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INTERNATIONAL IMPACTS ON V4 COUNTRIES: EVIDENCE FROM DYNAMIC PANEL DATA ANALYSIS

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Abstract
The aim of this article is to explore the international impacts on the Visegrad Four countries through the Total Factor Productivity (TFP). Simultaneously, we control for domestic factors of total factor productivity, namely for own research and development (R&D) productivity. The paper is organized as follows: After the Introduction, we present the empirical and theoretical grounds of the article, foremost the empirical phenomenon known as knowledge accumulation paradox. In the third section, we proceed to the model determination and data selection. The fourth section devotes to the estimation results and the fifth section covers robustness checks and provides some further discussion points. The last section brings up once again the key results of the paper.

Keywords: Patent, Technology, Productivity, V4

JEL classification: F43, O31, O47

1. Introduction

The Visegrad Four (V4) countries represent the largest politically and economically coordinated market within the Eastern EU. In the last two decades, they have undergone significant changes. The first decade was marked by transition from centrally planned to market-driven economy what is still considered in the local V4 scientific community as been rather speedy and out of proper control. The second decade can be labelled as integration years as V4 countries got integrated into the European Union, North-Atlantic Treaty Organization and OECD. This integration phase was accompanied by rising international impacts on V4 economic growth, i.e. impacts unfolded by international flows of goods and services (trade), flow of capital (foreign direct investments and portfolio investments) and flow of labour (Lipková et al., 2012). In the past months, V4 were celebrating the 10th anniversary of their accession to the EU and that drives scientific and stakeholder community to review and refine the course of the economy. The questions emerge: How big part did international trade and flows of capital play in the growth of the V4 countries? Did the flows unfold other than mere pecuniary impacts? If so, how substantial were the international impacts on the knowledge capital and local productivity?

The international impacts on the economic growth (measured most usually by gross domestic product, GDP) are at least twofold. First of all, the trade balance conventionally enters the GDP calculation as part of net exports (following the expenditure-based approach to GDP calculation). The flows of capital enter the GDP through the Cobb-Douglas production function where they serve as the production inputs (production-based approach to GDP calculation). Second of all, both the factors (trade, foreign capital) convey certain knowledge which might be new to the local economy they flow in. This incoming knowledge may increase the local productivity and thus, further contribute to economic growth (Keller, 2010; Krammer, 2014).

The aim of this article is to explore the international impacts of the second kind. In an attempt to do so, we take the Total Factor Productivity (TFP) as a measure of productivity growth in an economy since we do not care so much if the incoming knowledge is labour or capital productivity enhancing. We, however, discriminate between the international flows and are concerned about the magnitude, direction and relative magnitude (compared to other channels of knowledge diffusion) of their impacts. Simultaneously, we control for domestic factors of total factor productivity, namely for own research and development (R&D) productivity. is important to mention that in this paper we do not study the mobility of human capital and its impacts on the TFP – simply because the data is scarce.

The paper is organized as follows: In the upcoming section, we present the empirical and theoretical grounds of the article. Further, we proceed to the model determination and data selection. In the fourth section, we present the estimation results and the fifth section is devoted to some robustness checks and discussion. The last section brings up once again the key results of the paper which do not aspire to be fully conclusive but rather conducive for portraying complexities of international impacts on economic growth in the V4 area.

2. Theoretical and empirical background

In the last published study (Puškárová and Zajac, 2014), the knowledge accumulation paradox in the Visegrad Four countries got illustrated. It stands for the imbalance between the total factor productivity and productivity of domestic research and development activities. In the Figure 1 and 2, we recall this paradox and show that even though Hungary and the Czech Republic do perform better than their V4 counterparts in terms of domestic R&D productivity and thus, shall dispose also of larger pools of knowledge accumulated, the calculated data on TFP development (Figure 2) suggests otherwise – throughout the period, less R&D-spending and -patenting Slovakia and Poland experienced throughout the observation period higher TFP levels than the Czech Republic and Hungary.

The R&D productivity is calculated as the elasticity of the output - knowledge capital - to the inputs - R&D investments.

$$E_{it} = \log_{S_{it}} K_{it} \quad (1)$$

where E_{it} stands for output elasticity, S_{it} for R&D investments in a country *i* and time *t* and K_{it} for the knowledge capital in a country *i* and time *t* measured most usually using patents or patent applications volume.

Figure 1 - Domestic R&D productivity

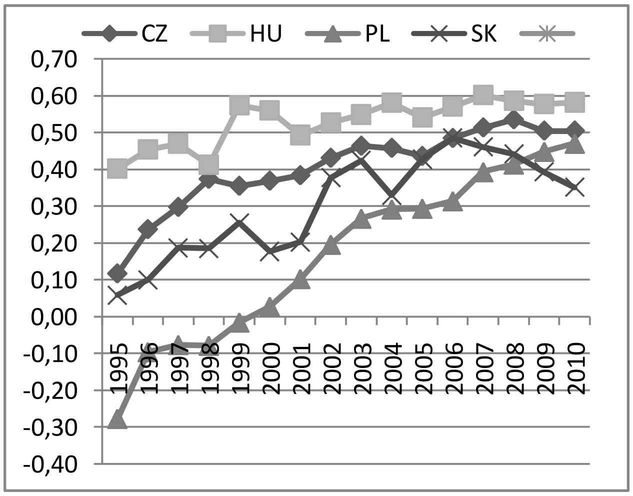
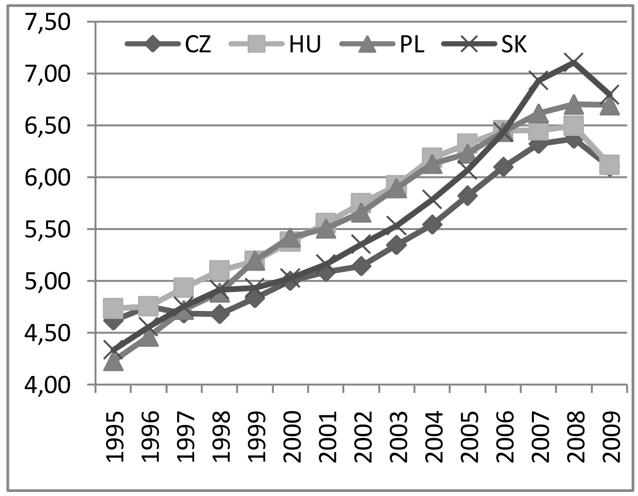


Figure 2 - TFP (as impact on GDP)



Source: own calculations, TFP based on Dujava (2012), data Eurostat 2014 in EUR

Literature provides certain explanation for this paradox. First of all, the endogenous growth theory (Jaffe, 1986; Eaton and Kortum, 1999) declares that the total factor productivity is not just the subject of domestic, but also international flows. As goods, services, capital or human capital (and labour, in general) cross borders they carry along certain knowledge which may be taken over by local agents (companies, state, and households). Thus, this literature suggests that Slovakia is the greatest beneficiary of foreign-sourced knowledge. That might be a justifiable assumption as Slovakia has largely opened to international flows and in terms of various measures (such as foreign languages skills, mobility of students) raised their ability to accept knowledge from abroad more than their V4 counterparts (Puškárová and Zajac, 2014).

Second, the TFP might be overestimated here due to, for example, shadow economy what the V4 countries have been suffering from for quite some time now. Shadow economy conventionally leads to higher consumption (consumers have more money since they avoid taxes). In case we calculate GDP as the sum of private consumption, government consumption, investments and foreign consumption (net export), shadow economy leads to higher calculated values of GDP. TFP is a secondary variable and is calculated as a residual of the GDP and production inputs (usually work and capital). In case of a shadow economy, GDP is higher but production inputs usually stay officially intact. The additional market demand (consumption) drives domestic firms to increase the prices and prefer un-official work (paying the employees based on some mutual unwritten agreement). As a result, the residual between the production inputs and GDP - the TFP - is larger.

Third, the computation problem arises also with the R&D productivity. Literature agrees on the ambiguous role of EPO patent applications as a proxy for R&D output. Griliches (1990), Keller (2010) and many others highlight that a large pool of knowledge never gets patented and thus, patent applications or volume of patents granted are just weak proxies of knowledge capital in the economy. In this paper, we will address these issues. We will first test for the presence and magnitude of the knowledge spillovers, estimate the impact of the domestic R&D productivity and then employ series of robustness checks with alternative computations for TFP and alternative variables driving R&D productivity (such as human capital).

3. Model

We start our model with the classic Cobb-Douglas production function in the country i and time *t*:

$$Y_{it} = F_{it} L_{it}^{a} C_{it}^{1-a} \exp(\varepsilon_{it}) \quad (2a)$$

where Y_{it} denotes the output, L_{it} labour, C_{it} physical capital, F_{it} total factor productivity. The exponential error term ε_{it} is assumed to be identically and independently distributed with mean zero and standard deviation σ^2. a, $1-a$ are the output elasticities with respect to labour and physical capital. From this equation we can easily determine how to calculate the Total Factor Productivity for our estimations:

$$F_{it} = Y_{it} / L_{it}^{a} C_{it}^{1-a} \exp(\varepsilon_{it}) \quad (2b)$$

Now, we recall the Jaffe (1986) theorem that TFP is the subject to internal knowledge capital K^i and external knowledge capital K^e:

$$F = f(K^I, K^E) \quad (3)$$

In this paper, the K^I is a result of domestic knowledge production factors (Jones, 1995; Jones, 2005) for which the key essence is the R&D productivity *P*. The stock of external knowledge K^E can be proxied by the two channels of international technology diffusion – foreign direct investments (FDI) *D* and imports *M*. To be fair, there might be other channels of international knowledge transfer considered such as R&D investments or mobility, but for the sake of this paper, we follow the approach of Keller (2010) and Krammer (2014) and focus on the imports and FDI. So TFP can be viewed as:

$$F = f(r, F, I\,) = P^{\lambda} D^{\nu} M^{\varphi} \exp(\varepsilon) \quad (4)$$

where λ, ν and φ are elasticities of TFP on R&D productivity, foreign direct investments and imports, respectively.

In an empirical version of this model, we expect that there is some heterogeneity between observations depending on the unobserved factors which relate to a particular unit in time such as education system disparities or cultural factors, Slovakia's entry to eurozone in 2009, disparities in domestic market size. Thus, we include also fixed effects μ into the model. Moreover, literature suggests that there are some other factors of the TFP not captured in the R&D productivity, imports or foreign direct investments and these factors are autocorrelated in time (Cingano, 2014; Fischer et al., 2009). Even though the literature does not manage to speak univocally here (static model defended by e.g. Krammer (2014)), we decided to include also the lagged TFP with the elasticity ρ into our model.

When we combine Eq. (2b) and Eq. (4), include fixed effects and lagged TFP and finally take logs we arrive at the following equation:

$$\ln F_{it} = \rho \ln F_{it-1} + \lambda \ln P_{it} + \nu \ln D_{it} + \varphi \ln M_{it} + \mu_{it} + \varepsilon_{it} \qquad (5)$$

As for our data preparation, F_{it} was calculated following Dujava (2012) based on Eurostat data (GDP per worker, revenue-based shares of two factors – labour and capital, labour is number of employees per year, capital is level of investment stock per year), D_{it} is represented by gross foreign direct investment stock in a country per year and M_{it} was proxied using volume of imported goods. μ_{it} represents the fixed effects which take care of the heterogeneity between the observations. The data for both variables come from UNCTAD Stat online databases. The R&D productivity P_{it} was calculated as elasticity of patent applications to the European Patent Office (EPO) on R&D expenditures (referred in Eurostat online databases as Gross Expenditures on R&D).

4. Estimation results

The panel is constructed using the data for V4 countries and all the years that we have the observations for and that cover both the transition and integration years. As a result we could balance the panel for the years 1995-2010. The model as denoted in the Eq. (5) is estimated using the Arellano-Bover/Blundell-Bond estimator with fixed effects in the GMM (generalized method-of-moments) estimation. The basics of the panel data estimation were developed by Baltagi (1995) and Wooldridge (2002). We decided to employ the Arellano-Bover/Blundell-Bond estimator instead of Arellano-Bond one as we assume that the lagged-levels of the dependant variable TFP are weak instruments of the TFP and thus, we want to employ additional moment conditions in which lagged differences of the dependent variable are orthogonal to levels of the disturbances. Just since the literature does not agree on the static vs. dynamic version of the TFP model, we run the estimation for both the versions. The results of both estimations are presented in Table 1.

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Table 1 - Estimated model - static and dynamic GMM version

Variable	Static model	Dynamic Arellano-Bover/ Blundell-Bond model
ln P	0.331**	0.282*
	(2.91)	(2.18)
ln D	0.0889**	0.0676**
	(3.25)	(2.51)
ln M	0.191*	0.148**
	(2.17)	(2.66)
C	1.398***	
	(12.15)	
Δ ln F		0.200
		(0.23)
N	64	60
R^2	0.8210	

Notes: the dependent variable is *tfp*; *, **, and *** indicate parameters that are significant at 10%, 5% and 1% level respectively; (.) denotes t statistic; R^2 measures the goodness-of-fit of the model, the estimations are done with robust standard errors.

The estimation results suggest that domestic productivity of R&D sector reflects significantly and largely into the levels of TFP. The elasticity of the TFP on the domestic R&D productivity is around 0.3. Foreign direct investments (FDI) and trade are significant but the results point to smaller partial effects of the inflows of capital. Our model so adheres to the magnitudes of estimated impacts provided by Krammer (2014). Hanoušek et al. (2011) support our results by concluding that FDI knowledge spillovers weaken over time and panel studies, in general, are likely to find relatively lower spillover effects. Thus, we may expect that given the cross-sectional setting, the impacts from imports and FDI would be higher. Imports sustain, thus, to be the main channel of technology diffusion in the V4 countries. TFP responds to the 1% rise in imported goods and services with a rise by approximately 0.15%.

Given our theoretical and empirical setting, our results may raise various questions. As for the countries, we perform the estimations on rather size-varying sample of countries even though they have a lot in common (history, mentality, similar languages – except Hungary) and coordinate their international moves (R&D and mobility funding through Visegrad Funds). Since the size of the local market usually plays the role for FDI and trade, the impacts for the countries differ. Second, our time period covers years of transition and integration changes and we can debate to which extent the time dummies manage to capture those. Third, we can see that the paradox is in our case driven by the imports and FDI only to the limited extent. The question thus stands: What other variables may stand behind? How much variation can be explained by the foreign flows? We try to tackle these questions in the next section which includes robustness checks.

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5. Discussion

As mentioned earlier in the text, the calculation of the TFP is controversial. We employed the Montgomery approach what is considered as rather broad TFP-defining technique. The narrow identification of the TFP is provided by, for example, Fischer et al. (2009) who suggest calculating TFP from the gross value added (GVA) instead of GDP. In addition, they propose to include cost-based factor shares instead of revenue-based factor shares as the cost-based factor shares emerge more robust in the presence of imperfect factors. Using the calculus of Fischer et al. (2009) and with the help of the Cambridge Econometrics database, we re-estimated our model and the results are summarized in the Table 2.

Table 2 - Estimated model - static and dynamic GMM version with fixed effects

Variable	Static model	Dynamic Arellano-Bover/ Blundell-Bond model
ln P	0.0760***	0.342***
	(3.04)	(3.04)
ln D	0.0215***	-0.0472
	(2.77)	(-0.62)
ln M	0.0640***	0.0523***
	(2.95)	(2.71)
C	0.310***	
	(3.45)	
Δ ln F		1.587***
		(1.23)
N	44	40
R^2	0.397	

Notes: the dependent variable is tfp; *, **, and *** indicate parameters that are significant at 10%, 5% and 1% level respectively; (.) denotes t statistic; R^2 measures the goodness-of-fit of the model, the estimations are done with robust standard errors.

Further, we challenge the application of the Arellano-Bover/Blundell-Bond estimator as this estimator is considered to work properly in case number of countries is large and number of time units is fixed. In our case, we have only four different countries and thus, we compare our results for V4 with the estimation of the model on the sample of 33 countries (EU28 countries + EFTA countries + Turkey and Macedonia), and then separately for the Transition EU and separately for the Western EU sample. Table 3 reproduces the estimations accordingly.

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Table 3 - Estimated model –-static and dynamic GMM version with fixed effects for Expanded EU sample, Western EU sample and Transition EU sample

	Transition EU		Western EU		Expanded EU	
	Static model	Dynamic Arellano-Bover/Blundell-Bond model	Static model	Dynamic Arellano-Bover/Blundell-Bond model	Static model	Dynamic Arellano-Bover/Blundell-Bond model
ln P	0.323***	0.0723*	0.0626	0.168***	0.411***	0.0985***
	(8.13)	(2.51)	(1.03)	(6.26)	(15.05)	(24.56)
ln D	0.107***	0.0229	0.0481***	-0.00718***	0.0724***	-0.00160
	(9.15)	(1.73)	(7.35)	(-4.00)	(10.36)	(-0.90)
ln M	0.224***	0.253***	0.113***	0.0358**	0.137***	0.158***
	(4.58)	(13.13)	(4.02)	(2.58)	(4.61)	(88.37)
C	1.377***		2.144***		1.642***	
	(23.90)		(34.23)		(38.28)	
Δln F		0.611***		0.704***		0.664***
		(11.14)		(19.21)		(47.00)
N	201	178	246	203	447	381
R^2	0.792		0.480		0.709	

Notes: the dependent variable is tfp; *, **, and *** indicate parameters that are significant at 10%, 5% and 1% level respectively; (.) denotes t statistic; R^2 measures the goodness-of-fit of the model. The Expanded EU covers countries of EU28, EFTA and countries applying for EU membership (Macedonia, Turkey). The Western EU stands for pre-2004 EU countries, transition EU countries represent the rest of the Expanded EU sample.

The dynamic panel results point to the strong and significant impact of the domestic R&D productivity, particularly in the Western EU countries. The impact of foreign direct investments is not significant for the transition countries, but significant and slightly negative for the Western EU what can find its justification in reality since the Western EU are donors of the foreign direct investments and thus, donors of knowledge. The impacts of international imports are significant and positive for all countries in the sample, although more for the Transition than the Western ones. The TFP seems to be strongly autocorrelated in time what complies with other empirical results (Fischer et al., 2009). In addition, the strong autocorrelation of the TFP might be also imputable to the limited representation of R&D output in the EPO patent applications volumes.

In addition, we check the efficiency of instruments' portfolio. The persistency of the series when we employ the lags of dependent variables shall indicate that our GMM is for our data the proper estimator. Simultaneously, we extend our model to another channel of international knowledge flows – the impact of foreign R&D investments. The data comes from Eurostat and they are in the form of a percentage share on total R&D investments. Since accessed the EU, the inflow of foreign R&D investments into the V4 has boomed. The largest portion compared to the total investments has been registered for Slovakia (almost 15%) but that might be imputable to the fact that local total R&D has been falling steadily even after the EU accession. In terms of volumes, Hungary tops the list. Foreign R&D certainly may bring some knowledge and lead to productivity rise: foreign R&D coming from more research-experienced countries are accompanied with high requirements on the skills, way of conduct, output and efficiency. That forces local researchers to comply with the higher requirements and to produce more efficiently.

Table 4 - Estimated model - static and dynamic GMM version with fixed effects (2 and 3 lags)

Variable	Dynamic Arellano-Bover/ Blundell-Bond model
ln P	0.282***
	(3.74)
ln D	0.0169*
	(2.07)
ln M	0.0865**
	(2.64)
ln R	-0.00173*
	(-2.38)
L1 - ln F	1.044***
	(8.20)
L2 - ln F	-0.0520
	(-0.17)
L3 - ln F	0.0656
	(0.33)
N	40

Notes: the dependent variable is tfp; *, **, and *** indicate parameters that are significant at 10%, 5% and 1% level respectively; (.) denotes t statistic; R denotes share of R&D investments coming from abroad on total R&D investments; L1, L2 and L3 represent first, second and third lag; the estimations are done with robust standard errors.

The results as displayed in the Table 4 point to the fact that foreign direct investments have only very small effect on the domestic productivity growth. Obviously, when studying impacts of the foreign R&D, one should look closer on the type of R&D investments (some investments may have smaller dissemination chances than the others) and study also output of the R&D investments. Not all R&D leads to new knowledge and sometimes the projects end with no significant results at all. Some people may come up with a remarkable innovation idea and marketize it with little resources. Other may spend years of researching and funding on an idea that never makes it to the market.

In the last part of the paper, we would like to draw attention to other local (Table 5) and international (Table 6) factors of R&D productivity and check the correlations. That may help to identify other factors that stand behind the process of R&D productivity growth.

Table 5 - Correlations between R&D productivity and selected local variables*

Variable	*lnP*	*hc_ stmob*	*ln hc_spec*	*hc_ terteduc*	*teducex*	*ln wageuni*	*ln wagegov*	*ln wagebus*	*lnfpat*
lnP	1.0000								
hc_stmob	0.1151	1.0000							
lnhc_spec	-0.3384	-0.2303	1.0000						
hc_terteduc	0.5402	-0.1788	0.3113	1.0000					
teducex	0.0883	-0.5412	0.2272	0.4331	1.0000				
lnwageuni	0.6985	-0.4794	-0.2410	0.4300	0.3432	1.0000			
lnwagegov	0.3455	-0.2895	0.5517	0.6861	0.3435	0.5287	1.0000		
lnwagebus	0.6787	-0.0508	0.1993	0.7682	0.2652	0.6401	0.8366	1.0000	
lnfpat	0.7560	0.2203	-0.5580	0.1986	-0.1356	0.6353	0.2957	0.5722	1.0000

Source: Eurostat 2014 online databases
*Note: lnP refers to data in Figure 1, hc_stmob to % of students from V4 studying in another EU or EEC country, lnhc_spec refers to % of graduates in math and science specializations, hc_terteduc refers to % population with tertiary education, teducex to % of public expenditures spent on tertiary education, lnwageuni refers to an average R&D wage at universities, lnwagegov to an average public R&D wage, lnwagebus to an average business R&D wage, lnfpat to EPO patent applications filed with foreign co-inventors.

Table 6 - Correlations between R&D productivity and selected international variables*

Variable	*lntfp*	*hc_stmob*	*lnhc_spec*	*hc_terteduc*	*lnfpat*	*lnfinnex*	*fdistock*	*imp*
hc_stmob	0.5825	1.0000						
lnhc_spec	0.3888	-0.2303	1.0000					
hc_terteduc	0.7411	-0.1788	0.3113	1.0000				
lnfpat	0.5054	0.2203	-0.5580	0.1986	1.0000			
lnfinnex	0.6920	-0.3813	0.4567	0.7443	0.4196	1.0000		
fdistock	0.8514	0.2857	-0.0543	0.5729	0.7857	0.7109	1.0000	
imp	0.7839	-0.2085	0.7011	0.7500	0.2736	0.9079	0.6873	1.0000
lnP	0.5989	0.1151	-0.3384	0.5402	0.7560	0.5188	0.8501	0.3953

Source: Eurostat 2014 online databases, UNCTAD stat online databases
*Note: lnP refers to data in Figure 1, hc_stmob to % of students from V4 studying in another EU or EEC country, lnhc_spec refers to % of graduates in math and science specializations, hc_terteduc refers to % population with tertiary education, lnfpat to EPO patent applications filed with foreign co-inventors, lnfinnex to volume of R&D expenditures coming from abroad in EUR p.c., lnfdistock refers to % of foreign direct investments stock on GDP, imp is % of imports on GDP.

The Tables 5 and 6 suggest that R&D productivity in V4 countries as defined by Eq. (1) develops correlated with local wages, availability of human capital (measured by portion of population with tertiary education) and with foreign involvement in patentable research. In the international arena, the local TFP seems to progress together with all international inflows – of capital, goods and services as well as student mobility, investments and foreign involvements in local R&D research. The R&D productivity is, on the other hand, tight-progressing only with foreign involvement in local patenting and FDI stock. There is not much correlation with the imports which emerge in the estimations of our model particularly significant for the TFP. The link of foreign direct investments and local firms' innovative activities (and implicit, local R&D productivity) was particularly explored by Čaplánová et al. (2012). The tables are presented solely as a contribution to discussion what role other internal and international factors might play for V4 factor productivities.

6. Conclusions

Empirical data presented in this paper shows a discrepancy between the observed TFP development and R&D productivity of V4 countries. Considering the most effective economy in terms of producing EPO patent applications with the given R&D funds available, Hungary outperforms the Czech Republic, leaving Slovakia and Poland lagging behind. However, both Slovakia and Poland experience faster growth of TFP. In order to examine the nature of this empirical phenomenon, we drew on the model of knowledge capital and proxied its two parts – internal and foreign pools of knowledge – using R&D productivity, imports and foreign direct investments. Using the dynamic GMM panel data estimator, we did run the inspection into V4 countries throughout 1995-2010 and accompanied the estimations using robustness checks of TFP determination and sample expansions to 33 countries located in Europe (Turkey included).

The results point to the dominant role played by non-patentable knowledge what reflects into the strong autocorrelation coefficient by the TFP. However, the international impacts come out of the estimations also visible. The imports account for a large part of foreign-driven TFP gains. The impact of foreign direct investments is, on the other hand, rather to be questioned. The impacts of our proxy of domestic knowledge capital – the R&D productivity – emerge significant and strong in the estimations, more for Western part of Europe, but that is expected as the Western EU countries are more R&D spending as well as patenting.

In the light of our results, the V4 countries may reconsider their strategies of large support of foreign direct investments. When aiming at building knowledge economy and focusing on total factor productivity raise, the FDI do not perform as good as trade. Moreover, FDI cost the local budget quite a lot – tax relief, targeted tailor-made public support are just few examples here. Trade seems to be doing more efficient work here – it costs foremost public revenues on taxes, export subsidies or import quotas. Thus, integration and trade barriers removal finds justification in reality for V4.

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