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

Summary

The objective of this paper is the analysis of the role of technology gap in explaining the aggregate intensity of Polish exports over the period 1999–2011 in a panel of all possible Polish trade partners. We construct a basic export model in a gravity framework and further augmented by incorporating various measures of technological gap. We find it to play a substantial role in determining the intensity of Polish trade relations. In general, Poland exports more to countries at the similar level of technological sophistication. We test the robustness of the results and find that the impact of technology gap varies with respect to different groups of partners depending on their technological level.

Keywords: technology gap, gravity model, panel data, semi-mixed effects, PPML

1. Introduction

Surprisingly relatively little attention was given in the empirical literature to the issue of technology or innovation gap in determining the intensity of trade flows with the use of gravity approach. The objective of this paper is the analysis of the role of technology gap in explaining the aggregate intensity of Polish exports over the period 1999–2011 in a panel data setting. We construct a basic export model in a gravity framework and further augmented by incorporating various measures of the technological gap or technological distance vis-à-vis Poland. We expect the technology gap to play significant role in determining the intensity of our trade relations. The lack of adequate data does not allow us to test it, at least for the time being, on a more disaggregated, sectoral or product level.

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The nexus between technology and trade is multifaceted and has been investigated since the earliest contributions to economics. Technology differentials were the basis of trade model based on an absolute advantage of Smith as well as on comparative advantage of Ricardo. The later technology gap theory developed by Posner[2] or Freeman[3] describes an advantage enjoyed by a country that introduces a new good into a market, gaining a first-mover advantage due to technological lead and establishing initial exporter status. Initial importers can become exporters with a certain lag due to imperfect nature of diffusion of knowledge. Vernon[4] and Hirsch[5] developed, in turn, the theory of product life cycle. The theory was further elaborated by Krugman[6] in his general-equilibrium model of bilateral trade with a product cycle. Innovating North has an initial advantage in the production of innovative goods becoming their exporter. However, the non-innovating South can eliminate the advantage over time due to 'technology borrowing'. The Northern economy is thus forced to innovate continually to maintain its relative leader position.

The empirical support for technology gap based trade is mixed. The initial static cross-sectional verification by Soete[7] was strongly in favor of the concept. The international trade performance of innovative sectors in OECD-countries was found to be a function of their relative technological performance measured by technology-output indicators. The more elaborated analysis by Cotsomitis et al.[8] showed, however, that technology gap theory was unable to predict the direction of high technology trade between OECD economies correctly. The authors attribute it to the inadequate theoretical formulation of the theory. Namely, it is based on overall technology leadership and does not allow for product-level variation[9].

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2 M.V. Posner, *International trade and technical change*, "Oxford Economic Papers" 1961, vol. 13, pp. 323–341.

3 Ch. Freeman, *The Plastics Industry: A Comparative Study of Research and Innovation*, "Economic Review" 1963, vol. 26, pp. 22–62.

4 R. Vernon, *International investment and international trade in the product cycle*, "The Quarterly Journal of Economics" 1966, vol. 80(2), pp. 190–207.

5 S. Hirsch, *Hypotheses Regarding Trade between Developing and Industrial Countries*, in: *The International Division of Labor*, ed. H. Giersch, Mohr, Tubinger 1974.

6 P. Krugman, *A Model of Innovation, Technology Transfer, and the World Distribution of Income*, "Journal of Political Economy" 1979, vol. 87, pp. 253–266.

7 L.G. Soete, *A General Test of Technological Gap Trade Theory*, "Weltwirtschaftliches Archiv" 1981, vol. 117, pp. 638–660.

8 J. Cotsomitis et al., *A re-examination of the technology gap theory of trade: some evidence from time series data for OECD countries*, "Review of World Economics" 1991, vol. 127(4), pp. 792–799.

9 An excellent and holistic overview of the role of technological gap in trade and growth is given by Kubielas (S. Kubielas, *Innowacje i luka technologiczna w gospodarce globalnej opartej*

The remainder of the paper is the following. Section 2 reviews the concept of gravity and presents selected empirical studies on the role of technology gap and R&D stock in the gravity setting. Section 3 presents the empirical model and data sources. Section 4 considers the measurement of the technology gap while Section 5 presents results of estimation. Section 6 concludes.

2. The concept of gravity in empirical analysis of trade intensity

The gravity equation framework frequently attributed to Tinbergen[10], has been widely used to explain the intensity and pattern of international trade flows[11]. It is one of the most successful empirical models in which bilateral trade is proportional to the size of partners and inversely proportional to the distance between them. This basic framework is commonly extended to incorporate diverse variables of proximity or distance that could potentially affect mutual trade intensity.

The critical review of contemporary studies shows that researchers are rather flexible in selection of explanatory variables based on the context or aim of their particular analyses. A very detailed description of possible variables used in gravity equations is given in Kepaptsoglou et al.[12] Head and Mayer[13] give a detailed examination and evaluation of gravity theory as well as empirical tools and methods utilized. Advancement in the field is evident with more robust methods being constantly developed and applied. The literature clearly

na wiedzy. Strukturalne i makroekonomiczne uwarunkowania, Wydawnictwa UW, Warszawa 2009). According to him technology gap can play a role of both a barrier or an incentive to trade and to effective catching-up (structural convergence).

10 J. Tinbergen, *The World Economy. Suggestions for an International Economic Policy*, Twentieth Century Fund, New York 1962.

11 E.g. J.H. Bergstrand., *The gravity equation in international trade: Some microeconomic foundations and empirical evidence*, "Review of Economics and Statistics" 1985, vol. 67(3), pp. 474–481; J.E. Anderson, E. van Wincoop, *Gravity with Gravitas: A Solution to the Border Puzzle*, "American Economic Review" 2003, vol. 93(1), pp. 170–192; J.E. Anderson, *The Gravity Model*, „Annual Review of Economics" 2011, vol. 3(1), pp. 133–160.

12 K. Kepaptsoglou et al., *The Gravity Model Specification for Modelling International Trade Flows and Free Trade Agreement Effects: A 10-Year Review of Empirical Studies*, "The Open Economics Journal" 2010, vol. 3, pp. 1–13.

13 K. Head, T. Mayer, *Gravity Equations: Workhorse, Toolkit, and Cookbook*, in: *The Handbook of International Economics*, ed. G. Gopinath, vol. 4, Elsevier, North-Holland 2014.

states that to obtain unbiased estimates one needs to put particular emphasis to the proper econometric specification of the gravity equation[14].

In their influential paper, Santos Silva and Tenreyro[15] indicated that the logarithmic transformation of the original gravity model was an inappropriate approach to estimate elasticities. As an alternative, they proposed the use of the Poisson pseudo-maximum likelihood estimator (PPML). Proenca et al.[16] have recently recommended the application of semi-mixed effects method which relaxes the very strict assumptions of RE but keeps more restrictions than FE. This particular setting (semi-mixed model estimated with PPML) is going to be applied in the present article.

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 the technology gap or technological distance in explaining bilateral trade flows within the gravity framework.

Martinez-Zarzoso and Ramos[17] utilize a composite index capturing technology and human knowledge gaps in an augmented gravity framework in a cross-sectional study on a large sample of 62 developed and developing countries in 1999. The model for exports is estimated with standard OLS on a standard double log specification. The authors utilize a composite Technology Achievement Index (TAI) developed by the UN for the purpose of Human Development Reports. The index, depicted by eight distinct achievement indicators[18], is supposed to capture how efficient is a country in creation and diffusion of new as well as existent technologies and in building of a human skill base for technology creation. TAI indices for exporters and importers are introduced separately to test their significance in subsamples of weakthy and poor exporters. They include a standard set of conditioning variables controlling in addition for infrastructure endowment. The impact of exporters' TAI on the value of exports is statistically significant

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14 P. Egger, *A note on the proper econometric specification of the gravity equation*, "Economic Letters" 2000, vol. 66, (1), pp. 25–31.

15 J. Santos Silva, S. Tenreyro, *The log of gravity*, "The Review of Economics and Statistics" 2006, vol. 88(4), pp. 641–658.

16 I. Proenca et al., *Semi-mixed effects gravity models for bilateral trade*, "Empirical Economics" 2015, vol. 48(1), pp. 361–387.

17 I. Martinez-Zarzoso, L. Marquez-Ramos, *Does technology foster trade? Empirical evidence for developed and developing countries*, "Atlantic Economic Journal" 2005, vol. 33(1), pp. 55–69.

18 M. Desai et al., *Measuring the Technology Achievement of Nations and the Capacity to Participate in the Networking Age*, "Journal of Human Development" 2002, vol. 3(1), pp. 301–311.

and positive for both rich and developing countries. It is, however, statistically significant for importers' TAI only for the sample of poor economies.

Filippini and Molini[19] include technological distance based on an indicator proposed by Lall[20] in an extended gravity panel model to examine the relevance of the technology gap in trade flows between East Asian industrializing countries and selected developed countries over a period of 30 years. They consider developed and developing countries separately further decomposing it into manufacturing and non-manufacturing trade flows. The authors applying FE estimator positively verify the hypothesis that bilateral trade tends to increase in technological similarity between countries. For East Asian economies technological distance serves as an incentive to catch up and compete with advanced countries.

In a recent study by Wang et al.[21] for 19 OECD countries over the period of 1980–1998 the authors show that levels of R&D stock, similarities in domestic R&D stock, market size as well as inward FDI stock play a major role in determining the value of exports. Domestic R&D stock plays a bigger role than GDP and FDI in promoting bilateral trade. 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 furthermore found to be the second most important variable in explaining trade flows in the OECD countries just after the geographical distance. The results yield support to new growth theories[22].

3. The empirical model and the data

Taking into account the method of estimation (PPML) and the use of the semi-mixed effect model, the estimated model takes the following form:

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19 C. Filippini, V. Molini, *The determinants of East Asian trade flows: a gravity equation approach*, "Journal of Asian Economics" 2003, vol. 14(5), pp. 695–711.

20 S. Lall, *Technological capabilities and industrialization*, "World Development" 1992, vol. 20(2), pp. 165–186.

21 C. Wang C. et al., *Determinants of bilateral trade flows in OECD countries: evidence from gravity panel data models*, "World Economy" 2010, vol. 33(7), pp. 894–915.

22 E.g. P. Aghion, P. Howitt, *Endogenous Growth Theory*, MIT Press, Cambridge 1998; G. Grossman, E.M. Helpman, *Trade, Knowledge Spillovers, and Growth*, "European Economic Review" 1991, vol. 35 (2–3), pp. 517–526; P.M. Romer, *Endogenous technological change*, "Journal of Political Economy" 1990, vol. 98, Part 2, pp. S71–S102.

$$\text{export}_{it} = \exp\left[\ln\alpha_0 + \beta_1 \ln Y_{it} + \beta_2 \ln d_i + \gamma \ln X_{it} + \rho \ln Tech.Gap_{it} + \nu_t + \eta_i\right]\varepsilon_{it} \quad (1)$$

where $Y_{i,t}$ is the size of the partner, d_i is the distance to partner's capital from Warsaw measured in kilometers, $X_{i,t}$ is the conditioning set of standard gravity variables describing bilateral trade relations and $Tech.Gap_{i,t}$ is the measure of the technological gap in interest to us. We expect the coefficient on it to be statistically significant.

The explained variable (export) is the value of exports from Poland to a given trade partner in million EUR in a given year. Membership in the EU28 is utilized as the clustering variable (EU). The basic explanatory variables include the size of partner as measured by the log of its real GDP (real GDP) and the log of distance between trade partners (distance). In accordance with the gravity, a theory the coefficient on real GDP of partner should be positive and negative on distance.

Economic theory postulates that trade between two countries at the similar level of development is more intense. We adopt natural log of absolute difference in real income per capita as a measure of the gap in the level of development (dev. similarity) and expect the coefficient on it to be statistically significant and negative. We will apply the above mathematical formula (natural log of absolute difference) to all variables depicting the gap/similarity between the trade partner and Poland and in particular to the technological gap. The basic specification of our model furthermore incorporates the control for the level of institutional quality of a given trade partner (inst. quality) as well as a set of dummy variables, in line with literature of the subject, for common border (border) and basic forms of trade agreements – free trade areas (FTA) and custom unions (CU). We expect both the border effect and the positive impact of trade agreements to hold. We apply the standard measure of the rule of law as a measure of institutional quality.

We utilize COMEXT data set as a principal source of trade data. For the set of explanatory variables, we utilize first of all the Penn World Tables 8.0. The data set provides information on real GDP, capital, labor and human capital endowments, import and export shares as well as TFP of all countries considered. The data for institutional quality come from Worldwide Governance Indicators dataset (WGI) compiled by Kaufmann et al.[23] We also utilize the World Development Indicators (WDI).

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[23] D. Kaufmann et al., *The Worldwide Governance Indicators: Methodology and Analytical Issues*, World Bank Policy Research Working Paper no. 5430, 2010.

4. Approximating technological gap

In a classic paper, Dosi and Soete[24] postulated that technological gap should be preferably be measured by the difference in patenting performance vis-à-vis the US – the country at the world technology frontier. They thus apply technology-output or R&D efficiency indicator. Other authors utilize for instance the share of high or medium-high technology goods or sectors in exports or in 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 significance of both technology-inputs and technology-outputs many researchers try to build composite technology or innovation level indicators as has been the case with TAI described above or as is the case with the Summary Innovation Index (SII) utilized in European Innovation Scoreboards[25]. The use of composite measures has clear advantages and disadvantages. Grupp and Mogee[26] show that their use has already led to purposeful manipulation which obviously should be prevented as it could result in false policy recommendations or policy decisions.

In the present paper, we will introduce several measures of a technological gap not favoring any of the utilized approaches thus including both technology-input and technology-output proxies. We furthermore refrain from construction of a composite measure of technological sophistication.

Economic growth theory postulates that technological sophistication can be proxied by TFP. Our preferred measure of the technological gap will thus be the difference in TFP levels as measured by the natural log of absolute difference in TFP levels between a given partner and Poland in a given year (dif.tfp). As technology could be skilled-biased we have to take into account the of the gap in human capital endowment (dif.hc). For human capital we utilize PWT 8.0 measure (hc) – an index of human capital per person based on average years of schooling and returns to education.

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24 G. Dosi, L.G. Soete, *Technology Gap and Cost Based Adjustment: Some Explorations on the Determinants of International Competitiveness*, "Metroeconomica" 1983, vol. 35, pp. 197–222.

25 *Innovation Union Scoreboard*, European Commission, Brussels 2015.

26 H. Grupp, M.E. Mogee, *Indicators for national science and technology policy: how robust are composite indicators?*, "Research Policy" 2004, vol. 33(9), pp. 1373–1384.

As a proxy for technology gap from a technology-input perspective, we utilize the difference in R&D intensity – GERD given by a ratio to GDP (dif.gerd). Furthermore, we will divide the countries according to GERD intensity into four groups of low, lower middle, upper middle and high R&D intensity for our robustness checks. Having analyzed the distribution of GERD, we chose the following threshold levels: 10^{th}, 50^{th} and 90^{th} centile of distribution. In turn as a proxy for technology gap from a technology-output perspective, we utilize the difference in total patenting activity per 1 million inhabitants (dif.patentspc) or the difference in scientific journals citations per 1 million inhabitants (dif. scjournals_pc). Moreover, similarly to GERD, we divide the countries according to patenting intensity into four groups of low, lower middle, upper middle and high patenting intensity for the purpose of our robustness checks applying identical threshold-levels: 10^{th}, 50^{th} and 90^{th} centile of distribution[27].

Applying the above set thresholds to Poland we note that its performance relative to a global sample of countries is rather mediocre. In GERD Poland is close to the mean jumping from lower middle to upper middle GERD intensity group. In the patenting activity, its position is weaker and within the analyzed period Poland falls from upper middle to lower middle group of countries.

The various measures of technology gap will enter the regression separately or simultaneously if possible. In order to eliminate a potential bias we calculate the correlation measures and construct correlation matrix. The analysis shows that dif.patentspc and dif.scjournals_pc should not be included in the same regression.

5. Econometric results and discussion

The analysis is carried out for all possible trade partners of Poland present in the COMEXT dataset over the period 1999–2011. The number of countries in particular models is limited due to data restrictions in particular in PWT 8.0. The explained variable is the value of Polish exports in million EUR. As has already been said we utilize a semi-mixed effects panel estimated with the use of PPML. A dummy for EU membership (EU) plays the role of a clustering variable.

[27] The estimates for that subsamples will not be shown in the present article due to article size limitations. Nonetheless, they are available upon request.

The results for the broad sample of trade partners is provided in Table 1. The following tables present our robustness checks. Tables 2 to 5 present results for subsamples of countries grouped by GERD into high, upper middle, lower middle as well as low R&D intensity trade partners. The obtained results are not sensitive to the inclusion of time fixed-effects. We have decided therefore to exclude them from the analysis. We have to note first of all that the basic, as well as extended specification of the gravity model, fit the data – the overall fit of the model is high – explaining from 90.5 to 98.7 percent of the variation in the explained variable depending on the specification in the broad sample of countries.

In interpreting the results we will focus obviously on the variables of interest in the present paper – related to the impact of technology gap on the intensity of Polish exports to a given group of countries. Nonetheless, we will comment shortly on the standard gravity variables. In nearly all analyzed specifications (apart from some for low GERD/patenting subsamples) the coefficients on distance are statistically significant at 1 per cent and negative as expected. Poland exports primarily to nearby countries which can be associated with lower transportation and information costs. The impact of immediacy is further strengthened by sharing of the common border. It is indicative of the existence of the positive border effect as postulated by theoretical literature.

The size of trade partner as measured by the log of real GDP has a significant and positive impact on Polish exports. The elasticity is close to 1 in most cases. The impact of membership in the EU (EU) is positive and statistically significant in most of the specifications. Poland exports more, ceteris paribus, to partners within the internal market of the EU. The impact of a gap in development as shown by dev.similarity is negative as expected in most of the specifications. However, it is statistically significant only in a few of specifications. Its impact and significance vary in subsamples as expected. All in all, Poland tends to export more to countries at the similar level of development. Poland at the same time exports more, ceteris paribus, to countries with better quality of institutions as proxied by the rule of law (inst. quality). The impact of it on the explained variable is sometimes insignificant, however. Finally, the impact of both standard forms of trade agreements – free trade areas (FTA) and customs unions (CU) is positive and significant in most of the samples analyzed.

It is quite clear from the analysis of Table 1 that technology gap matters for Polish exports to a broad sample of countries. Generally speaking, the smaller the gap, the larger are Polish exports to a given partner. It is evident for the difference in TFP (dif.tfp) in model G2 and holds in G4 even if we control for difference in skills (dif.hc). It is worth to note that as a rule, an increase in the gap in human capital or skills endowment boosts Polish exports (G3 and further). The gap measured by technology-input proxy (GERD) has a negative impact on exports even if we simultaneously account for the difference in TFP and human capital (G4) and technology-output gap as measured by citation of scientific journals (G10). It is insignificant only if we include the gap in patenting intensity – similarly to dif.gerd (G9). The gap as measured by patenting intensity is negative only in G8 and disappears if we include dif.gerd (G9). Last but no least the impact of the gap measured by citations in scientific journals is always insignificant (G7 and G10).

We expect the above results, however, to vary significantly for smaller subsamples of countries depending on relative position of Poland to a given group regarding technological sophistication. Thus Tables 2–5 present results for subsamples of trade partners grouped by GERD from low to high intensity. For low GERD intensity partners (Table 2) the technology gap, if statistically significant, has a positive impact on Polish exports. Poland seems to enjoy the technological leadership bonus. We have to note a low number of observations for that group, however. For lower middle GERD intensity partners (Table 3) technology gap measures, apart from citations in scientific journals, have an adverse impact on Polish exports. For upper middle GERD intensity partners (Table 4) none of the gaps matter for Polish exports. And finally for the last group of high GERD intensity partners (Table 5) the impact of gap as measured by TFP is negative, gap in human capital has once again positive impact, difference in GERD is insignificant however the no of observations is clearly very low and we refrain from the interpretation (H5, it applies to H8–10 as well). The gap measured by patenting intensity has negative (H6) while measured by citation in scientific journals positive impact on Polish exports (H7).

6. Summary and directions for further research

The objective of this paper has been to investigate the role of technology gap in explaining the intensity of Polish exports at the general (country level). We have utilized a popular and robust trade gravity approach further augmenting it with technology gap measures. The analysis has been carried out for all possible trade partners of Poland over the period 1999–2011 in a panel data framework. To obtain unbiased results, we have utilized semi-mixed effects model using PPML estimator as suggested by the most recent literature of the subject.

In measuring the technology gap we have utilized several approaches taking into account differences in TFP, GERD (technology-input), patenting & citation in scientific journals (technology-outputs) while controlling for differences in human capital. All in all, Poland exports more to countries at the similar level of technological sophistication. We have however proven that this general conclusion has to be treated with caution as the results for subsamples of countries by GERD intensity levels. It is clear that the results vary mostly depending on whether Poland enjoys leadership, followership or is a peer vis-à-vis a given group. The result supports the general hypothesis of technology gap theory.

The analysis, data allowing, should be applied to other emerging economies and at the global level including all possible trade flows. Secondly, as has been stressed in the introduction, the precise verification of the theory requires the analysis at a disaggregated sectoral level.

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Rola luki technologicznej w handlu Polski. Estymacja panelowa modelu grawitacji

Streszczenie

W niniejszej pracy przeanalizowano rolę luki technologicznej w wyjaśnianiu intensywności polskiego eksportu w latach 1999–2011 w panelu obejmującym wszystkich partnerów handlowych Polski. W tym celu zbudowano podstawowy model empiryczny eksportu na podstawie podejścia grawitacyjnego, który w kolejnym kroku został poszerzony o różne miary luki technologicznej. Okazało się, że odgrywa ona znaczną rolę w determinowaniu intensywności polskich stosunków handlowych. Polska eksportuje przede wszystkim do krajów będących na podobnym poziomie zaawansowania technologicznego. Przetestowano wiarygodność wyników i stwierdzono, że wpływ luki technologicznej różni się w zależności od poziomu technologicznego grup partnerów handlowych.

Słowa kluczowe: luka technologiczna, model grawitacji, dane panelowe, efekty semi-mixed, PPML

Table 1. Gravity model of Polish exports – general sample

	(G1)	(G2)	(G3)	(G4)	(G5)	(G6)	(G7)	(G8)	(G9)	(G10)
VARIABLES	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2
distance	–1.176***	–1.295***	–1.279***	–1.344***	–1.416***	–1.170***	–1.367***	–1.442***	–1.344***	–1.474***
	(0.0548)	(0.0565)	(0.0625)	(0.0597)	(0.104)	(0.0940)	(0.0720)	(0.0926)	(0.0900)	(0.110)
real GDP	0.852***	0.871***	0.867***	0.866***	0.933***	0.843***	0.877***	0.857***	0.837***	0.880***
	(0.0208)	(0.0203)	(0.0209)	(0.0196)	(0.0422)	(0.0351)	(0.0231)	(0.0366)	(0.0427)	(0.0400)
dev. similarity	–0.0218	0.0533	–0.00500	0.0615	0.0269	0.137**	0.00729	0.0811	0.0713	0.0268
	(0.0362)	(0.0458)	(0.0377)	(0.0438)	(0.0489)	(0.0591)	(0.0470)	(0.0599)	(0.0698)	(0.0590)
inst. quality	0.172***	0.0976**	0.136**	0.0850*	–0.119	0.00411	0.0749	–0.0459	0.118	0.0202
	(0.0519)	(0.0486)	(0.0553)	(0.0484)	(0.0869)	(0.0754)	(0.0605)	(0.0935)	(0.109)	(0.109)
border	0.688***	0.573***	0.540***	0.451***	0.521***	0.851***	0.473***	0.459***	0.548***	0.398***
	(0.0855)	(0.0651)	(0.0877)	(0.0691)	(0.120)	(0.103)	(0.0975)	(0.0880)	(0.0992)	(0.0948)
FTA	0.210***	0.209***	0.140*	0.146*	0.312**	0.612***	0.0960	0.253*	0.326**	0.171
	(0.0697)	(0.0801)	(0.0739)	(0.0785)	(0.122)	(0.129)	(0.0941)	(0.138)	(0.162)	(0.144)
CU	0.345***	0.341***	0.181	0.199	0.408**	0.838***	0.106	0.472**	0.726***	0.408**
	(0.131)	(0.120)	(0.139)	(0.126)	(0.187)	(0.172)	(0.155)	(0.185)	(0.202)	(0.204)
EU	0.816***	0.686***	0.824***	0.708***	1.178***	1.293***	0.903***	1.029***	1.082***	0.991***
	(0.0899)	(0.0861)	(0.0942)	(0.0865)	(0.140)	(0.133)	(0.112)	(0.137)	(0.146)	(0.137)
dif.tfp		**–0.152*****		**–0.152*****				**–0.154*****	**–0.170*****	**–0.146*****
		(0.0227)		**(0.0222)**				**(0.0315)**	**(0.0271)**	**(0.0305)**
dif.hc			**0.0937*****	**0.0962*****	**–0.0349**	**0.00151**	**0.0893*****	**0.0126**	**0.0344**	**–0.00194**
			(0.0256)	**(0.0208)**	**(0.0316)**	**(0.0317)**	**(0.0237)**	**(0.0256)**	**(0.0348)**	**(0.0247)**
dif.gerd					**–0.143*****			**–0.0862****	**–0.0170**	**–0.0781***
					(0.0468)			**(0.0357)**	**(0.0429)**	**(0.0443)**
dif.patentspc						**–0.133*****			**–0.0492**	
						(0.0303)			**(0.0359)**	
dif.scjournals_pc							**0.0563**			**0.0329**
							(0.0402)			**(0.0430)**
constant	3.903***	3.699***	4.541***	4.252***	3.979***	2.010***	5.099***	4.549***	3.929***	5.020***
	(0.419)	(0.408)	(0.471)	(0.426)	(0.682)	(0.686)	(0.610)	(0.659)	(0.739)	(0.799)
Observations	1,777	1,187	1,429	1,187	466	544	951	415	339	372
R-squared	0.905	0.943	0.915	0.948	0.954	0.977	0.934	0.970	0.987	0.971

Note: All regressions carried out using semi-mixed effect ppml with EU as clustering variable. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimated using STATA 12. Dependent variable – total exports in million EUR. Total number of observations (Observations).

Source: own calculations.

Table 2. Gravity model of Polish exports – low GERD intensity partners

	(L1)	(L2)	(L3)	(L4)	(L5)	(L6)	(L7)	(L8)	(L9)	(L10)
VARIABLES	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2
distance	–2.078***	–2.349***	–2.240***	–2.460***	–2.263***	0.927***	–1.753*	–2.584***	–5.186***	–2.194***
	(0.304)	(0.277)	(0.245)	(0.215)	(0.243)	(0.352)	(1.013)	(0.210)	(1.904)	(0.841)
Real GDP	0.834***	0.940***	0.549***	0.700***	0.519***	1.863***	0.482***	0.613***	0.570*	0.506***
	(0.120)	(0.124)	(0.119)	(0.177)	(0.101)	(0.268)	(0.0811)	(0.122)	(0.328)	(0.0317)
Dev. similarity	–0.403**	–0.310	–0.388**	–0.294	–0.291**	2.359***	–0.491**	–0.440*	–0.592	–0.623***
	(0.185)	(0.440)	(0.174)	(0.393)	(0.140)	(0.502)	(0.200)	(0.240)	(0.492)	(0.240)
Inst. quality	0.509**	0.146	0.686*	0.399	0.594*	–6.022***	0.539	1.012	0.404	1.468***
	(0.231)	(1.068)	(0.356)	(1.013)	(0.312)	(1.298)	(0.342)	(0.671)	(0.728)	(0.283)
FTA	–0.0261	–0.495	–0.737**	–1.170***	–0.744**	–0.607	–1.169	–0.699**	–4.933***	–0.343
	(0.164)	(0.562)	(0.346)	(0.433)	(0.317)	(0.376)	(1.656)	(0.276)	(1.537)	(1.247)
CU	–0.357	–0.599*	–1.014***	–1.084**	–0.896**	4.020***	–1.508	–1.175***	–5.268	–0.996
	(0.406)	(0.353)	(0.367)	(0.439)	(0.349)	(0.393)	(2.378)	(0.380)	(3.749)	(2.269)
EU	–0.214	0.0862	–0.717	–0.504	–0.628		0.399	–1.479		–1.165
	(0.419)	(1.492)	(0.620)	(1.468)	(0.611)		(2.166)	(1.062)		(2.061)
dif.tfp		**–0.243**		**–0.234**				**0.0640**	**–1.830*** **	**0.228***
		(0.339)		**(0.307)**				**(0.198)**	**(0.191)**	**(0.131)**
dif.hc			**0.632*** **	**0.487*** *	**0.650*** **	**–1.221*** **	**0.888*** **	**0.557*** **	**1.733*** *	**0.813*** **
			(0.172)	**(0.203)**	**(0.149)**	**(0.196)**	**(0.138)**	**(0.150)**	**(0.862)**	**(0.0685)**
dif.gerd					**3.239*** **			**3.104*** **	**2.731*** **	**3.033*** **
					(0.425)			**(0.524)**	**(0.296)**	**(0.918)**
dif.patentspc						**0.0612**			**–0.278**	
						(0.123)			**(0.180)**	
dif.scjournals_pc							**4.911***			**1.902**
							(2.520)			**(2.351)**
constant	14.74***	14.37**	20.69***	19.08**	22.48***	–48.56***	27.83*	24.95***	46.63***	28.44**
	(2.697)	(6.675)	(3.610)	(7.500)	(3.175)	(10.50)	(14.49)	(5.354)	(17.63)	(13.57)
Observations	50	30	37	30	37	19	30	30	14	23
R-squared	0.959	0.962	0.946	0.952	0.993	0.997	0.977	0.994	0.999	0.993

Note: All regressions carried out using semi-mixed effect ppml with EU as clustering variable. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimated using STATA 12. Dependent variable – total exports in million EUR. Total number of observations (Observations).

Source: own calculations.

Table 3. Gravity model of Polish exports – lower middle GERD intensity partners

	(LM1)	(LM2)	(LM3)	(LM4)	(LM5)	(LM6)	(LM7)	(LM8)	(LM9)	(LM10)
VARIABLES	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2
distance	–1.083***	–1.407***	–1.282***	–1.339***	–1.201***	–1.639***	–1.466***	–1.286***	–1.594***	–1.403***
	(0.158)	(0.102)	(0.154)	(0.110)	(0.127)	(0.265)	(0.179)	(0.109)	(0.234)	(0.136)
real GDP	0.766***	0.796***	0.887***	0.778***	0.902***	1.040***	0.893***	0.797***	0.948***	0.855***
	(0.0729)	(0.0661)	(0.0778)	(0.0618)	(0.0650)	(0.113)	(0.0817)	(0.0579)	(0.106)	(0.0694)
dev. similarity	0.104	0.293***	0.0617	0.270**	0.0320	0.141	0.0220	0.228**	0.171	0.0966
	(0.104)	(0.102)	(0.122)	(0.107)	(0.105)	(0.108)	(0.130)	(0.106)	(0.106)	(0.116)
inst. quality	0.219	0.00645	–0.146	–0.118	–0.269*	–0.374**	0.0597	–0.177	–0.173	–0.0670
	(0.139)	(0.102)	(0.165)	(0.132)	(0.156)	(0.179)	(0.148)	(0.131)	(0.181)	(0.123)
border	0.604***	0.413***	0.229	0.354**	0.388**	0.130	–0.0882	0.413***	0.0955	0.123
	(0.166)	(0.134)	(0.182)	(0.141)	(0.152)	(0.237)	(0.220)	(0.137)	(0.210)	(0.177)
FTA	0.158	–0.0335	0.213	0.0283	0.210	–0.00992	0.147	0.0707	–0.128	0.0789
	(0.240)	(0.231)	(0.294)	(0.258)	(0.242)	(0.372)	(0.344)	(0.234)	(0.381)	(0.262)
CU	0.00823	0.0194	–0.320	–0.0310	–0.0189	–0.715	–0.624	0.0861	–0.667	–0.225
	(0.338)	(0.297)	(0.402)	(0.320)	(0.329)	(0.663)	(0.464)	(0.303)	(0.641)	(0.380)
EU	0.731***	0.493**	1.275***	0.853***	1.474***	0.898*	0.956**	1.019***	0.651	0.992***
	(0.265)	(0.240)	(0.354)	(0.296)	(0.331)	(0.500)	(0.378)	(0.305)	(0.493)	(0.323)
dif.tfp		**–0.162*****		**–0.156*****				**–0.132*****	**–0.123*****	**–0.0670**
		(0.0449)		**(0.0431)**				**(0.0440)**	**(0.0268)**	**(0.0421)**
dif.hc			**0.156****	**0.120*****	**0.0824***	**0.0886**	**0.155*****	**0.0887****	**0.148*****	**0.0848****
			(0.0618)	**(0.0446)**	**(0.0495)**	**(0.0655)**	**(0.0491)**	**(0.0389)**	**(0.0535)**	**(0.0364)**
dif.gerd					**–0.227*****			**–0.109**	**0.0740**	**–0.180*****
					(0.0866)			**(0.0668)**	**(0.0469)**	**(0.0498)**
dif.patentspc						**–0.0947****			**–0.0184**	
						(0.0445)			**(0.0360)**	
dif.scjournals_pc							**0.694*****			**0.546*****
							(0.145)			**(0.109)**
constant	3.462***	3.737***	4.038***	3.794***	2.973**	4.194**	7.143***	3.306***	4.884***	5.711***
	(0.964)	(0.878)	(1.184)	(0.990)	(1.174)	(1.666)	(1.505)	(1.037)	(1.525)	(1.280)
Observations	229	171	178	171	178	125	168	171	118	161
R-squared	0.937	0.970	0.948	0.973	0.972	0.993	0.976	0.976	0.997	0.986

Note: All regressions carried out using semi-mixed effect ppml with EU as clustering variable. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimated using STATA 12. Dependent variable – total exports in million EUR. Total number of observations (Observations).

Source: own calculations.

Table 4. Gravity model of Polish exports – upper middle GERD intensity partners

	(UM1)	(UM2)	(UM3)	(UM4)	(UM5)	(UM6)	(UM7)	(UM8)	(UM9)	(UM10)
VARIABLES	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2
distance	–1.411***	–1.523***	–1.515***	–1.557***	–1.518***	–1.479***	–1.398***	–1.564***	–1.510***	–1.390***
	(0.0976)	(0.123)	(0.101)	(0.132)	(0.110)	(0.151)	(0.140)	(0.142)	(0.191)	(0.182)
real GDP	0.662***	0.699***	0.697***	0.689***	0.696***	0.685***	0.690***	0.688***	0.666***	0.674***
	(0.0372)	(0.0327)	(0.0347)	(0.0365)	(0.0346)	(0.0461)	(0.0337)	(0.0360)	(0.0548)	(0.0340)
dev. similarity	–0.0765**	–0.0661**	–0.0700**	–0.0629**	–0.0703**	–0.0688**	–0.0682*	–0.0633**	–0.0617**	–0.0604*
	(0.0302)	(0.0268)	(0.0285)	(0.0262)	(0.0282)	(0.0278)	(0.0349)	(0.0259)	(0.0250)	(0.0326)
inst. quality	0.189***	0.135*	0.210***	0.177**	0.216**	0.222**	0.225***	0.187**	0.225*	0.251**
	(0.0719)	(0.0766)	(0.0768)	(0.0777)	(0.0850)	(0.0865)	(0.0785)	(0.0852)	(0.128)	(0.105)
border	–0.420***	–0.439***	–0.469***	–0.494***	–0.464***	–0.469***		–0.485***	–0.470***	
	(0.0908)	(0.0929)	(0.122)	(0.120)	(0.129)	(0.125)		(0.125)	(0.152)	
FTA	0.354***	0.315***	0.309***	0.310***	0.302**	0.330***	0.364**	0.297**	0.314**	0.364**
	(0.108)	(0.104)	(0.106)	(0.101)	(0.128)	(0.111)	(0.154)	(0.125)	(0.127)	(0.158)
EU	0.737***	0.678***	0.642***	0.579***	0.638***	0.641***	0.765***	0.570***	0.557***	0.735***
	(0.109)	(0.144)	(0.144)	(0.180)	(0.149)	(0.141)	(0.118)	(0.189)	(0.182)	(0.180)
dif.tfp		**0.0286**		**0.0474**				**0.0492**	**0.0500**	**0.0176**
		(0.0656)		**(0.0702)**				**(0.0713)**	**(0.0714)**	**(0.0714)**
dif.hc			**0.0332**	**0.0399**	**0.0361**	**0.0293**	**–0.00974**	**0.0454**	**0.0467**	**0.00716**
			(0.0362)	**(0.0369)**	**(0.0381)**	**(0.0452)**	**(0.0219)**	**(0.0404)**	**(0.0404)**	**(0.0288)**
dif.gerd					**0.00447**			**0.00796**	**0.0206**	**0.0262**
					(0.0356)			**(0.0357)**	**(0.0489)**	**(0.0345)**
dif.patentspc						**–0.0120**			**–0.0219**	
						(0.0403)			**(0.0526)**	
dif.scjournals_pc							**–0.0264**			**–0.0401**
							(0.0350)			**(0.0341)**
constant	8.169***	8.562***	8.526***	9.015***	8.571***	8.361***	7.552***	9.113***	8.943***	7.691***
	(0.571)	(0.901)	(0.707)	(1.029)	(0.833)	(0.924)	(1.038)	(1.169)	(1.280)	(1.498)
Observations	264	172	208	172	208	201	185	172	165	151
R-squared	0.945	0.947	0.945	0.950	0.945	0.945	0.949	0.950	0.949	0.948

Note: All regressions carried out using semi-mixed effect ppml with EU as clustering variable. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimated using STATA 12. Dependent variable – total exports in million EUR. Total number of observations (Observations).

Source: own calculations.

Table 5. Gravity model of Polish exports – high GERD intensity partners

	(H1)	(H2)	(H3)	(H4)	(H5)	(H6)	(H7)	(H8)	(H9)	(H10)
VARIABLES	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2	E_exp2
distance	–1.206***	–1.252***	–1.279***	–1.302***	–2.390***	–0.931***	–1.260***	–2.817***	–4.503***	–2.551*
	(0.0628)	(0.0651)	(0.0726)	(0.0707)	(0.739)	(0.127)	(0.0997)	(0.737)	(1.108)	(1.361)
real GDP	0.862***	0.869***	0.862***	0.868***	0.838***	0.756***	0.857***	0.797***	0.716***	1.293***
	(0.0252)	(0.0250)	(0.0262)	(0.0245)	(0.0919)	(0.0446)	(0.0268)	(0.0943)	(0.0985)	(0.112)
dev. similarity	0.00481	0.144**	0.0271	0.147**	–0.797**	0.000980	0.0791	–1.303	–0.894	–1.269***
	(0.0550)	(0.0684)	(0.0571)	(0.0654)	(0.401)	(0.0619)	(0.0765)	(0.837)	(0.674)	(0.406)
inst. quality	0.0835	0.0398	0.0540	0.0351	–0.940**	–0.344***	0.0202	–0.902**	–1.324***	–1.217***
	(0.0604)	(0.0565)	(0.0639)	(0.0555)	(0.470)	(0.0942)	(0.0723)	(0.452)	(0.252)	(0.188)
border	0.507***	0.635***	0.421***	0.546***		0.210	0.612***			
	(0.150)	(0.164)	(0.146)	(0.155)		(0.261)	(0.224)			
FTA	0.309***	0.235**	0.193*	0.127	–1.029*	0.797***	–0.123	–1.770*	–2.925**	–0.795
	(0.102)	(0.118)	(0.110)	(0.114)	(0.544)	(0.252)	(0.127)	(0.964)	(1.307)	(0.535)
CU	1.149***	1.171***	1.394***	1.427***						
	(0.328)	(0.314)	(0.322)	(0.299)						
EU	0.740***	0.615***	0.780***	0.670***	0.268	1.737***	0.977***	–0.118	–3.000	1.234
	(0.104)	(0.103)	(0.108)	(0.103)	(1.231)	(0.278)	(0.146)	(1.132)	(1.897)	(2.639)
dif.tfp		**–0.171*** **		**–0.172*** **				**0.0443**	**0.0983**	**0.138*** **
		(0.0306)		**(0.0294)**				**(0.0782)**	**(0.0742)**	**(0.0475)**
dif.hc			**0.0918** **	**0.0997*** **	**–0.147**	**–0.0157**	**0.0946** **	**–0.0304**	**–0.201**	**–0.415**
			(0.0381)	**(0.0357)**	**(0.308)**	**(0.0542)**	**(0.0414)**	**(0.304)**	**(0.169)**	**(0.258)**
dif.gerd					**–0.387**			**0.165**	**0.0379**	**0.671** **
					(0.530)			**(0.819)**	**(0.634)**	**(0.315)**
dif.patentspc						**–0.146** **			**–0.253**	
						(0.0677)			**(0.177)**	
dif.scjournals_pc							**0.383*** **			**0.953*** **
							(0.103)			**(0.340)**
constant	3.864***	2.597***	4.390***	3.139***	21.43***	2.499**	4.485***	30.19***	41.98***	20.26
	(0.594)	(0.743)	(0.648)	(0.752)	(4.044)	(1.115)	(1.204)	(10.47)	(11.82)	(13.46)
Observations	1,234	814	1,006	814	43	199	568	42	42	37
R-squared	0.839	0.860	0.843	0.869	0.988	0.929	0.893	0.990	0.988	0.999

Note: All regressions carried out using semi-mixed effect ppml with EU as clustering variable. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimated using STATA 12. Dependent variable – total exports in million EUR. Total number of observations (Observations).

Source: own calculations.