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What Determines Export Performances in High-tech Industries[3]

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Abstract: The paper aims to identify the determinants of exports in high-technology sectors (high-tech, HT) of Visegrad countries (the Visegrad four, V4: Poland, the Czech Republic, Slovakia and Hungary) and the core member states of the European Union (EU). Based on the augmented gravity model, we estimate the regressions on panel data of the bilateral export flows of the EU-15 and V4 with the rest of the world in 1999−2011, by employing the Poisson pseudo-maximum-likelihood (PPML) estimator. The comparison of the estimations of overall export flows with the estimates explicitly done for the high-tech sectors allows us to outline the main characteristics of the existing gap in high-tech export performances of the EU-15 and V4. Estimation results find that while for the EU-15, human capital accumulation is statistically significant and export flows increase with similarity in physical capital accumulation of the trade partner; for V4, instead of similarity, the difference in physical capital stock increases exports and human capital accumulation does not yield statistically significant effects.

Keywords: international trade, high-technology, Visegrad group, gravity model

JEL Codes: F14, F15, F55

1 Introduction

As the recent literature outlines (Hatzichronoglou 1997; Srholec 2005; Baesu *et al.* 2015; Eurostat 2015), the high-technology (high-tech, HT) sectors present the fastest growing sectors in international trade and provide the necessary grounds for economic growth in the current globalized world economy. Due to the importance of development of a knowledge-based economy, investments in research, development, innovation and skills constitutes a key policy area for the EU. According to the data of Eurostat (2015), in 2012, the EU had almost 46,000 enterprises in high-tech manufacturing. Four countries, namely Germany, the United Kingdom, Italy and the Czech Republic, together account for around 53% of the high-tech sector in the EU-28. In terms of the total value of exports, Germany was the leading exporter of high-tech products in 2013, followed by the Netherlands, France, the United Kingdom and Belgium. Thus, within the EU-28 the main exporters in high-tech are presented by the core EU-15 countries. While one may reasonably argue that there is a gap in export performances between the core and the new member states (NMS) of the EU in HT sectors, the topic is not yet studied systematically.

To fill the gap in the literature, which lacks an elaboration of the trade intensities in HT sectors among NMS, we focus the research on the case of Visegrad countries and we aim to identify characteristics and determinants of export performances of V4 in HT manufacturing industries. We employ the augmented gravity model to estimate regressions on the panel data of bilateral export flows in high-tech sectors relatively to the overall exports of the EU-15 and V4 with the rest of the world in 1999−2011. Together with the standard gravity variables, our model controls for the technology gap and the difference in factor endowments of the trade partners. Following Santos Silva and Tenreyro (2006), we estimate the model by PPML for the EU-15 and V4 separately. The estimation results show that while for the EU-15, human capital accumulation is statistically significant and export flows increase with similarity in physical capital accumulation of the trade partner; for V4, instead of similarity, the difference in physical capital stock increases exports and human capital accumulation does not yield statistically significant effects.

The rest of the paper is organized as follows: section 2 briefly reviews the statistics around exports in high-tech sectors, section 3 presents literature review, section 4 specifies the model and describes the data, followed by estimation results in section 5. Finally the last section concludes the findings of the analysis.

2 Quick review of high-tech exports

Based on the data sourced by Eurostat (NACE Rev.2, at the 3-digit level), we briefly review the R&D expenditures and the shares of different technology groups in the overall exports of the EU-15 and V4. Additionally, we elaborate the structure of high-tech exports for the EU-15 and V4 separately.

Fig. 1 and Fig. 2 present the share of high-tech products in the overall exports of the EU-15 and V4. According to the level of technological intensity (R&D expenditure/value added), overall exports are divided into 'high-technology' (HT), 'medium high-technology'

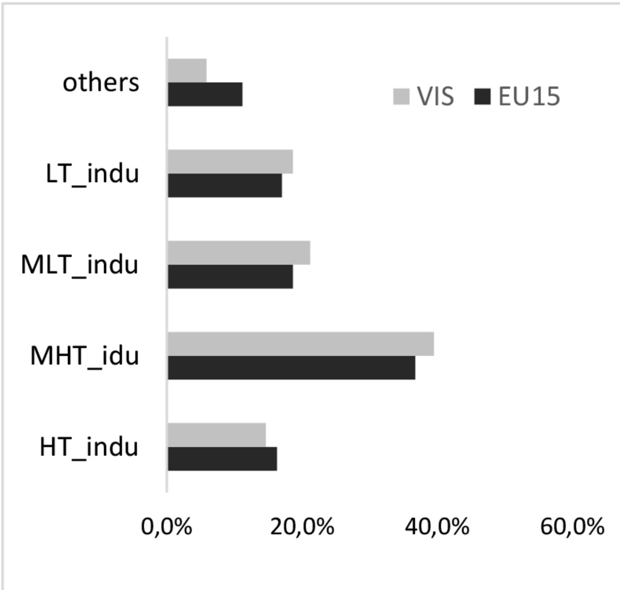

Fig. 1. Share of technology sectors in the exports of EU-15 and V4 in 2013, (in %)
Source: Authors' own calculations based on the data from Eurostat, (HT, NACE Rev.2, 3-digit level).

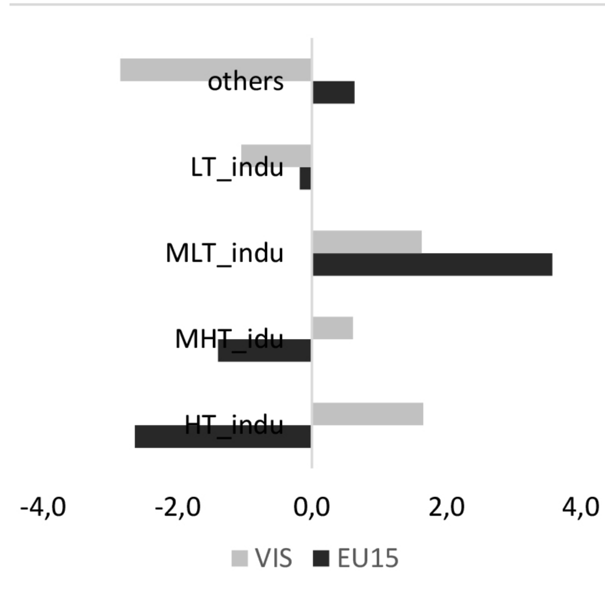

Fig. 2. Change in the shares of technology sectors in exports of EU-15 and V4 over 2004-2013, (in % points)
Source: Authors' own calculations based on the data from Eurostat, (HT, NACE Rev.2, 3-digit level).

Tab. 1. The percentage share of different product groups in HT exports of the EU-15 and V4 in 2013

Product groups	EU15	VIS
Manufacture of basic pharmaceutical products	4.7 %	0.8 %
Manufacture of pharmaceutical preparations	32.8 %	15.3 %
Manufacture of electronic components and boards	6.0 %	3.7 %
Manufacture of computers and peripheral equipment	11.5 %	14.1 %
Manufacture of communication equipment	10.1 %	24.7 %
Manufacture of consumer electronics	3.1 %	27.8 %
Manufacture of instruments and appliances for measuring, testing and navigation; watches and clocks	9.6 %	8.9 %
Manufacture of irradiation, electro-medical and electrotherapeutic equipment	2.6 %	0.4 %
Manufacture of optical instruments and photographic equipment	1.8 %	1.4 %
Manufacture of magnetic and optical media	0.2 %	0.1 %
Manufacture of air and spacecraft and related machinery	17.6 %	2.8 %

Source: Authors' own calculations based on the data from Eurostat, (HT, NACE Rev.2, 3-digit level).

(MHT), 'medium low-technology' (MLT) and 'low-technology' (LT).[1] As the figures illustrate, the share of EU-15 exceeded that of V4 in 2013. Although, relatively to 2004, in 2013, the HT share in total exports increases for V4 and decreases for the EU-15.

The disaggregated data of high-tech exports by the product groups are reported in Tab. 1 and Fig. 3. As the latter two illustrate, the EU-15 mainly export pharmaceutical products (approx. 37% of exports of HT comes from this product group). While the exports of V4 exhibit a completely different structure. That is to say, the Visegrad countries mainly export consumer electronics and communication equipment.

1 See the detailed information on: http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

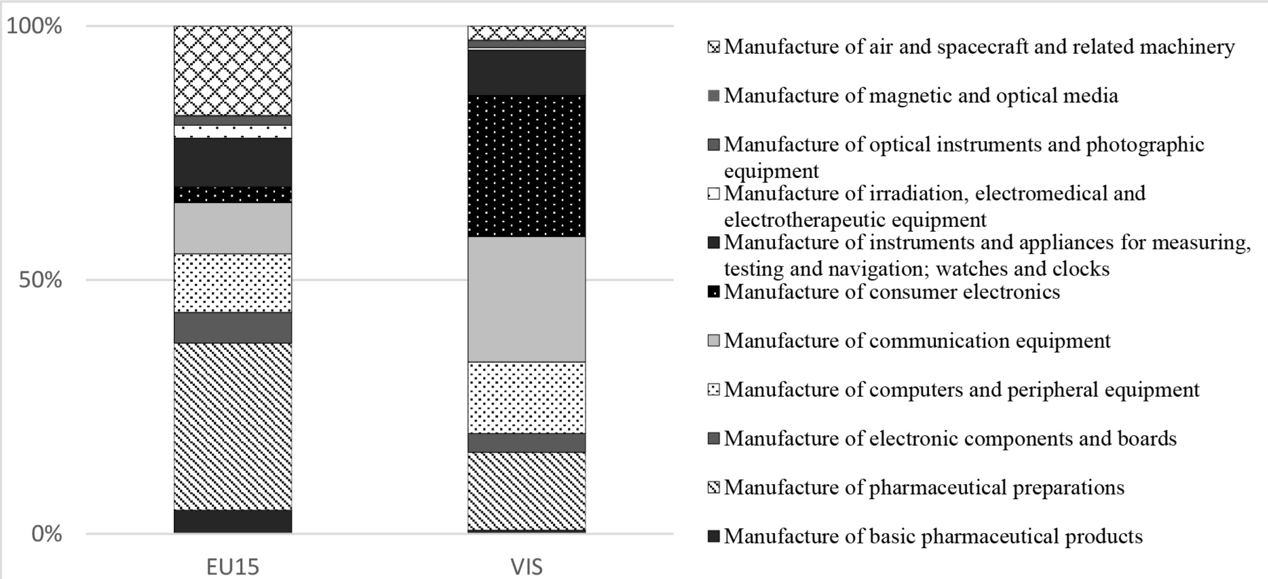

Fig. 3. The structure of HT exports of the EU-15 and V4 in 2013
Source: Authors' own calculations based on the data from Eurostat, (HT, NACE Rev.2, 3-digit level).

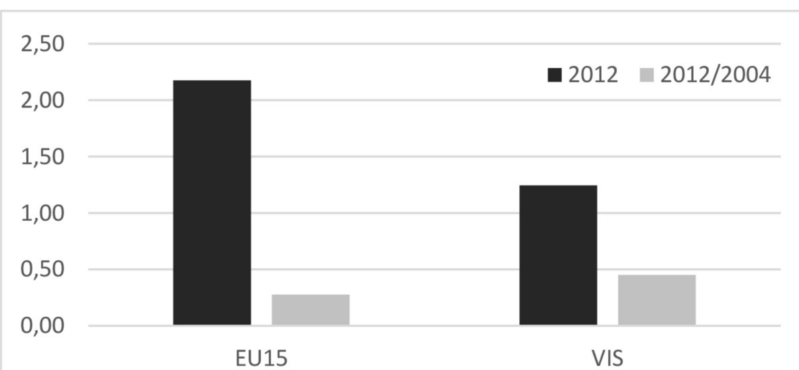

Fig. 4. Share of R&D expenditures in GDP in 2012 (in %) and changes in the share over 2004−2012 (in % points)
Source: World Bank, World Development Indicators database.

To characterize the difference in specialization of the EU-15 and V4, we also report the data of the R&D spending. As Fig. 4 demonstrates, in 2012, the R&D spending in the EU-15 was twice as large as that of the V4. However, the dynamics of R&D spending over the period 1999−2012 indicates that in comparison to 2004, in 2012 the change in the R&D expenditure of V4 is positive and two times larger than the change in that of the EU-15.

Since R&D expenditures are crucial for specializing in the manufacturing of pharmaceutical products, it is not surprising that the R&D expenditures of the EU-15 exceed that of V4. However, it is remarkable that as the data reveal, after the EU accession, V4 are characterized by increased R&D expenditures.

3 Literature review

The most popular methodology for empirical trade analysis is the theoretical framework of gravity model introduced by the crucial work of Jan Tinbergen (1962) (see studies of Soloaga and Winters 2001; Ghosh and Yamarik 2004; Carrère 2006; Santos Silva and Tenreyro 2006; Baier and Bergstand 2009; Magee 2008; Acharya *et al.* 2011). The model based on a law called the 'gravity equation' by analogy with the Newtonian theory of gravitation reflects the relationship between the size of economies, the amount of their trade and the distance between the trade partners, in the following form:

$$X_{ij} = GS_j M_j \Phi_{ij} \quad (1)$$

where X_{ij} is the monetary value of exports from i to j, M_j controls for all the importer-specific factors that make up the total importer's demand and S_j comprises exporter-specific factors that represent the total amount exporters are willing to supply. G is an independent variable such as the level of world liberalization and Φ_{ij} represents the trade costs between i and j countries. The latter is mainly represented as the country-pair-specific information such as contiguity and distance, common language, ethnic groups or borders, common memberships in regional trade agreements and tariff rates between trade partners.

The literature highlights that the high technology industries are those expanding most strongly in international trade and their dynamism helps to improve performance in other sectors due to the creation of spillovers as positive externalities. In 1997, Hatzichronoglou stated that in the context of economic globalization, technology is a key factor in enhancing growth and competitiveness in business. Firms that are technology-intensive innovate more, penetrate new markets, use available resources more productively and as a result, offer higher remuneration to the people they employ (Hatzichronoglou 1997).

However, the trade in high-tech sectors may demonstrate some special characteristics. Srholec (2005) outlines that the main exporters of high-technology goods might not necessarily be the developed countries with a higher spending on R&D. Instead, the paper underlines the emergence of remarkably growing exports of high technology products from developing countries and explains this phenomenon by the fragmentation of the production processes. Namely, author states that the latter might be explained by the trade in the components. In other words, developing countries may import the components from the developed countries, which spend reasonable efforts on R&D, and then employ the local labour force to produce the final goods eventually for exporting purposes.

Concerning the EU, Baesu *et al.* (2015) outline that the performance of high-technology sectors might play the essential role in catching-up of NMS with the core EU-15 countries. Although the trade performances in high-tech sectors is not systematically studied, the literature outlines some general peculiarities of the trade directions of V4 after the EU accession. Namely, Hornok, (2010), Hunya and Richter (2011) and Foster (2011) find that surprisingly, the trade among these four countries after the EU enlargement has been increased relatively more than the one with the other European countries.

Additionally, there are a few recent studies that examine the impacts of technological endowments on the trade intensities by introducing new measures based on different technological indices. Filippini and Molini (2003) construct a proxy for technological distance between trade partners based on the technological indicators (TI; Archibugi and Coco 2002). The latter account for the creation of technology, diffusion of technology and development of human skills. Authors estimate the augmented gravity equation for trade flows among East Asian countries in 1970−2000. The estimation results indicate that the technological gap among countries strongly determines the trade flows; countries tend to exchange more when there is little gap in their technology endowments.

More recently, Wang, Wei and Liu (2010) identify the main causes of recent trade flows in OECD countries by putting an emphasis on R&D and FDI. They estimate the augmented gravity model for 19 OECD countries in 1980−1989. Estimation results find that the levels and similarities of market size, domestic R&D stock and inward FDI stock are positively related to the volume of bilateral trade, while the distance between trading countries has a negative impact. Finally, the authors conclude that their estimations support the new economic growth theories and the OECD countries face new trade trends grounded on FDI inflows and domestic R&D.

Additionally, the intra-industry trade (IIT) could be considered as the reasonable approximation of the technology gap between the trade partners. IIT was observed in the sixties and was defined as simultaneous imports and exports of goods under the same product-level classification (Verdoorn 1960; Balassa 1966 or Grubel 1967). Theory predicts that the higher is the similarity of economic development of trade partners, the higher is IIT among them (Helpman and Krugman 1985). Overall, IIT could account for the shortened technology gap between the trade partners.

Our paper accounts for the difference in factor endowments and introduce the different measures for technology gap. We deliver the estimations for overall exports and for-high-tech exports separately for both V4 and the EU-15, that allows us to identify the main reasons why the gap between the EU-15 and V4 in high-tech exports exists. Namely, we employ the similarity in R&D spending and IIT as an approximation of the technology gap between the trade partners.

Overall, our analyses aim to cover the gap in the literature in two ways: first, we examine the export performances of the EU countries in high-tech sectors, separately for the old and the new member states to provide comparisons; second, we aim to identify the determinants of the high-tech exports relatively to the exports in all sectors by controlling for the difference in factor endowments and the technology gap between the trade partners.

4 Model specification and data description

Although the gravity model is already a commonly accepted and a standard tool to study the trade flows, the specification of the equation for estimation purposes differs according to the approaches of different authors. The most remarkably, Santos Silva and Tenreyro (2006) in their seminal paper have raised a problem that has been ignored so far by both the theoretical and applied studies. In particular, they argued that the logarithmic transformation of the original model is not a relevant approach to estimate elasticities. Namely, the multiplicative trade models with multiplicative error do not satisfy the assumption of the homoscedasticity of the error term, since there is dependency between the error term of transformed log-linear model and the regressors, which finally causes inconsistency of the ordinary least squares estimator or the random and fixed effects estimator.

As an alternative, authors propose an estimation of the gravity model in levels using the PPML estimator. Besides tackling the problem of heteroscedasticity of the error term, the estimator deals with the zero value observations in trade flows. Additionally, unlike the standard Poison approach, PPML does not require the data to be Poison type, in other words, it does not require the dependent variable to be an integer. Finally, PPML allows to identify the effects of time invariant factors. The latter is a very important feature for our analyses, since we aim to test the effects of several dummy variables indicating memberships in different regional agreements together with the time dummy controlling for the occurrence of crisis during the estimation period.

Following the contribution of Santos Silva and Tenreyro (2006), we analyse the trade of all the EU members with rest of the world based on the following estimation equation:

$$\begin{aligned} X_{ijt} = {} & \beta_0 + \beta_1 \ln\left|Y_{it} - Y_{jt}\right| + \beta_2 \ln(Pop_{it}) \\ & + \beta_3 \ln\left(Pop_{jt}\right) + \beta_4 \ln\left(Z_{ij}\right) + \beta_5 D_{ijt} \\ & + \beta_6 D'_{ij} + \beta_7 \ln\left(\mathrm{sim}R\&D_{ijt}\right) + \beta_8 IIT_{ijt} \\ & + \beta_9 \ln\left(diffK_{ijt}\right) + \beta_{10} \ln\left(diffH_{ijt}\right) \\ & + \mu_{ij} + \varepsilon_{ijt} \end{aligned} \tag{2}$$

where X_{ijt} is the export flow from i to j at time t, either in all the trade sectors or in high-tech manufacturing industry sectors. As for the right-hand side of the equation, we include independent variables approximating the market size, geography, technological gap and the difference in factor endowments between the trade partners. Namely, the market related variables are $|Y_{it}-Y_{jt}|$, which stands for the absolute value of the difference between the current GDPs of the importer and exporter countries and Pop_{it} and Pop_{jt}, and indicate populations at time t in the reporter and partner countries respectively. Geographical variables are presented by Z_{ij}, which is the non-binary but time invariant information such as distance between the exporter and importer countries; D'_{ij} stands for contiguity and equals one when the trade partners share the common border and zero otherwise; D_{ijt} presents a dummy for a membership in the EU, which equals one if a trade partner belongs to the EU and zero otherwise.

The remaining variables such as sim$R\&D_{ijt}$ and IIT_{ijt} present proxies for the technology gap between the trade partners. Namely, sim$R\&D_{ijt}$ stands for the similarity in the R&D expenditures[2] of the trade partners i and j at time t and IIT_{ijt} controls for IIT, either in all sectors or only in the high-tech sectors between exporter and importer countries at time t.[3] Finally, $diffH_{ijt}$ and $diffK_{ijt}$ stand for factor endowment and are calculated as the absolute value of the difference between the physical and human capital stocks per capita[4] between the trade partners i and j at time t. As for the last two com-

2 The similarity index for expenditures on R&D is calculated as follows: $simRD_{ijt} = 1 - \frac{|RD_{it} - RD_{jt}|}{|RD_{it} + RD_{jt}|}$, where RD_{it} and RD_{jt} represent expenditures on R&D of a reporter country i and a partner country j at time t.

3 We calculate IIT by the Grubel-Lloyd (*GL*) index as follows: $IIT_{R,P,j,t} = 1 - \frac{\sum_R \sum_P \sum_{i\in j} |X_{RPit} - M_{RPit}|}{\sum_R \sum_P \sum_{i\in j} (X_{RPit} + M_{RPit})} \cdot 100$ where R stands for a reporter, P for a partner and i for a commodity.

4 Namely the differences are calculated as follows: $diff(K) = \left|\frac{K_{it}}{P_{it}} - \frac{K_{jt}}{P_{jt}}\right|$, $diff(H) = \left|\frac{H_{it}}{P_{it}} - \frac{H_{jt}}{P_{jt}}\right|$, where K_{it} and K_{jt} represent the physical capital stock, H_{it} and H_{jt} – human capital index and P_{it} and P_{jt} population of a reporter country i and a partner country j at time t.

Tab. 2. Variables employed in the model

Variable Name	Description	Source	Expected sign
lndiff_gdp	Natural logarithm of the absolute difference between the current GDPs of the importer and exporter countries	WDI	-
ln_pop_r	Natural logarithm of population of a reporter country	WDI	+
ln_pop_p	Natural logarithm of population of a partner country	WDI	+
ldistance	Natural logarithm of geographical distance between the capital of the trading partners	CEPII	-
contig	Dummy variable standing for the neighbouring countries	CEPII	+
EU_par	Dummy variable denoting the EU membership of a partner country	Authors'	+
ln_iit	Natural logarithm of the intra-industry trade index in overall exports	Authors' calculation	
lniit_high	Natural logarithm of the intra-industry trade index in high-tech exports	Authors' calculation	
ln_sim_RD	Natural logarithm of the similarity index of R&D spending	WDI	+
ln_diff_ck	Natural logarithm of the absolute difference between the per capita physical capital stocks of a reporter and a partner country	PWT 8.0.	-
ln_diff_hc	Natural logarithm of the absolute difference between the per capita human capital stocks of a reporter and a partner country	PWT 8.0.	-

Source: Authors' own compilation.

ponents of the equation, μ_{ij} is the time invariant individual characteristics for each pair of trade partners and ε_{ijt} is the error term that is assumed to be normally distributed with mean zero. Exporter countries are all the 28 EU members, while as importers together with the EU countries, we take the rest of the world consisting of 234 countries in our sample.

The data of the export and trade flows in high technology manufacturing industries sectors come from the Eurostat based on the Statistical Classification of Economic Activities in the European Community (NACE Rev.2) at the 3-digit level for compiling groups. Namely, statistics on high-tech industry (HT) comprises of economic, employment and science, technology and innovation (STI) data which describe manufacturing applied based on the technological intensity. Three approaches are used to identify technology-intensity: sectoral, product and patent approach. To analyse the significance of HT in trade, we use the sectoral approach. It is a particular aggregation of the manufacturing industries, more precisely, according to the level of their technological intensity (R&D expenditure/value added), manufacturing activities are grouped to 'high-technology' (HT), 'medium high-technology' (MHT), 'medium low-technology' (MLT) and 'low-technology' (LT).[5]

The data of the current GDP levels in millions of US dollars and expenditures on R&D as the percentage of the GDP are included from the World Development Indicators database complied by the World Bank. The data for the physical and human capital stocks are taken from the Penn World Tables version 8.0. (PWT 8.0). The data for other variables such as distance and contiguity are taken from the CEPII database. According to the data availability, the sample covers the period from 1999 to 2011.

Tab. 2 reports employed variables grouped into three groups as described above. Some descriptive statistics of the variables of interest together with correlation matrix are provided in Tab. A and Tab. B in the Appendix. It is remarkable that the correlation matrix does not report the problem of collinearity between the independent variables.

5 See the detailed information on: http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

5 Estimation results

As discussed in the previous section, we estimate the augmented gravity model by PPML estimator, where all the variables, except the dependent variable and dummies, are taken in logarithms. The latter two are taken in levels. We run regressions on export flows in all sectors as well as only in high-tech sectors for the EU-15 and Visegrad countries separately.

The estimation results are presented in Tab. 3. First two columns provide estimations for the export flows in all and in high-tech sectors for the EU-15. Similarly, the third and the fourth columns provide estimations for the export flows in all and in high-tech sectors for V4.

As Tab. 3 illustrates, the absolute difference between the current GDPs of trade partners yields a negative sign at 1% significance level for all sectors as well as for high-tech sectors in case of the EU-15; however, it is not statistically significant for V4. This finding indicates that the overall economic similarity with the trade partner is important only for the EU-15 export performances. Population of the reported countries yields positive sign at the 1% significance level, implying the positive impact of possible increase in the domestic production due to the larger labour supply. However, the latter is not statistically significant only for V4 exports in high-tech sectors. This result gives us an intuition to state that relative to the EU-15, the population increase in V4 countries is associated more to the unskilled rather than skilled labour supply and that is why an increase in population does not contribute to the export performances in high-tech sectors. Population of the partner country is positive at the 1% significance level for all sectors and for both group of countries and thus, indicates that the possible expansion of demand on a given trade partner's market increases exports of the EU-15 and V4.

Distance yields the negative sign as expected at the 1% significance level for all the countries and all the

Tab. 3. Estimation results, overall and high-tech exports of the EU-15 and V4

	(EU 15) all sectors	**(EU 15) high-tech**	**(V4) all sectors**	**(V4) high-tech**
ln_gdpdiff	-0.107***	-0.201***	-0.0469	0.0851
	(-9.92)	(-15.70)	(-1.66)	(1.82)
ln_pop_r	0.501***	0.478***	0.473***	0.0291
	(41.24)	(26.46)	(16.97)	(0.77)
ln_pop_p	0.509***	0.538***	0.636***	0.607***
	(58.52)	(43.22)	(31.17)	(24.45)
contig	0.372***	0.248***	0.211**	-0.146
	(11.36)	(5.24)	(2.63)	(-1.29)
ldistance	-0.405***	-0.396***	-0.718***	-0.579***
	(-24.01)	(-17.58)	(-20.48)	(-9.10)
EU_par	0.245***	0.349***	0.818***	1.401***
	(8.12)	(7.56)	(16.08)	(15.13)
ln_iit	0.776***		0.573***	
	(32.48)		(15.90)	
lniit_high		0.490***		0.284***
		(15.12)		(6.02)
ln_sim_RD	0.277***	0.503***	-0.0823	0.371***
	(8.47)	(11.27)	(-1.01)	(3.66)
ln_diff_hc	0.0250***	0.0407***	0.0179	-0.0205
	(3.58)	(4.40)	(1.06)	(-1.10)
ln_diff_ck	-0.101***	-0.119***	0.101***	0.0989**
	(-10.64)	(-8.09)	(4.50)	(3.04)
cons	15.87***	17.04***	13.33***	12.29***
	(88.29)	(65.99)	(42.41)	(24.79)
N	140155	13182	30989	2912

Note: *t* statistics in parentheses; significance at the 10%*, 5%** and 1%*** levels

Source: Author's own calculations, Stata (2013).

sectors. The coefficient of the dummy standing for contiguity also yields expected sign and is statistically significant with the only exception of high-tech sectors for V4. This finding implies that unlike to the EU-15, V4 might not necessarily export high-tech products to the neighbouring countries. The dummy for the EU partnership of a trade partner yields positive sign as expected and is statistically significant at the 1% significance level with remarkably high magnitude for V4. This finding indicates that the EU enlargement had the positive impacts on export performances for all the sectors for both old and new EU member states, however, the positive outcomes are higher for V4.

Our estimations also find intra-industry trade to be positive and statistically significant for all the sectors for both the EU-15 and V4. However, the magnitudes of the coefficients are higher for the overall export flows than for the exports in high-tech sectors, which implies that technology gap is larger in high-tech sectors compared to the aggregated overall exports. Additionally, the magnitudes of the coefficients are twice larger for the EU-15 than the ones for V4. The latter implies, that the technology gap between the EU-15 and its trade partners is smaller than the gap between V4 and its trade partners. Additionally, similarity in R&D spending with the trade partner yields positive and statistically significant coefficients for all the sectors of the EU-15, although the magnitude of the coefficient for high-tech sectors is twice as large as that of the overall sectors. This implies that R&D expenditures have higher explanatory power on high-tech exports of the EU-15. However, in case of V4, R&D spending yields positive and statistically significant coefficient only for the high-tech sectors. The latter implies that the overall exports of V4 are based on the products which do not require high R&D spending. This intuition is confirmed by rest of the estimations.

Namely, the difference in per capita human capital endowment is statistically significant only for the EU-15 with twice the magnitude for exports in high-tech sectors than the overall exports. However, human capital endowment of V4 is not found to be statistically significant for any of the technology sectors. This finding is also in line with the finding concerning population. As our estimations reported, population increase was not significant only for V4 and high-tech sectors. Therefore, once the human capital endowment is not found to be statistically significant to explain the export performances of V4, our intuition to state that population increase is associated with the unskilled labour supply in V4 is confirmed. Besides, the difference in per capita physical capital accumulation is statistically significant for all the sectors of the EU-15 and V4. However, while for the former it yields negative sign, for the latter it yields the positive sign. This finding implies, that while for the EU-15, the trade is increasing with the countries owning similar physical capital stock, for V4, the trade is determined actually by the difference in physical capital accumulation. So, our results show that V4 countries might trade either with the developing countries which own less physical capital than V4 or with more advanced countries which own larger physical capital stock than V4.

To identify explicitly whether the difference in physical capital stock is more important for exporting to more advanced countries or less advanced ones, we split the trade partners into high and low income country groups and again run regressions only for export flows of V4 in high-tech sectors. Estimation results are reported in Tab. 4.

As Tab. 4 indicates, our estimations stay robust, since all the variables yield expected signs again. The absolute

Tab. 4. Estimation results, exports in high-tech sectors of V4, with high and low income countries

	(V4) high-income	**(V4) low-income**
ln_gdpdiff	0.0468	0.310
	(0.97)	(1.28)
ln_pop_r	0.0532	0.155
	(1.34)	(1.34)
ln_pop_p	0.734***	0.620***
	(24.14)	(8.80)
contig	-0.166	1.159***
	(-1.49)	(4.22)
ldistance	-0.608***	-1.399***
	(-10.04)	(-8.14)
EU_par	1.026***	
	(11.23)	
lniit_high	0.206***	0.0340
	(4.04)	(0.72)
ln_sim_RD	0.513***	0.0178
	(4.56)	(0.09)
ln_diff_hc	-0.0190	-0.0351
	(-1.04)	(-0.53)
ln_diff_ck	0.130***	0.535**
	(3.72)	(3.20)
cons	12.35***	9.471***
	(27.18)	(3.95)
N	2223	685

Note: *t* statistics in parentheses

Significance at the 10%*, 5%** and 1%*** levels

Source: Authors' own calculations, Stata (2013).

difference between the current GDPs of trade partners and population in a reporter country are not statistically significant as in the previous case. The population of a partner country is again positive and statistically significant at the 1% significance level for both, high and low income trade partners. Contiguity yields the expected sign as in the previous case and is statistically significant only for the low-income trade partners. Distance has negative sign and is statistically significant at the 1% significance level for both income category countries; however, the magnitude for the low-income trade partners are larger. This implies that the low-income countries less likely afford imports from the distant countries. The EU membership of a partner country again yields the positive and statistically significant coefficient, and therefore, indicates the positive impacts of the EU enlargement on export performances.

IIT is positive and statistically significant at 1% significance level only for the exports with high-income countries. Likewise, similarity in R&D spending is positive and statistically significant only for the exports with high-income countries. These findings show that smaller technology gap and R&D spending is important only for the exports with high-income countries. However, as in the previous case, the human capital endowment does not have explaining power – neither for the exports with high-income and nor for the exports with low-income trade partners.

Finally, the per capita physical capital accumulation also yields a positive sign and is statistically significant for both high and low income countries. However, the magnitude of the coefficient standing for the low-income countries is four times higher than the one standing for the high-income countries. Therefore, this finding implies that the difference in per capita physical capital accumulation increases the high-tech exports more to the low-income countries than to high-income ones. On the other hand, since the coefficient is positive and statistically significant for high-income countries as well, we can conclude that the difference in physical capital endowment also increases the high-tech exports of V4 to the advanced countries.

6 Conclusions

The paper aimed to identify the main determinants of export performances in high-tech sectors of V4 in relation to the EU-15. Based on the augmented gravity model, we estimated the regressions on panel data of export flows of the EU-15 and V4 with the rest of the world over the time period 1999−2011. Together with market and geography related variables, we controlled for the technology gap and the difference in factor endowments of the trade partners. We followed the recent advancement in empirical trade literature and provided estimation results by PPML estimator.

Estimation results indicated that for the EU-15, human capital accumulation is statistically significant and export flows increase with similarity in physical capital accumulation of the trade partner; while for V4, the human capital accumulation appears insignificant and instead of similarity, the difference in physical capital stock yields a positive and significant impact on export flows. Additionally, after grouping the trade partners into low and high income countries, the regression results revealed that the difference in physical capital endowment has four times higher positive impacts on high-tech exports with the low-income countries than the high-income countries. The latter, together with our statistical analysis provided in section 2, might imply that V4 mainly export communication equipment and consumer electronics to the less developed countries that cannot afford buying better quality products from the more advanced producers creating innovations in high-technology.

Overall, our findings demonstrate that V4 gain the comparative advantage on exporting the products that are not human capital intensive and don't require high R&D spending. Therefore, our analysis suggests that in order to catch up with the EU-15 in high-tech export performances, V4 needs to increase investment in human capital and R&D. Additionally, in order to shift exports from low-income countries to high-income countries, V4 should also increase physical capital accumulation. This will ensure that in the long-run, the physical capital endowment of V4 will be high enough to benefit from trade with the advanced and innovator countries.

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Appendix

Tab. A. Summary statistics

Variable	Mean	Standard Deviation	Min	Max	Observations
Ex_v_T	80955	689751	0	54700000	774713
diffgdp	23040	15079	2	112786	696876
pop_R	26	26	0	83	692491
pop_P	47	155	0	1324	588201
contig	0	0	0	1	754735
distcap	5716	3937	60	19586	754735
EU_par	0	0	0	1	774713
iit_T	0	0	0	1	771738
iit	0	0	0	1	774668
sim_RD	1	0	0	1	275716
diff_hc	1	2	0	15	501275
diff_ck	57365	36908	2	273033	588201
high_inc	0	0	0	1	774713
low_inc	0	0	0	1	774713

Source: Authors' own calculations, Stata (2013).

Tab. B. Correlation matrix

	diffgdp	pop_R	pop_P	contig	distcap	EU_par	iit_T	iit	sim_RD	diff_hc	diff_ck	high_inc	low_inc
diffgdp	1												
pop_R	-0.008	1											
pop_P	0.0432	-0.0152	1										
contig	-0.157	0.0356	-0.0443	1									
distcap	0.0234	0.038	0.1523	-0.2438	1								
EU_par	-0.0858	-0.0488	-0.1644	0.1684	-0.5464	1							
iit_high	-0.1278	0.1669	-0.0009	0.277	-0.1998	0.2789	1						
iit	-0.184	0.266	-0.0223	0.4212	-0.3402	0.4471	0.5296	1					
sim_RD	-0.3725	-0.05	0.1166	0.1918	-0.2641	0.2604	0.2246	0.3285	1				
diff_hc	0.1655	-0.1759	-0.0444	-0.0499	-0.0696	0.0606	-0.1072	-0.15	0.0192	1			
diff_ck	0.7352	0.025	0.0899	-0.1575	0.1302	-0.1615	-0.1498	-0.213	-0.3777	0.1006	1		
high_inc	-0.1806	-0.0411	-0.2599	0.095	-0.1487	0.4385	0.2193	0.3352	0.2924	0.1402	-0.2592	1	
low_inc	0.1803	0.0411	0.2607	-0.0951	0.1505	-0.4376	-0.219	-0.3348	-0.2927	-0.14	0.2594	-0.9979	1

Source: Authors' own calculations, Stata (2013).

Physical Capital Stock

The new version of PWT allows to relax the assumption of the constant depreciation rate of capital and standard capital and labour share (30% and 70%) in the production function. Additionally, the initial capital stock is not calculated based on the steady-state approach and the assumption of a single depreciation rate of capital for all countries and years is relaxed. Namely, the new dataset splits total investments into 6 groups of assets (structures, transport equipment, computers, communication equipment, software, other machinery and assets) and introduces geometric depreciation rates for each of the groups separately. Since the asset decomposition of investment varies across countries and years become no longer necessary (for more details see Inklaar and Timmer 2013). For the comparison of productivity between countries, it is used as a second order approximation to the production function as the Törnqvist quantity index of factor inputs, which is more flexible than Cobb–Douglas function.

Human Capital Stock

The data on human capital index in fact present the average years of schooling corrected by the rates of return to education based on the findings of cross-country Mincerian wage regressions evidencing that the early years of education have higher return than the later years. Based on the database of Barro and Lee (2012) the index is constructed in the following way:

$$hc_{it} = e^{\varphi(s_{it})}$$

where hc_{it} is the human capital index of country i at time t, s_{it} stands for the average years of schooling for the population aged 15 and older in country i at time t and the function $\varphi(s_{it})$ is chosen according to the arguments in Caselli (2005) and the work of Psacharopoulos (1994). Namely, it is the linear function with the following rates of return to the schooling years:

$$\Phi(s) = \begin{cases} 0.134 * s, & if\ s \leq 4 \\ 0.134 * 4 + 0.101 * (s - 4), & if\ 4 < s \geq 8 \\ 0.134 * 4 + 0.101 * 4 + 0.068 * (s - 8), & if\ s > 8 \end{cases}$$

PWT uses the data on average years of schooling provided by Barro and Lee database (last update 2014). The database constructs the number of years of schooling s_t in the following way:

$$s_t = \sum_{a=1}^{A} l_t^a s_t^a$$

where l_t^a is the population share of group a in population 15 and above and s_t^a is the number of years of schooling of every age group a. The latter divides the population in five-year age groups in a way to get: a =1: 15–19 age group, a =2: 20–24 age group, ... , a =13: 75 and above. The number of years of schooling of age group a in time t, s_t^a is calculated as follows:

$$s_t^a = \sum_j h_{j,t}^a \, Dur_{j,t}^a$$

where h_j^a is the fraction of group a having attained the primary, secondary and tertiary educational level *(j = primary, secondary, tertiary)* and *Dur* indicates the corresponding duration in years for every level.