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## Conference Paper

# Regional Technology Spillovers: The Case of Central and Eastern European Countries

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- **Regional Technology Spillovers: The Case of Central and Eastern European Countries**

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*Abstract:* This paper investigates the Western European countries R&D spillovers on Central and Eastern European (CEE) countries productivity. We employ an industry-level panel data estimation scheme and introduce various control variables. While the current literature estimates that productivity increase results in one third from the local R&D investments and in two third from the R&D investments from abroad, our empirical analysis indicates that the contribution of foreign R&D in the CEE countries productivity is even larger. We also find that the country size and geographical distance from the main trading partner has important effect on the R&D spillovers. We find quite consistent evidence that larger countries absorb better the spillovers from foreign R&D. The geographical distance from the main trading partner is negatively related to the spillovers from foreign R&D.

*Keywords:* R&D spillover, absorptive capacity, geographical proximity, catching-up economies

*JEL classification:* O33, O47; F43

## **1. Introduction**

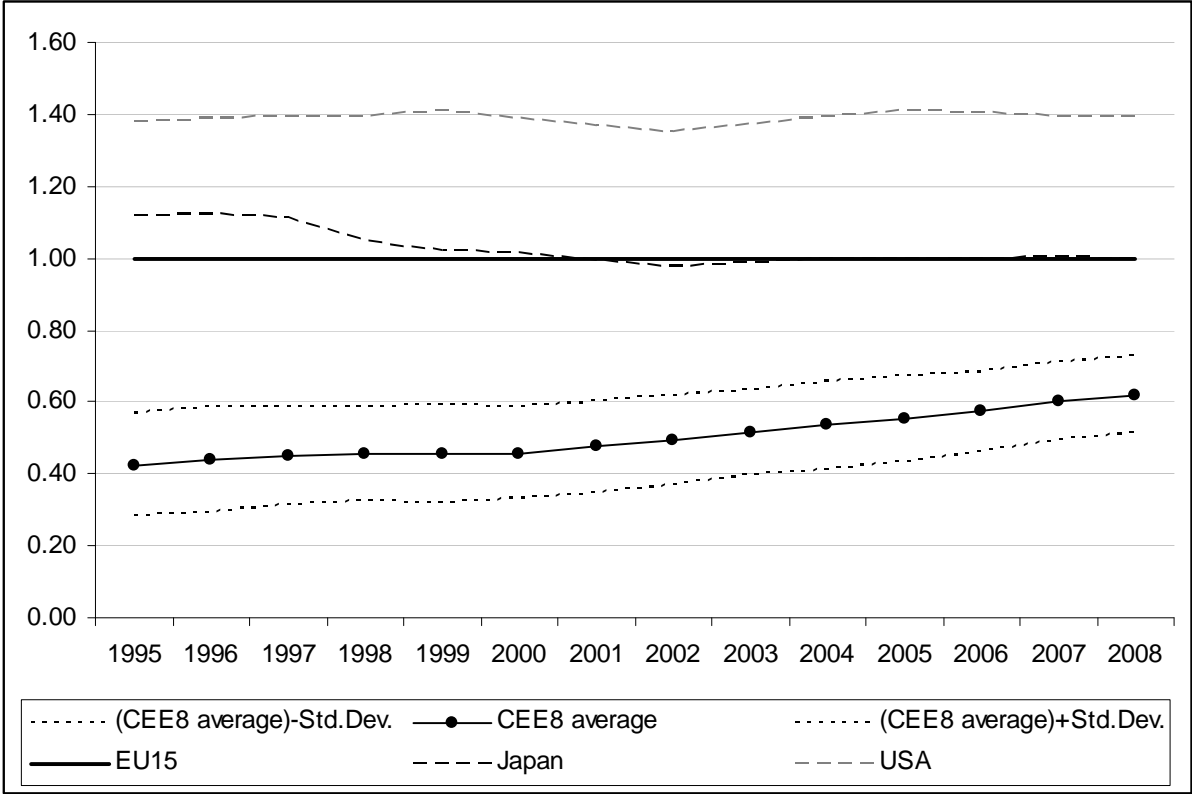
The process of European integration has introduced a valuable empirical example on the impact of economic integration on income convergence. The two recent EU enlargement rounds have shown us interesting developments in participating countries income levels. Many empirical papers confirm that the real convergence within the new member countries of 2004 has accelerated throughout the EU accession process (Vojinović and Próchniak 2009 estimate the unconditional  $\beta$  and  $\sigma$  convergence). Another line of empirical literature has shown that the income convergence has taken place between the new members group and the old members, EU15 (Matkowski and Próchniak 2007). Salsecci and Pesce (2009) show by growth accounting that most of the economic growth in these countries is attributable to total factor productivity growth. This indicates that within the integration process these countries have converged in real terms and the productivity growth has had a crucial role in this convergence.

The Figure 1 picture these developments in Central and Eastern European (CEE) countries. Just a glance to the figure tells the same story as the upper cited empirical papers. Despite the relatively uneven starting position, the GDP per capita has significantly equalised within the

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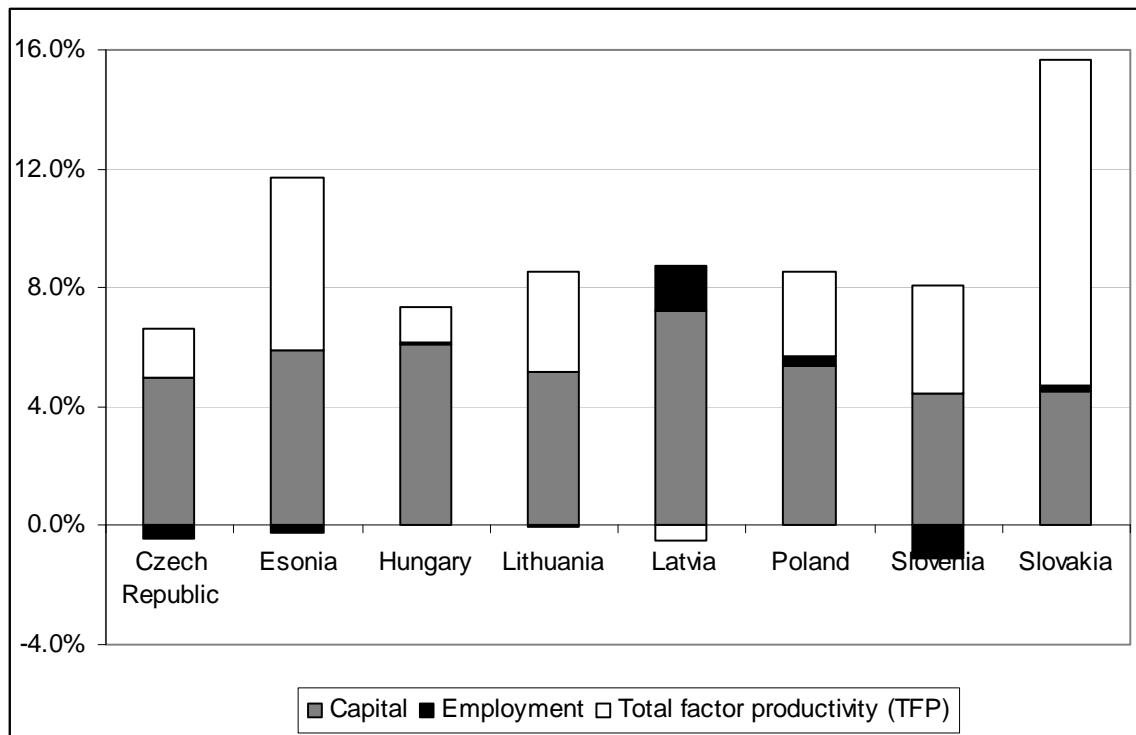
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group of CEE countries. The catching-up with European Union core has been even more remarkable, the income gap between CEE8 and EU15 has decreased by 20 percentage points over the last 13 years. The growth accounting exercise of manufacturing real growth shows that the total factor productivity has had a substantial role in manufacturing growth. There has been an intensive capital deepening in all countries in the data set, the role of capital stock in manufacturing growth has also been substantial while employment has even decreased.



**Figure 1.** GDP per inhabitant at Purchasing Power Standard, Europe vs Japan and USA, 1995-2008.

Source: Eurostat database (2010): Economy and Finance: National Accounts: GDP and main components.



**Figure 2.** Contribution of production inputs to GDP growth, manufacturing 1996-2007 (Hungary since 1999, Latvia since 1998, Poland since 1997 and Slovakia since 2001; assuming capital share of 0.35 and labour share of 0.65).

Source: Eurostat database (2010): Industry Trade and Services: Structural Business Statistics; own calculations.

In this paper we purpose to shed light on the characteristics behind the relatively uneven development behind the new EU member countries from Central and Eastern Europe (CEE). We investigate what factors have contributed to the development of these countries productivities, hence an economic growth in the longer perspective. In particular we investigate whether the R&D spillovers from rich Western European countries, differences in individual countries absorptive capacity and geographical proximity from rich Western neighbours explain the CEE countries productivity growth. We make use of the panel of the CEE8 countries manufacturing industries data from 1995-2007. The productivity is measured by total factor productivity and the import volumes have taken for the foreign R&D diffusion channel.

There is a vast literature on the technology spillovers (see e.g. Keller 2004), but the groups of CEE countries are not comparatively investigated. Coe, Helpman and Hoffmaister (2009) bring out that the vast empirical literature on international R&D spillovers has developed since the seminal empirical paper of Coe and Helpman (1995) on three directions. First, the development of better capture and measure of foreign R&D capital stock. Second, controlling for additional factors that influence the total factor productivity. Third, employment of more advanced econometric techniques. We make use of these contributions: proceed from the most recent knowledge on foreign R&D capital stock definition, control for various determinants of productivity and employ the advantageous panel data econometric tools. But the main contribution of this paper concerns the group of countries under investigation. The comprehensive multi-country analysis on developing or transition countries are rare in the literature of international R&D spillovers and up to our knowledge there is no industry-level investigation on the group of transitional Central and Eastern European countries. This group of countries provide an interesting example for the analysis of international R&D spillovers.

The CEE countries are typical middle income countries that devote not many resources on R&D, but in the same time they are tightly integrated into common economic ground of EU with highly developed countries. Since this group of countries have witnessed a fast economic growth and catch-up before and after the integration into the European Union, the R&D spillovers from their Western neighbours have presumably been vast.

## **2. Related literature and background**

It may be generalised that the productivity development of a country, industry or firm is determined by two main factors: its own effort do develop new technologies and some external technology pool. The ability to internalize the latter into the own productivity growth depends again on many factors like: various technology diffusion channels as foreign direct investment (FDI); import and export; and absorptive capacity as geographic and technological proximity from technology leaders, human capital etc.

The R&D returns or R&D elasticities of productivity differ somewhat across countries and industries and depend on the employed estimation method. Wieser (2005) shows by the meta-analysis of firm level results that R&D elasticities of productivity differ across countries, industries and in terms of estimation method. The USA R&D elasticities are higher than those of Europe and Japan indicating probably its' higher efficiency. By Wieser (2005) the average firm-level R&D elasticity over statistically significant results is 0.132, with a standard deviation of 0.094. This elasticity is somewhat higher when the firm specific effects are controlled for in the time-series analysis, 0.179 and 0.104 respectively.

The theoretical and empirical literature on technology diffusion usually confirms that at least to some extent technology is a public good. The literature survey by Wieser (2005) found that intra-industry elasticity of R&D spillovers seem to be higher than the ones for the inter-industries. In terms of the importance of international R&D spillovers there seem to be no country pattern, for the USA firms the national R&D pool is the most important source of productivity growth while the Japanese firms benefit mostly from the international R&D pool and European firms from either of them. Acharia and Keller (2009) conclude from their comprehensive empirical study on high-income countries that the relevance of foreign technology for the local productivity varies substantially across countries and industries. Their estimations indicate that R&D spillovers from European countries, Germany, France and UK, come mostly via trade; while other channels are more important for US, Japan and Canada.

The studies of technology diffusion usually bring out three channels of technology diffusion: FDI, import and export. Keller (2004) discusses in literature survey on international technology diffusion that largest consensus is in the literature on technology diffusion through FDI. The empirical evidence reveals that there are positive spillovers from FDI to host country productivity, but the presence of spillovers depends on particular characteristics of a firm and a country. In terms of international trade the results are more diverse. While empirical studies reveal that import performs as technology diffusion channel, the same is not clear for the export. We give a short overview of the literature in terms of the main technology diffusion channels and absorptive capacity.

## *FDI*

The entry of multinational enterprises (MNE) or other type of foreign investments onto the domestic market is expected to raise domestic firms' productivity via exchange of high-skilled specialist, imitation or increased competition. The amount of literature on FDI or multinational MNEs impact on domestic firms' productivity is again vast; see e.g. Keller (2004) for a survey; and Görg and Strobl (2001) and Meyer and Sinani (2009) for a meta-analysis of this literature. The traditional methodological approach is to regress firm-level total factor productivity with industry-level share of FDI (mostly the employment share of workers employed in foreign entity). Keller (2004) generalises that empirical firm level studies are rather positive about the significance of the host country productivity gains from FDI, but there are also many studies that find insignificant or negative relations. Keller (2004) discusses that the FDI spillovers are probably found to be negative because of the competition effect or due to the uncontrolled endogeneity of FDI, i.e. FDI enters to the relatively weak sectors. Görg and Strobl (2001) perform meta-analysis and find that the cross-sectional studies find positive spillovers while most panel data studies do not find a positive result. They also show that there is a possible publication bias as papers that find the relation to be statistically significant get more probably published.

Görg and Strobl (2001) study did not indicate that productivity spillovers from FDI are different in developed countries compared to developing countries. In the more recent and voluminous meta-analysis study Meyer and Sinani (2009) show that this relation between FDI spillover and country development level is quadratic. High- and low-income countries benefit the most from the FDI. Low-income countries benefit mostly from the demonstration/imitation effects while high-income countries benefit from the competition effect. The middle group faces weak/negative spillovers due to negative competition effect (local firms are too weak to counter tighter competition) and weak imitation effect: They find the similar quadratic relation between FDI spillovers and human capital proxies as patenting, tertiary education or R&D expenditures. The Central and Eastern European countries classify according to this study to the middle group with the weakest FDI spillovers, hence we could expect relatively weak spillovers from FDI also for the consecutive study.

It is claimed that the aggregate level studies are not a good methodological approach to estimate FDI spillovers (Keller 2004, Görg and Strobl 2001). FDI may influence only a certain type of firms and sectors: firms with a certain size and not too distant from the foreign firms' technology level benefit from FDI and productivity gain is larger in high-tech sectors compared to low-tech sectors. However, Görg and Strobl (2001) find in the meta-analysis that the results on FDI productivity spillovers do not depend on the aggregation level, the firm- and industry-level studies provide a similar result. Contrarily, Meyer and Sinani (2009) find that industry-level studies overestimate the FDI spillovers compared to firm-level studies. To avoid this aggregation bias, we do not analyse the technology diffusion via FDI and will analyse only the foreign trade variables role in technology diffusion.

## *Import*

Import influences domestic firms' productivity mainly through imported intermediate products and knowledge attached to these products. In autarchy, the local firms are often not able to supply as good intermediate products as the ones from world's technology frontier or it is very costly to create these inputs domestically. This means that the trade liberalisation

brings always along at least a certain amount of productivity growth from the augmented production possibilities frontier. Coe and Helpman (1997) generalise on theoretical literature that there are four channels of technology diffusion through trade. First, larger variety of intermediate products and production equipment increases the productivity of local resources. Secondly, international trade produces channels of communication for cross-border learning. Thirdly, foreign contacts support imitation of foreign technologies. Fourthly, foreign trade supports (e.g. via imitation) the development of new technologies. The latter three channels can operate as well via FDI, while the first one can operate only through trade.

The empirical literature confirms the importance of import as a technology diffusion channel (see e.g. Coe and Helpman (1995); Keller 2002; Coe, Helpman and Hoffmaister (2009) and literature survey by Keller (2004)). The usual methodological approach there is to regress total factor productivity with domestic R&D stock and measure of foreign R&D stock, where the foreign R&D stock is found as import-share-weighted trade partners' R&D stock. There have also been disagreements in empirical results whether the bilateral import shares provide a relevant contribution for the foreign R&D stock variable. For example Keller (1998) introduces random import share weight for a foreign R&D stock variable and receives equally good results. However the later empirical literature has found that this country-specific import weighting scheme comprise a better explanatory power than the introduction of equal weights for every country (see e.g. Coe *et al.* 2009 and Keller (2000), Keller (2002)).

As low-income countries are relatively far from world's technology frontier and allocate proportionally less resources on their own R&D, the importance of foreign R&D spillovers on these countries is even more important. Coe, Helpman and Hoffmaister (1997) find that low-income countries that trade more with developed countries with high R&D stock face higher productivity growth. They also find that the import of machinery and equipment performs empirically better than just an aggregate import of goods and services for the direct effect of imports on productivity. Coe *et al.* (1997) perform their analysis at the country level, however more recent industry-level evidence by Savvides and Zachariadis (2005) and Shiff and Wang (2008) confirm their results. The studies on developing countries usually do not include the home country R&D in the econometric analysis. It has been justified by the low R&D stock and often missing data for the developing countries. We test for this omission by including also the home country R&D into the analysis, because although significantly lower than in their technology leaders the R&D effort in CEE countries amounts in average more than 1% of GDP.

### *Geography and absorptive capacity*

Technology absorption depends on many factors as: ethnic scientific community, tertiary education (human capital), institutions (Coe, Helpman, Hoffmaister 2009). Better human capital increases total factor productivity directly through higher productivity of the labour force, but more qualified labour eases also the absorption of foreign technologies. Coe *et al.* (1997) find that developing countries that have higher secondary education enrolment ratios face higher productivity growth. Surprisingly, they find no support for the absorptive role of the human capital, as the interaction effect of foreign R&D stock and human capital is statistically insignificant. The latter result do not seem to be consistent in the empirical findings as Savvides and Zachariadis (2005) find that education interacts positively and significantly with foreign R&D stock. Shiff and Wang (2008) complement these results by estimating these effects separately from North-South and South-South trade. They conclude

that there is an absorptive role of human capital from the technologies from North to South, but human capital has no role for the better absorption of technologies from South to South.

### *Country size*

Keller (2004) discusses that the importance of foreign R&D depend largely on the size of the country under discussion. Based on the empirical studies on OECD countries TFP elasticity of domestic and foreign R&D he generalises that 20% of the overall effect of R&D on productivity originates from the foreign R&D in large countries, while the same proportion is much larger, 60% in small countries. Hence, the foreign sources of knowledge are much more important for smaller countries than for larger ones. He explains it by the higher openness and therefore better diffusion of technologies to smaller countries and the fact that per definition for larger countries the total foreign technology pool is relatively smaller.

### *CEEC*

While the international literature on technology transfer is vast, the evidence on CEE countries is much narrower. Kolasa (2008) demonstrates that the Polish industries' productivity levels have been catching up with the German ones. The direct effect of technology transfer from Germany has been weak, while the accumulated technology in Germany has had positive effect on Polish productivity with a yearly time-lag. Also the local R&D shows high returns and innovation expenditures have important effect on productivity growth.

## **3. Model**

We employ a production function method to calculate the total factor productivity (TFP) at national and industry level. Firstly, the TFP is calculated as a Solow residual from the estimation of Cobb-Douglas production function. The value added is produced under the Cobb-Douglas technology as follows; the notation is adopted from Coe *et al.* (1997):

$$Y_{cit} = F_{cit} L_{cit}^{\alpha} K_{cit}^{\beta} \quad (1)$$

Where  $Y$  denotes value added,  $F$  productivity,  $L$  labour input and  $K$  capital input. The subscript  $c$  denotes countries,  $c=1, \dots, 8$ ;  $i$  industries,  $i = 1, \dots, 22$ ; and  $t$  time,  $t= 1, \dots, 14$ . The total factor productivity (TFP) is then calculated as a residual from the estimation of production function:

$$\ln F_{cit} = u_{cit} = \alpha \ln L_{cit} + \beta \ln K_{cit} \quad (2)$$

Our main specification estimates the effect of own R&D stock and foreign R&D stock weighted by import, education and geographical proximity from a technological leader to the total factor productivity:

$$\log F_{cit} = \alpha^c + \alpha^t + \alpha^S \log S_{cit} + \alpha^{Sf} \log S_{cit}^f + \alpha^E \log E_{cit} + \alpha^D \log D_{ct} + u_{it} \quad (3)$$



Where  $S$  denotes R&D capital stock and  $S^f$  foreign R&D capital stock,  $E$  is the secondary school enrolment ratio,  $D$  is the geographical distance from the main high-income trade partner in kilometres,  $u_{it}$  is assumed to be a white noise error term. The foreign R&D capital stock is calculated as follows:

$$S_{cit}^f = \sum_{c' \neq c} m_{cc'} S_{c'it}$$

Where  $c'$  indicates a trading partner from high-income countries,  $c'=1, \dots, 17$ , including EU15 countries, USA and Japan.  $m_{cc'}$  denotes the share of import from a particular high-income country  $c'$  to country  $c$ . The sum of these import shares for a CEE country  $c$ ,  $\sum_{c'=1}^{17} m_{cc'}$ , is smaller than 1 (or equal to one if all the import comes from the high-income countries) and is interpreted as a import share from high-income countries.  $S_{c'it}$  indicates R&D stock of industry  $i$  in high-income country  $c'$ . Alternatively the import from high-income country is divided by domestic country GDP for the measure of  $m_{cc'}$ .

We perform also various extensions for the main specification. Firstly, we add a country size and domestic R&D stock interaction term. There is empirical evidence that larger countries benefit more from domestic R&D than smaller countries. Coe *et al.* (2009) find on the data of OECD countries that G7 countries benefit less from foreign R&D than small OECD members. We introduce a size dummy that is equal to one for countries that have more than 10million inhabitants.

#### 4. Data

It is a well known fact that R&D expenditures are internationally highly concentrated to the high-income countries as USA, Japan and G7 countries from Europe. Hereafter we discussed as a North or technologically leading countries the following OECD countries: EU15 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom), USA and Japan.

The data covers the business sector of manufacturing. The business sector R&D returns are found to be higher than the ones of the public sector; hence for better international comparability only the business sector is included.

GDP – 1995-2008, at the prices of year 2000 in millions of Euros. The GDP deflator of the whole manufacturing was used for Latvia and Poland and the industry-level deflator for other countries. Source: Eurostat database.

Employment – employment is measured as total annual working hours per industry. If the working hours were not available it was calculated based on employment and average working hours in manufacturing or in industry.

Import – share of import from partner country to total import

R&D stock – Business sector R&D investments are used to calculate R&D stock. The perpetual inventory method is used, assuming yearly depreciation of 5%.

Foreign R&D stock – country import share weighted foreign industry R&D stock (control also for the scale effect)

Capital stock – perpetual inventory method based on investments into physical capital, assuming yearly depreciation of 10%. The first year of the capital stock time series was taken equal to the conventional share of capital stock in GDP, 60%

Distance – distance from capital of a main trading partner (based on Google Maps Distance Calculator), flying distance in kilometres

Size – size of a country in millions of inhabitants

Education – proportion of population with secondary education, among young population aged 20-24.

## 5. Results

Uncontrolled idiosyncratic effects that influence both R&D and productivity cause a simultaneity bias of coefficients. We lag R&D variable by one period to alleviate the simultaneity problem. The estimation results based on specification 3 are presented in Table 1. All the estimations are based on the model with fixed effects (i.e. controlling for industry specifics within countries). The preliminary estimation results are presented only in terms of labour productivity.

**Table 1.** Labour productivity spillovers, fixed effects, 1995-2007.

	Log(labour productivity)	Log(labour productivity)	Log(labour productivity)	Log(labour productivity)
Log(R&D stock)	0.008 (0.006)	0.017* (0.009)	0.018* (0.009)	0.016 (0.010)
Log(foreign R&D stock)	0.008 (0.091)	-0.197 (0.136)	0.472 (0.497)	0.864*** (0.269)
Log(R&D stock) *log(country size)		-0.012 (0.008)	-0.013* (0.007)	-0.010 (0.008)
Log(foreign R&D stock) *log(country size)		0.122* (0.063)	0.115** (0.044)	0.204*** (0.059)
Log(foreign R&D stock) *log(distance from main trade partner)			-0.120 (0.094)	-0.073*** (0.027)
Log(foreign R&D stock) *log(secondary education enrolment)				-0.179*** (0.053)
Time dummies	X	X	X	X
No of obs.	1203	1203		
No of groups	131	131		

Robust standard errors in parenthesis. Significance levels \*\*\*, \*\*, \* indicate respectively significance at 0.01, 0.05, 0.1 level of significance.

## 6. Summary

The results indicate that the increase in domestic R&D stock leads to around 0.016% productivity growth in Central and Eastern European countries. The estimations of the returns of foreign R&D stock are rather jumpy and depend much on the introduced interaction terms. The final specification with all the controls shows that the foreign R&D stock returns are around five times higher than the local ones. However one must keep in mind the sensitivity of the estimates when interpreting this result. The country size is negatively related to the local R&D returns, but this effect is statistically not significant (however not much away from the significance). There is quite consistent evidence that the larger countries absorb better the spillovers from foreign R&D. The same is true for the distance from the main trading partner,

when the geographical distance from the main trading partner is smaller, the foreign R&D stock is better absorbed and results in higher productivity gains. Surprisingly the educational enrolments are negatively related to foreign R&D absorptions. This contradicts the theoretical literature and previous empirical findings. One could explain this contradiction by a relatively high enrolment rates within observed Central and Eastern European countries. These countries have lately witnessed high growth of education enrolment rates, but this might also have led to the drop in the quality of the education

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