)	(SN7)	(SN8)	(SN9)	(SN10)	(SN11)	(SN12)
ln_gdp_par	0.700***	0.698***	0.672***	0.698***	0.730***	0.695***	0.717***	0.722***	0.722***	0.794***	0.769***	0.724***
	(0.0179)	(0.0173)	(0.0179)	(0.0180)	(0.0180)	(0.0172)	(0.0186)	(0.0202)	(0.0174)	(0.0178)	(0.0191)	(0.0180)
ln_gdp_rep	0.858***	0.855***	0.843***	0.858***	0.893***	0.851***	0.865***	0.860***	0.889***	0.952***	0.941***	0.889***
	(0.0230)	(0.0224)	(0.0223)	(0.0232)	(0.0233)	(0.0226)	(0.0235)	(0.0260)	(0.0217)	(0.0217)	(0.0234)	(0.0228)
ln_distance	-0.775***	-0.786***	-0.777***	-0.767***	-0.689***	-0.741***	-0.677***	-0.823***	-0.855***	-0.744***	-0.728***	-0.796***
	(0.0395)	(0.0398)	(0.0378)	(0.0397)	(0.0443)	(0.0387)	(0.0452)	(0.0377)	(0.0399)	(0.0448)	(0.0442)	(0.0506)
rld	-0.136***	-0.129***	-0.0779***	-0.132***	-0.0790***	-0.132***	-0.110***	-0.159***	-0.193***	-0.0392	-0.00516	-0.0971***
	(0.0275)	(0.0274)	(0.0262)	(0.0279)	(0.0295)	(0.0268)	(0.0271)	(0.0264)	(0.0234)	(0.0309)	(0.0283)	(0.0271)
eu	1.583***	1.583***	1.423***	1.566***	1.547***	1.561***	1.532***	1.588***	1.527***	1.594***	1.590***	1.531***
	(0.0934)	(0.0929)	(0.0927)	(0.0937)	(0.0964)	(0.0932)	(0.0928)	(0.0931)	(0.0928)	(0.0894)	(0.0897)	(0.0984)
diff_hc		0.0637***										
		(0.0218)										
diff_ctfp			-0.369***									
			(0.0493)									
diff_k_l				-0.0411**								
				(0.0202)								
diff_gerd					-0.145***							
					(0.0233)							
diff_epc						-0.141***						
						(0.0253)						
diff_techred							-0.148***					
							(0.0218)					

diff_uspto								0.144***				
								(0.0353)				
diff_uspto_pc									0.141***			
									(0.0328)			
diff_jrn										0.135***		
										(0.0199)		
diff_jrn_pc											-0.163***	
											(0.0216)	
diff_emp_rd												0.0446
												(0.0293)
Constant	-7.163***	-6.998***	-7.528***	-6.768***	-9.192***	-6.204***	-8.002***	-8.012***	-7.286***	-12.40***	-9.995***	-8.427***
	(0.647)	(0.636)	(0.612)	(0.666)	(0.756)	(0.648)	(0.731)	(0.588)	(0.586)	(0.724)	(0.732)	(0.713)
No of observations	6,167	6,167	6,167	6,167	5,536	6,167	6,165	6,067	6,167	4,766	4,766	5,307
R-squared	0.550	0.548	0.619	0.554	0.597	0.587	0.597	0.591	0.623	0.669	0.706	0.593
No of parameters	6	7	7	7	7	7	7	7	7	7	7	7
Log-likelihood	-7.246e+06	-7.182e+06	-6.726e+06	-7.217e+06	-6.148e+06	-7.073e+06	-6.853e+06	-6.706e+06	-7.007e+06	-3.784e+06	-3.734e+06	-6.040e+06
AIC	1.450e+07	1.440e+07	1.350e+07	1.440e+07	1.230e+07	1.410e+07	1.370e+07	1.340e+07	1.400e+07	7567030	7468658	1.210e+07
BIC	1.440e+07	1.430e+07	1.340e+07	1.430e+07	1.220e+07	1.400e+07	1.360e+07	1.330e+07	1.390e+07	7.492e+06	7.394e+06	1.200e+07

Note: All regressions carried out using semi-mixed effect ppml with the EU28 as a clustering variable. Robust standard errors in parentheses. *significant at 10 percent; **significant at 5 percent; ***significant at 1 percent. Estimated in STATA 14. Dependent variable – bilateral exports in millions USD.

Source: own study.

Table 6. Technological gap in the exports within the EU28 – semi-mixed effects model estimated with the PPML – a north-north (NN) trade

Variables	(NN1)	(NN2)	(NN3)	(NN4)	(NN5)	(NN6)	(NN7)	(NN8)	(NN9)	(NN10)	(NN11)	(NN12)
ln_gdp_par	0.629***	0.627***	0.628***	0.629***	0.634***	0.619***	0.618***	0.653***	0.629***	0.658***	0.641***	0.613***
	(0.0215)	(0.0217)	(0.0217)	(0.0215)	(0.0227)	(0.0235)	(0.0216)	(0.0231)	(0.0215)	(0.0211)	(0.0214)	(0.0242)
ln_gdp_rep	0.643***	0.641***	0.642***	0.643***	0.643***	0.633***	0.632***	0.665***	0.643***	0.678***	0.661***	0.614***
	(0.0215)	(0.0211)	(0.0218)	(0.0215)	(0.0222)	(0.0230)	(0.0212)	(0.0237)	(0.0215)	(0.0208)	(0.0198)	(0.0232)
ln_distance	-0.817***	-0.816***	-0.818***	-0.817***	-0.788***	-0.800***	-0.810***	-0.797***	-0.814***	-0.926***	-0.950***	-0.777***
	(0.0325)	(0.0325)	(0.0326)	(0.0326)	(0.0331)	(0.0330)	(0.0330)	(0.0333)	(0.0330)	(0.0329)	(0.0300)	(0.0370)
rld	-0.0828***	-0.0827***	-0.0817***	-0.0819***	-0.0791***	-0.0892***	-0.0582***	-0.0672***	-0.0827***	-0.0154	-0.00448	-0.0810***
	(0.0166)	(0.0167)	(0.0166)	(0.0165)	(0.0171)	(0.0175)	(0.0160)	(0.0170)	(0.0166)	(0.0130)	(0.0134)	(0.0174)
eu	2.655***	2.667***	2.653***	2.659***	3.484***	2.682***	2.729***	2.632***	2.655***	2.106***	2.072***	3.616***
	(0.284)	(0.284)	(0.284)	(0.284)	(0.274)	(0.285)	(0.285)	(0.283)	(0.285)	(0.280)	(0.282)	(0.278)
diff_hc		0.0158										
		(0.0202)										
diff_ctfp			-0.0115									
			(0.0182)									
diff_k_l				0.00692								
				(0.0215)								
diff_gerd					-0.0653***							
					(0.0212)							
diff_epc						-0.0305*						
						(0.0184)						

diff_techred							-0.122***					
							(0.0228)					
diff_uspto								0.0453**				
								(0.0200)				
diff_uspto_pc									-0.00679			
									(0.0205)			
diff_jrn										0.0402**		
										(0.0187)		
diff_jrn_pc											-0.0794***	
											(0.0199)	
diff_emp_rd												-0.0315
												(0.0236)
Constant	-4.260***	-4.194***	-4.268***	-4.332***	-5.422***	-3.848***	-4.014***	-5.430***	-4.242***	-5.160***	-3.749***	-4.657***
	(0.651)	(0.648)	(0.649)	(0.674)	(0.656)	(0.745)	(0.647)	(0.783)	(0.653)	(0.709)	(0.591)	(0.697)
No of observations	1,873	1,873	1,873	1,873	1,630	1,873	1,871	1,799	1,873	1,424	1,424	1,520
R-squared	0.662	0.662	0.663	0.662	0.667	0.665	0.665	0.657	0.661	0.799	0.797	0.662
No of parameters	6	7	7	7	7	7	7	7	7	7	7	7
Log-likelihood	-7.683e+06	-7.679e+06	-7.680e+06	-7.682e+06	-6.900e+06	-7.668e+06	-7.361e+06	-7.369e+06	-7.682e+06	-2.922e+06	-2.881e+06	-6.633e+06
AIC	1.540e+07	1.540e+07	1.540e+07	1.540e+07	1.380e+07	1.530e+07	1.470e+07	1.470e+07	1.540e+07	5843563	5762638	1.330e+07
BIC	1.530e+07	1.530e+07	1.530e+07	1.530e+07	1.380e+07	1.530e+07	1.470e+07	1.470e+07	1.530e+07	5.820e+06	5.739e+06	1.320e+07

Note: All regressions carried out using semi-mixed effect ppml with the EU28 as a clustering variable. Robust standard errors in parentheses. *significant at 10 percent; **significant at 5 percent; ***significant at 1 percent. Estimated in STATA 14. Dependent variable – bilateral exports in millions USD.

Source: own study.

in the so-called 4th Industrial Revolution (Liu, 2017). However, the nature of its impact could change driving not only the intensity of trade per se but more towards horizontal or vertical differentiation thus driving the various components of intra-industry trade.

Nonetheless, in order to verify the technology gap based trade fully, the analysis should be conducted for larger datasets of countries – OECD or preferably global, in order to fully account for the differentiation in technological sophistication levels as well as for other contributing factors. Secondly, as it has already been stressed, the precise verification of the theory similar to Soete (1981) requires the analysis at a disaggregated sectoral level. The next step envisaged will be an analysis of mutual trade of OECD countries at a disaggregated level (40 + sectors) along with the sectoral dimension. We also envisage further investigation of the impact of technology gap in the short and long run which has not been addressed in the present analysis.

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