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The role of technology gap in the trade of Poland: Panel estimation in the gravity framework

The analysis presented in the following paper has been carried out for 234 trade partners of Poland in the period 1999–2013. We have selected the largest available dataset to obtain the most precise estimates possible. The technology gap has been measured by TFP and relative patenting performance controlling for quality of institutions as well as technology and innovation indices of the Global Competitiveness Report. To obtain unbiased results, we utilize semi-mixed effects model using the Poisson pseudo-maximum likelihood (PPML) estimator. The gravity framework proves to be robust. The coefficients on technology gap indicators differ significantly between different groups of trade partners by the level of income and the level of technological sophistication. The role of the technology gap is evident and supports the principal theoretical postulates.

Keywords: technology gap, trade, gravity, semi-mixed effect panel model

JEL classification: C23, F10, F14, F15

Rola luki technologicznej w wymianie handlowej Polski. Estymacja panelowa modelu grawitacyjnego

Analiza przedstawiona w poniższym artykule przeprowadzona została na próbie 234 partnerów handlowych Polski w okresie 1999–2013. Wybrany został możliwie największy dostępny zbiór danych w celu uzyskania najbardziej precyzyjnych szacunków. Luka technologiczna została oddana poprzez różnicę w poziomie produktywności całkowitej TFP oraz względnej skuteczności patentowania po uwzględnieniu poziomu jakości instytucji oraz wskaźników technologicznych i innowacyjności z Globalnego Raportu Konkurencyjności WEF. W celu uzyskania nieobciążonych wyników wykorzystano nowatorski model panelowy typu *semi-mixed effects* estymowany metodą PPML. Formuła modelu grawitacji zgodnie z oczekiwaniami okazała się dobrze opisywać intensywność polskiej wymiany handlowej. Szacunki parametrów przy miarach luki technologicznej okazały się różnić znacznie pomiędzy podgrupami partnerów w zależności od poziomu ich dochodów oraz zaawansowania technologicznego. Ogólnie rzecz biorąc, zgodnie z postulatami teoretycznymi, luka technologiczna odgrywa dużą rolę w wyjaśnianiu intensywności polskiej wymiany handlowej.

Słowa kluczowe: luka technologiczna, wymiana handlowa, grawitacja, model panelowy typu *semi-mixed effects*

Klasyfikacja JEL: C23, F10, F14, F15

Introduction

The technology gap theory, as advocated by Posner [1961], describes an advantage enjoyed by the country that introduces new goods into a market, thus gaining the initial edge and establishing its exporter status. The nexus between technology, innovation gap and trade is, however, much more complex and has been investigated since the earliest contributions to economics. Technology differentials were the basis of the Ricardian trade model and lay behind his concept of comparative advantage, but they had not been adequately modelled before the seminal contributions of Posner [1961] and Vernon [1966]. The role of technology and innovation gap and its implications in an endogenous setting have been further emphasised in the new trade and growth literature. An excellent and holistic overview of the function of the technology gap in trade and growth is provided by Kubielas [2009]. It can play a role of both a barrier and an incentive to trade to catch up and compete. Surprisingly, relatively little attention was given to the issue of technology or innovation gap in determining the intensity of trade flows with the use of gravity approach.

The gravity equation framework, frequently attributed to Tinbergen [1962], has been widely used to explain the intensity and pattern of international trade flows (e.g.: [Bergstrand, 1985; 1989; Anderson, Wincoop, 2003; Anderson, 2011]). It is one of the most robust empirical models in contemporary economics that, at the same time, for many years lacked proper theoretical foundations.

The framework of the model is based on the analogy with the Newtonian theory of gravity with the intensity of trade between partners proportional to their sizes (reflecting economic potential) and inversely proportional to the distance. This basic framework is commonly extended to incorporate various variables potentially affecting trade intensity. A critical review of numerous studies shows that researchers are rather flexible in the selection of explanatory variables based on the context or aim of their particular analyses. Apart from the standard variables, a set of specific variables is included that reflects various (including cultural) aspects of mutual proximity or barriers to bilateral trade flows.

A very detailed description of possible variables used in gravity equations was presented by Kepaptsoglou, Karlaftis, and Tsamboulas [2010]. Head and Mayer [2014] conducted a thorough examination and evaluation of the gravity theory as well as the empirical tools and methods it utilizes. The progress in this field is evident as more and more robust methods are being implemented, allowing for more precise estimates. To obtain unbiased results, one needs to put emphasis on the proper econometric specification of the gravity equation [Egger, 2000].

We would like to stress here the contribution by Silva and Tenreyro [2006], who in their seminal paper raised a problem of whether the logarithmic transformation of the original model is indeed a relevant approach to estimate elasticities. They argued that multiplicative trade models with multiplicative errors do not satisfy the assumption of the homoscedasticity of the error term since there is a dependency between the error term of the transformed log-linear model and the regressors which lead to the inconsistency of the popular OLS estimator as well as the random and fixed effects estimators. As an alternative, they proposed the estimation of the gravity model in levels using the Poisson pseudo-maximum likelihood estimator (PPML). Moreover, in their very recent contribution, Proença, Sperlich, and Savaşci [2015] suggested the use of a semi-mixed effects method which relaxes the very strict assumptions of RE but is still more restrictive than FE.

The goal of this paper is to investigate the actual role of technology and innovation gap in explaining the intensity of bilateral trade flows of Poland with its business partners at the general (country level) with the use of trade gravity approach. The analysis has been carried out for 234 trade partners of Poland in the period 1999–2013. Poland is an interesting case study of a Central European transition economy's gradual converging in income and technology levels to more advanced trade partners. We expect the technology and innovation gap to play a substantial role in its trade relations. Acknowledging the recommendations of Silva and Tenreyro [2006] as well as Proença, Sperlich, and Savaşci [2015], we select a semi-mixed effects model as the most relevant method of estimation.

The remainder of the article is structured as follows: Section 1 reviews selected empirical studies on the role of technology gap and R&D stock in the gravity setting; Section 2 presents the empirical model and describes the data sources utilized; Section 3 presents and discusses the estimation results. The last section concludes.

1. Review of selected empirical studies

Despite the critical role of the technology gap, surprisingly few empirical studies tested for technology gap or technology distance within gravity approach, both in cross-sectional and panel setting.

Martínez-Zarzoso and Márquez-Ramos [2005] utilized a composite index capturing technology and human knowledge deficiencies in an augmented gravity framework in a cross-sectional study on a large sample of 62 developed and developing countries in 1999. The model was estimated with OLS on the standard double log specification with a log of exports as the dependent variable. The authors utilized a composite Technology Achievement Index (TAI) introduced initially by the UNDP. The idea behind TAI was to capture how well a country as a whole is participating in creating, using and diffusing technology and in building a human skill base to acquire knowledge. TAI is an average of four related dimensions:

- creation of technology (measured by number of patents granted to residents and receipts of royalty and license fees from abroad),
- diffusion of recent as well as of old innovations (measured by internet hosts and exports of high-technology and medium-technology products for new and number of telephones and electricity consumption for early innovations respectively),
- human skills (average years of schooling and gross tertiary science enrolment ratio).

Martínez-Zarzoso and Márquez-Ramos [2005] introduce the TAI indices for exporters and importers separately and test them for two subsamples of wealthy and poor exporters (classified on the basis of exporters' real GDP *per capita*) and a standard set of conditioning variables in addition to infrastructure endowment. The impact of exporters' TAI on the value of exports is statistically significant and positive for both wealthy and developing countries. However, the impact of importers' TAI is statistically significant only for the sample of poor economies; for the sample of rich exporters, it is insignificant. The results are interesting despite the cross-sectional approach utilized. The use of panel data approach could bring obvious advantages, allowing for obtaining more precise and robust results.

Filippini and Molini [2003] include technological distance based on an indicator proposed by Lall [1992] in an extended gravity panel data model to examine the relevance of the technology gap in trade flows between East Asian industrializing countries and selected developed countries over the period of 30 years. They consider developed and developing countries separately, decomposing trade into manufacturing and non-manufacturing trade flows. The authors estimate the gravity equations using a fixed effect model without taking into account the country-pair effects or zero trade flows which, to some extent, biases the obtained results.

Filippini and Molini [2003] wanted to verify the hypothesis according to which countries tend to trade more with each other the more similar they are from a technological point of view. The hypothesis was positively verified – the wider the technological gap was, the more seldom they engaged in trade. Moreover, as for the East Asian industrializing countries, the authors concluded that the technological distance served as an incentive to catch up and compete with more advanced nations.

In a recent study by Wang, Wei and Liu [2010] on the determinants of bilateral trade flows in 19 OECD countries over the period of 1980–1998, the authors established that both levels and similarities in domestic R&D stock, as well as market size and inward FDI stock, play a major role. The Hausman test is applied to decide statistically whether a random or fixed effects model is more appropriate for a model with a log of exports as an explained variable. It is said that domestic R&D stock plays a bigger role in promoting bilateral trade than GDP and FDI. The authors conclude that a 1% increase in total domestic R&D stock increases bilateral trade by up to 1%, and a 1% increase in the R&D similarity between trade partners raises trade by around 0.4%. R&D is found to be the second most important variable in explaining trade flows in the OECD countries, preceded only by the geographical distance which traditionally captures transaction and transportation costs. The results yield support to new growth theories (e.g.: [Aghion, Howitt, 1992; 1998; Grossman, Helpman, 1991; Lucas, 1988; Romer, 1986; 1990]), which endogenize technological progress and put emphasis on R&D potential of countries.

2. The empirical model

In a classic paper, Anderson and Wincoop [2004] used export shares of trade partners to estimate the strength of gravity. The use of country-pair effect allows for eliminating the potential bias of mutual resistance described in the literature of the subject. An alternative approach can be utilized (e.g.: [Helpman, Melitz, Rubinstein, 2008]), in which the values of total trade flows are utilized. In our study, the value of exports from Poland to a given trade partner in EUR million is the explained variable.

The general form of the estimated empirical panel model with country-pair effects for total export takes the following general form:

$$\exp_{PL,i} = \alpha_0 + \beta_1 \ln Y_i + \beta_2 \ln d_{PL,i} + \beta_4 X_{PL,i} + \beta_6 dcp_{PL,i} + \beta_7 dt_t + e_{rct} \qquad [1]$$

where Y_i is the size of the partner, d_{PLi} is the distance to the partner and X_{PLi} is the conditioning set of variables describing bilateral trade relations.

The basic explanatory variables include the size of the partner as measured by the log of real GDP (real GDP) and the log of distance between trade partners (distance). It is proxied by geographical 'as the crow flies' distance from Warsaw to trading partner's capital measured in kilometres.

Two countries at a similar level of development should trade more intensely than countries characterized by a significant gap in the level of development; an increase in the gap should, therefore, coincide with a decreased intensity of Polish exports. Thus, we adopt the following measure of the difference in the standard of development (rlf) and expect the coefficient to be statistically significant and adverse:

$$rlf = \ln\left|ypc_f^c - ypc_h^r\right| \qquad [2]$$

We utilize COMEXT data set as a principal source of trade data. COMEXT is a statistical database on intra- and extra-EU trade of goods managed by Eurostat, the Statistical Office of the European Commission.

For the set of explanatory variables, we utilize a number of data sources, the principal one being the Penn World Tables 8.0 by Feenstra, Inkmaar and Timmer [2013]. The data set provides information on real GDP and population (thus real GDP *per capita*), capital and labour endowments (allowing for calculation of K/L ratios) as well as estimates of TFP. The data for patent applications come from the United States Patent and Trademark Office (USPTO). The data for institutional quality come from Worldwide Governance Indicators dataset (WGI) compiled by Kaufmann, Kraay and Mastruzzi [2010] and provided by the World Bank.

3. Econometric results and discussion

The analysis has been carried out for 234 trade partners of Poland in the period of 1999–2013. The explained variable is the value of Polish exports in EUR million. The estimation of core and extended specifications of the empirical model has been performed using a semi-mixed effects method suggested in a recent paper by Proença, Sperlich and Savaşci [2015] with a dummy variable for EU partner (EU) serving as a clustering variable. The estimation has been carried out in STATA 12 (ppml). The results are provided in Tables 1–5.

Taking into account the method of estimation, the estimated empirical panel model with country-pair effects for total export takes the following general form:

$$\exp ort_{ijt} = \exp\left[\ln \alpha_0 + \beta_1 \ln Y_{jt} + \beta_2 \ln D_{ij} + \gamma \ln X_{ijt} + \rho \ln Z_{ij} + \upsilon_t + \eta_{ij}\right] \varepsilon_{ijt} \quad [3]$$

where Y_j is the size of the partner, D_{ij} is the distance to the partner and X_{ijt} is the conditioning set of variables describing bilateral trade relations.

Table 1 presents the results for the broad sample of countries. Tables 2 to 5 present empirical verification of determinants of export intensity to high-, upper-middle-, lower-middle- as well as low-income countries. We expect the coefficients on the variables of interest to us to differ depending on the prosperity of the trade partner understood as a rough approximation of the level of technological sophistication.

Various specifications of the model have been tested. The results proved insensitive to the inclusion of time effects – as they do not significantly increase the fit of the model, we have decided not to include them in the tables. The general fit of the model is high – explaining from 62 to 95% of the variation in the explained variable depending on the specification. The results are robust against potential modifications.

In nearly all of the analysed specifications (apart from some for low-income countries, Table 5) the coefficients on distance are statistically significant at 1% and negative, as expected. The elasticity amounts to -1.65% on average (Table 1) with the highest value for lower-middle- (Table 4) and the lowest for upper-middle-income countries (Table 3). Poland exports primarily to proximate countries, in particular to other Member States of the EU. Geographical proximity has been shown to be a major determinant of bilateral trade flows as it is associated with lower transportation and information costs.

The size of the trade partner as measured by the log of real GDP has a significant and positive impact on Polish exports, in accordance with our expectations. The elasticity is close to 1% with the highest values for high-income countries (1.1% on average, Table 2) and the lowest for low-income countries (0.48% on average, Table 5).

The impact of membership in the European Union is clearly positive and statistically significant (Table 1). Poland exports more, *ceteris paribus*, to partners within the internal market of the EU. We would like to stress here once again that we treat the EU as the clustering variable. It is not present in the case of lower-middle- and low-income countries, as they are not part of the EU. We would also like to emphasize that old Member States of the EU are in the high-income group, while most of the so-called new Member States are in the upper-middle-income group.

The impact of a gap in development as shown by rfl is, as expected, negative in most of the specifications in the general sample and high-income countries; it is, however, statistically significant only in few specifications. Nevertheless, the coefficient on rlf is positive in some of the specifications of the model for lower-middle-income countries (see Table 4). All in all, Poland tends to export more to countries at a similar level of development.

Furthermore, Poland exports more, *ceteris paribus*, to countries with better quality of institutions as proxied by the rule of law and, in particular, to high-income partners (Table 2). Due to the correlation with GWCI and its sub-indices, the variable had to be excluded from the rest of specifications.

Next, three specifications (M3, M4, M5) analyse the impact of the differences between Poland and its trade partners in factor endowments, productivity, and technological sophistication on the intensity of Polish exports.

First of all, the greater the difference in factor endowments measured by the log of zero adjusted K/L ratio between Poland and its trade partner, the bigger its positive impact on the intensity of Polish exports (Table 1). If Poland, *ceteris paribus,* is relatively better endowed in capital than in labour, it exports more to a given country. We have to note, however, that this holds only for high- and upper-middle-income countries (Table 2 and 3). The coefficients for lower-middle- and low-income countries are statistically insignificant, which could point to the significance of classic factor endowments differences as postulated by Heckscher-Ohlin theory in explaining the trade relations of Poland (a relatively low share of intra-industry trade in differentiated products).

Secondly, the greater the difference in productivity levels – which could be treated as a rough proxy for the difference in levels of technological sophistication

– the lower the export intensity in the general sample (Table 1, M4). The TFP difference is measured by the log of zero adjusted TFP ratio between Poland and its trade partner. The TFP of a given country is first relativized by comparison to the world technology frontier – TFP for the US. The bigger the advantage of a foreign partner over Poland in TFP levels is, *ceteris paribus*, the less Poland exports there. Poland seems to export more to countries at a similar level of total productivity. A more detailed analysis shows that this result is mostly due to the high-income countries group (Table 2). It turns out, however, that the coefficient changes to positive and statistically significant for upper-middle- and lower-middle-income countries, and is insignificant for low-income countries – for these, a relative disadvantage in TFP boosts Polish exports.

Thirdly, as for the impact of the technological gap as measured by the log of absolute difference in cumulated patent applications (per 1 million population) in the USPTO between Poland and a foreign partner (CUMPAT), we chose patent applications in the US Patent and Trademark Office as an assessment of the ability of a given country to produce patents at the world technology frontier. We acknowledge that the distance to the technology frontier matters and could reflect the technology gap resulting from systemic factors. The USPTO provides information on patent applications by country for the period of 1965–2013. To eliminate cyclical factors, we have calculated the cumulated patent requests and compared the results directly between countries of different sizes to relativize them by population (per 1 million population). The US is a clear leader, followed by Switzerland, Japan, and Taiwan. The next group consists of Israel, Finland, and Sweden. The remainder of the elite consists of Canada, Denmark, the Netherlands, the UK, Germany and South Korea. Poland holds only the 47th rank with results similar to Costa Rica and Chile and thus can be considered as a technologically backward but converging country. Out of the Visegrad group countries, it is better only than Slovakia (54th position) and much worse than the Czech Republic and, in particular, Hungary (10 times the higher value of the variable).

The coefficient on CUMPAT is statistically insignificant in the broad sample (Table 1) as well as for high-income- and lower-middle-income countries (Tables 2 and 4, respectively). It is, however, statistically significant and adverse for upper-middle-income trade partners (Table 3) and positive and strong for low-income trade partners (Table 5).

In the last specifications (M6 to M9), we account for the overall level of competitiveness as indicated by the value of Global Competitiveness Index (GWCI) – a weighted index of 12 basic pillars of competitiveness [Schwab, 2014]; three of the pillars are of particular interest to us: technological readiness, business sophistication and innovation potential (9th, 11th and 12th pillar of GWCI, respectively). These are crucial in particular for efficiency-driven and innovation-driven economies.

Table 1. Results of estimation for Polish exports: Global sample of trade partners

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
distance	-1.644*** (0.0683)	-1.634*** (0.0673)	-1.655*** (0.0594)	-1.641*** (0.0659)	-1.642*** (0.0688)	-1.663*** (0.0729)	-1.649*** (0.0707)	-1.667*** (0.0714)	-1.665*** (0.0733)
real GDP	0.997*** (0.0367)	1.001*** (0.0354)	1.009*** (0.0301)	1.016*** (0.0387)	0.992*** (0.0360)	0.991*** (0.0301)	0.985*** (0.0271)	0.994*** (0.0309)	1.003*** (0.0314)
rlf	-0.0277 (0.0295)	-0.0806** (0.0334)	0.0443 (0.0287)	-0.0358 (0.0305)	-0.0651** (0.0318)	-0.0147 (0.0392)	-0.0307 (0.0415)	-0.00532 (0.0404)	-0.0467 (0.0409)
EU	0.697*** (0.0688)	0.547*** (0.0778)	0.543*** (0.0637)	0.756*** (0.0770)	0.658*** (0.0727)	0.604*** (0.0780)	0.613*** (0.0819)	0.596*** (0.0799)	0.521*** (0.0781)
institutional quality	–	0.140*** (0.0467)	–	–	–	–	–	–	–
K/L ratio	–	–	1.682*** (0.147)	–	–	–	–	–	–
TFP ratio	–	–	–	-0.663*** (0.215)	–	–	–	–	–
CUMPAT	–	–	–	–	0.0274 (0.0168)	–	–	–	–
GWCI	–	–	–	–	–	0.120** (0.0554)	–	–	–
innovation potential	–	–	–	–	–	–	0.101*** (0.0376)	–	–
business sophistication	–	–	–	–	–	–	–	0.0643 (0.0532)	–
technological readiness	–	–	–	–	–	–	–	–	0.141*** (0.0411)
constant	5.794*** (0.303)	6.193*** (0.311)	-2.806*** (0.792)	6.006*** (0.298)	6.051*** (0.287)	5.641*** (0.400)	5.920*** (0.345)	5.826*** (0.355)	5.766*** (0.374)
observations	2,125	1,777	2,125	2,125	2,125	736	736	736	736
R-squared	0.831	0.865	0.906	0.845	0.834	0.931	0.935	0.930	0.932

* All regressions carried out using semi-mixed effect ppml with EU as clustering variable; ***, **, and * denote significance at 1%, 5%, and 10%, respectively; dependent variable – total exports in EUR million.

Source: Estimated using STATA 12.

Table 2. Results of estimation for Polish exports to high-income countries

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
distance	-1.849*** (0.116)	-1.759*** (0.107)	-1.792*** (0.0847)	-1.988*** (0.0993)	-1.851*** (0.115)	-1.724*** (0.105)	-1.707*** (0.103)	-1.748*** (0.117)	-1.733*** (0.0984)
real GDP	1.113*** (0.0530)	1.098*** (0.0485)	1.113*** (0.0377)	1.165*** (0.0412)	1.115*** (0.0524)	1.066*** (0.0393)	1.058*** (0.0355)	1.075*** (0.0475)	1.082*** (0.0406)
rlf	-0.234*** (0.0464)	-0.278*** (0.0659)	-0.0443 (0.0493)	-0.156*** (0.0467)	-0.226*** (0.0543)	-0.131** (0.0616)	-0.132** (0.0611)	-0.0942 (0.0736)	-0.158*** (0.0574)
EU	0.143 (0.129)	0.232*	0.197** (0.0961)	0.158 (0.101)	0.137 (0.130)	0.393*** (0.144)	0.431*** (0.155)	0.355*** (0.136)	0.374*** (0.129)
institutional quality	–	0.180** (0.0821)	–	–	–	–	–	–	–
K/L ratio	–	–	1.878*** (0.162)	–	–	–	–	–	–
TFP ratio	–	–	–	-5.699*** (0.500)	–	–	–	–	–
CUMPAT	–	–	–	–	-0.00794 (0.0264)	–	–	–	–
GWCI	–	–	–	–	–	0.126	–	–	–
innovation potential	–	–	–	–	–	–	0.0901* (0.0504)	–	–
business sophistication	–	–	–	–	–	–	–	0.0240 (0.106)	–
technological readiness	–	–	–	–	–	–	–	–	0.160*** (0.0529)
constant	8.153*** (0.602)	7.873*** (0.644)	-3.041*** (1.102)	11.59*** (0.704)	8.122*** (0.605)	6.323*** (0.622)	6.506*** (0.566)	6.564*** (0.541)	6.256*** (0.572)
observations	553	481	553	553	553	257	257	257	257
R-squared	0.847	0.877	0.924	0.919	0.846	0.940	0.943	0.938	0.943

* All regressions carried out using semi-mixed effect ppml with EU as clustering variable; ***, **, and * denote significance at 1%, 5%, and 10%, respectively; dependent variable – total exports in EUR million.
Source: Estimated using STATA 12.

Table 3. Results of estimation for Polish exports to upper-middle-income countries

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
distance	-1.321*** (0.0421)	-1.305*** (0.0445)	-1.319*** (0.0428)	-1.332*** (0.0421)	-1.324*** (0.0415)	-1.292*** (0.0569)	-1.282*** (0.0573)	-1.257*** (0.0578)	-1.271*** (0.0580)
real GDP	0.848*** (0.0323)	0.838*** (0.0304)	0.838*** (0.0320)	0.828*** (0.0329)	0.842*** (0.0308)	0.813*** (0.0329)	0.816*** (0.0365)	0.819*** (0.0306)	0.835*** (0.0361)
rlf	0.0166 (0.0315)	-0.0121 (0.0317	-0.00135 (0.0302)	0.0376 (0.0341)	0.0196 (0.0310)	-0.0498 (0.0311)	-0.0562* (0.0292)	-0.0682** (0.0329)	-0.0720** (0.0344)
EU	0.643***	0.587*** (0.0817)	0.580*** (0.0614)	0.587***	0.645*** (0.0566)	0.500*** (0.105)	0.527*** (0.106)	0.571*** (0.0989)	0.450*** (0.115)
institutional quality	–	0.00702 (0.0581)	–	–	–	–	–	–	–
K/L ratio	–	–	0.504*** (0.169)	–	–	–	–	–	–
TFP ratio	–	–	–	0.380*** (0.131)	–	–	–	–	–
CUMPAT	–	–	–	–	-0.0450** (0.0219)	–	–	–	–
GWCI	–	–	–	–	–	0.155 (0.162)	–	–	–
innovation potential	–	–	–	–	–	–	0.0743 (0.143)	–	–
business sophistication	–	–	–	–	–	–	–	-0.108 (0.109)	–
technological readiness	–	–	–	–	–	–	–	–	0.224*** (0.0859)
constant	5.167*** (0.361)	5.422*** (0.388)	3.054*** (0.759)	5.101***	5.377***	5.445***	5.797*** (0.691)	6.321*** (0.642)	5.049*** (0.718)
observations	442	375	442	442	442	167	167	167	167
R-squared	0.924	0.925	0.927	0.925	0.928	0.947	0.946	0.953	0.952

* All regressions carried out using semi-mixed effect ppml with EU as clustering variable; ***, **, and * denote significance at 1%, 5%, and 10%, respectively; dependent variable – total exports in EUR million.
Source: Estimated using STATA 12.

Table 4. Results of estimation for Polish exports to lower-middle-income countries

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
distance	-2.067*** (0.0749)	-2.080*** (0.0802)	-2.063*** (0.0710)	-2.021***	-2.069***	-2.046*** (0.0582)	-2.005*** (0.0525)	-1.951*** (0.0721)	-1.957***(0. 0479)
real GDP	0.979*** (0.0359)	0.975*** (0.0360)	0.978*** (0.0353)	0.889*** (0.0320)	0.983*** (0.0358)	0.869*** (0.0428)	0.871*** (0.0446)	0.932*** (0.0339)	0.880*** (0.0328)
rlf	0.960*** (0.104)	0.860*** (0.0982)	0.955*** (0.102)	0.866*** (0.0846)	0.896*** (0.112)	-0.568** (0.272)	-0.691*** (0.258)	-0.812*** (0.231)	-1.167*** (0.238)
institutional quality	–	0.0920	–	–	–	–	–	–	–
K/L ratio	–	–	0.0946 (0.283)	–	–	–	–	–	–
TFP ratio	–	–	–	1.055*** (0.167)	–	–	–	–	–
CUMPAT	–	–	–	–	0.122 (0.0951)	–	–	–	–
GWCI	–	–	–	–	–	0.397 (0.283)	–	–	–
innovation potential	–	–	–	–	–	–	0.215 (0.228)	–	–
business sophistication	–	–	–	–	–	–	–	-0.246 (0.205)	–
technological readiness	–	–	–	–	–	–	–	–	0.332*** (0.114)
constant	0.236 (0.996)	1.378 (0.991)	-0.169 (1.628)	1.262 (0.866)	0.326 (0.989)	14.07*** (2.923)	15.78*** (2.539)	17.36*** (2.269)	19.35*** (2.140)
observations	555	468	555	555	555	176	176	176	176
R-squared	0.894	0.905	0.894	0.926	0.895	0.981	0.980	0.976	0.985

* All regressions carried out using semi-mixed effect ppml with EU as clustering variable; ***, **, and * denote significance at 1%, 5%, and 10%, respectively; dependent variable – total exports in EUR million.
Source: Estimated using STATA 12.

Table 5. Results of estimation for Polish exports to low-income countries

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
distance	-1.754*** (0.111)	-1.711*** (0.148)	-1.760*** (0.113)	-1.794*** (0.109)	-1.710*** (0.117)	-0.897 (0.692)	-0.837 (0.789)	-0.823 (0.805)	-0.975 (0.699)
real GDP	0.471*** (0.0652)	0.472*** (0.0797)	0.472*** (0.0655)	0.476*** (0.0661)	0.445*** (0.0734)	0.271*** (0.0654)	0.496*** (0.0698)	0.425*** (0.0652)	0.377*** (0.0554)
rlf	0.500 (0.445)	0.908** (0.460)	0.532 (0.461)	0.519 (0.448)	0.213 (0.445)	-1.053 (0.791)	-1.326 (0.926)	-1.228 (1.036)	-2.740*** (0.956)
institutional quality	–	-0.340* (0.178)	–	–	–	–	–	–	–
K/L ratio	–	–	-0.0577 (0.168)	–	–	–	–	–	–
TFP ratio	–	–	–	-0.253 (0.181)	–	–	–	–	–
CUMPAT	–	–	–	–	0.265*** (0.0808)	–	–	–	–
GWCI	–	–	–	–	–	1.764*** (0.324)	–	–	–
innovation potential	–	–	–	–	–	–	0.362 (0.417)	–	–
business sophistication	–	–	–	–	–	–	–	0.555*** (0.214)	–
technological readiness	–	–	–	–	–	–	–	–	1.715*** (0.305)
constant	7.810** (3.743)	3.352 (3.814)	7.819** (3.767)	7.998** (3.768)	9.446** (3.806)	10.91 (7.876)	15.85 (10.12)	14.64 (9.402)	28.36*** (8.300)
observations	575	453	575	575	575	136	136	136	136
R-squared	0.864	0.790	0.863	0.862	0.859	0.679	0.626	0.625	

* All regressions carried out using semi-mixed effect ppml with EU as clustering variable; ***, **, and * denote significance at 1%, 5%, and 10%, respectively; dependent variable – total exports in EUR million.

Source: Estimated using STATA 12.

According to the methodological report by the WEF, the technological readiness pillar measures the dexterity with which a given economy adopts existing technologies, with specific emphasis on its capacity to fully leverage ICT understood as a key horizontal or general purpose technology. Thus, it is composed of technology adoption (availability of the latest technologies, firm-level technology adoption, FDI, and technology transfer) and ICT uses (internet users, broadband internet subscriptions, internet bandwidth, mobile telephone and broadband subscriptions and fixed telephony lines).

The business sophistication pillar concerns two elements crucial for advanced economies, frequently lacking in basic sources of competitive advantage. First, the quality of overall business networks and supporting industries as measured by the quantity and quality of local suppliers. Secondly, the extent of their interaction and the quality of individual firms' operations and strategies (branding, marketing, distribution, advanced production processes, and the production of unique and sophisticated products) – cultural factors which spill over into the economy and lead to sophisticated and modern business processes across the country's business sectors.

Last but not least, the R&D innovation potential pillar focuses on broadly understood innovations and takes into account both input and output measures of national innovation system such as the capacity for innovation, quality of R&D institutions, BERD, university-industry collaboration in R&D, availability of scientists and engineers, patent applications, and IP protection.

In 2014, Poland with GWCI at 4.5 (1–7) was the 43rd economy out of 144 under consideration. Its position is rather weak in the pillars considered here, with technological readiness at 4.5 (48th position), business sophistication at 4.1 (63rd position) and R&D innovation at 3.3 (72nd position).

For the general sample of countries (Table 1), the impact of GWCI is positive and statistically significant. Poland exports more, *ceteris paribus*, to countries with higher values of the index. Innovation potential, as well as technological readiness have a positive and robust impact on Polish exports, while its partner's business sophistication is statistically insignificant.

The results, as could be expected, differ between the subsamples of countries. For high-, upper-middle- and lower-middle-income countries (please refer to Tables 2, 3 and 4), only technological readiness matters – the impact of GWCI and other pillars is insignificant. For low-income countries, both business sophistication and technical readiness matter and innovation potential have an insignificant impact. For low-income countries Poland exports more to countries with a higher value of GWCI.

Conclusions

The goal of this paper was to investigate the role of technology and innovation gaps in explaining the intensity of bilateral trade flows of Poland with its business partners at the country level. We utilized a popular and robust trade gravity approach. The analysis was carried out for 234 trade partners of Poland over the period 1999–2013. Technology or innovation gap was measured by several variables including TFP and relative patenting performance at the world technology frontier (USPTO). We also utilized the general index of competitiveness provided in the Global Competitiveness Report by the WEF [2014] as well as its three subindices related to technological readiness, business sophistication, and R&D innovation potential. To obtain unbiased results, we utilized semi-mixed effects model using Poisson pseudo-maximum likelihood estimator as suggested by the most recent literature on the subject.

The model fits the data well with a clearly positive impact of the size of a partner and a negative impact of distance. Overall, the obtained results suggest that the technology gap and innovation gap are consequential for Polish trade relations. Poland exports more to countries, *ceteris paribus*, with higher competitiveness, technological readiness and R&D potential – and, at the same time, to countries relatively more abounding in labour (K/L ratio) and at a similar level of total productivity (as measured by TFP ratio).

General conclusions should be treated with caution as the results differ significantly between the four groups of countries by income levels (high-, upper-middle-, lower-middle-, and low-income). It seems that they reflect not only the intensity of exports but also the composition of exports and thus should be interpreted group by group.

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