Productivity growth in Central and Eastern Europe. The role of capital imports and local conditions

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Abstract

The recent international crisis and the different recovery patterns of EU member states had raised again the question of competitiveness. In the late nineties, the opportunities for competitive improvements in post-transition economies were based on the foreign capital flows and technology. After adhesion to the EU, productivity gains in these countries still largely depend on their ability for foreign technology absorption and creation. In this paper, we analyse the role of foreign technology (embodied in capital and intermediate goods imports from more advanced countries) as the main driver of technology diffusion and productivity growth in the Central and Eastern European member countries. Two main factors are taken into consideration. On the one hand, the different impact that the transfer of technology may have on productivity depending on which sector receives foreign capital flows, manufacturing or services. On the second hand, as technology diffusion relies on the absorptive capacity, we control for the home country capability to domestically adopt foreign technology, such as the human capital and the level of domestic technology and development. Using an industrial-level data set, we apply panel data analysis to estimate the links between productivity and imports of capital goods in the CEE member states for the period 1995-2009. To detect if countries at different development stages have different patterns of technology absorption, we split the sample into two different country groups: more and less advanced countries. Our results suggest that capital imports are productivity enhancing in the Central and Eastern European economies, with a greater effect on less advanced countries. We also find that the evidence of technology diffusion through capital import is slightly more robust in the manufacturing sector than in the services one. Finally, our estimates confirm the relevance of human capital and technology gap in productivity gains.

Key words: imports of capital goods, productivity, CEE countries, local conditions

JEL classification: C33; F14; O4

Introduction

In this paper, we focus on the development of productivity in the Central and East European member countries (CEE) of the European Union and its relationship with international transactions. These countries have common past and similarities but regarding their economic development, structure and endowments they form a heterogeneous region. Significant disparities exist in income and productivity levels and policy challenges across the region. Still in 2012, per capita GDP in Slovenia, at 21,400 euros (in PPP-adjusted prices), was almost twice that in Bulgaria, at 12,100 and in Romania, at 13,500[1]. There have been also significant discrepancies in their efforts to stimulate domestic innovation. Slovenia, Czech Republic and Estonia are the best performers in this sense, showing levels in per capita expenditure on R&D that are close to those of the EU countries. By contrast, in 2012, the per capita expenditure on R&D in Romania and Bulgaria does not even reach 10 percent of the EU average.[2]

After the integration into the EU and before the economic crisis, productivity grew spectacularly in the new EU member states. The increase in competitiveness was the main stimulus to the economic growth and the engine of their convergence toward the income and productivity levels of advanced industrial countries. However, this productivity growth far from coming from domestic innovations was mainly a consequence of foreign factors. As Meriküll et al. (2013) has shown, the innovation effort in CEE has been modest and differences in knowledge creation in CEE and EU are still greater than the differences in income. External sources of productivity as trade and foreign investment have been crucial in their economic catching up process by stimulating knowledge transfers and innovation (IBRD, 2008). Among these external factors, we concentrate on imports of capital goods as the main driver of the international technology diffusion and productivity growth.

International technology diffusion through capital imports has been broadly studied in the economic literature[3]. The transfer of knowledge embodied in the trade of capital goods was already underlined by Rivera-Batiz and Romer (1991). Since then, it seems to be a consensus among researchers that less industrialized countries may benefit from technological innovations that occur in the more industrialized ones. According to Xu and Chiang (2005), for instance, productivity gains that stem from leader countries R&D are widespread over the world through trade and patenting. Similarly, Keller's model (2004) predicts that the import patterns of countries are relevant for their productivity behaviour. Concretely, it shows how a country that imports primarily from a leader country receives more technology embodied in intermediate goods than other that imports from follower countries. Coe and Helpman (1995) and Coe et al (1997) confirm this hypothesis showing empirically that countries more open to machinery and equipment imports from the world's technology leaders have also experienced faster growth.

However, productivity spillovers may be constrained by the limited ability of countries to adopt new technologies. In this sense, the level of a country's human capital has been considered both a source of productivity growth and one of the main factors determining the capacity of a country to learn and absorb new technologies (Benhabib and Spiegel, 1994; Coe et al, 1997; Seck, 2011). According to Benhabib and Spiegel (1994), for instance, human capital facilitates the adoption of technology from abroad and enhances the creation of domestic technology. In addition to human capital, other authors as Cohen and Levinthal (1989), Borezstein et al. (1998), Griffith et al. (2004),

[1] Source: Eurostat
[2] Eurostat data source.
[3]See Keller (2004) for a survey.

and Keller (2004) also emphasizes the role played by domestic R&D in providing the necessary background for technology adoption. For Cohen and Levinthal (1989), the firms' ability to assimilate technological knowledge from abroad can be dependent on their own innovation effort.

The degree of success in adopting foreign technology has been further related with the technological gap, and particularly with the distance between the domestic technology level and the technology frontier (Nelson and Phelps, 1966). According to Crespo et al. (2002), the effect of technology gap on international spillovers is not unambiguous as this may act in two opposite directions. On the one hand, the greater the technological gap of a country is, the higher the potential gains from foreign technology spillovers are expected. On the other hand, a higher technological distance may imply lower capacity to adopt foreign technology, thus gains can be restricted. For Glass and Saggi (1998), a larger development gap entails a lower capability of domestic firms to benefit from potential spillovers of foreign presence.
This paper provides additional evidence on the linkages between the international transfer of technology and productivity in the CEE member states, using a new and harmonized industry-level data set. Following Coe and Helpman (1995) and Coe et al (1997), we consider the stock of knowledge embodied in capital goods imports from advanced countries as the main driver of technology diffusion. In this work, we put special attention to the role played by local conditions in the assimilation of foreign technology, and particularly on the level of human capital, domestic R&D and technological gap as determinants of absorptive capacity. We consider also the different patterns of technology adoption across sectors and by development stages. To do that, we divide the sample, on the one hand, between manufacturing and services activities and, on the other hand, into country groups according to the per capita GDP and R&D efforts. Finally, in this work, we consider the more advanced econometric methodologies in panel data techniques by addressing both the presence of specific country effects and the potential endogeneity of regressors. We also employ two alternative econometric approaches that make our conclusion more robust.

Some previous empirical works has also investigated the links between foreign transactions and productivity in the CEE countries. However, most of them focus on the effect of FDI on productivity. This is, for instance, the case of Holland and Pain (1998); Barrel and Holland (2000); Bijsterbosch and Kolasa (2010) and see other references in Javorcik, 2008). The few works that analyses the impact of capital import on economic performance across countries employ aggregate data (Kutan and Yigit, 2009) or use enterprise data, but concentrate on one specific country (as Halpern et al. 2009 for Hungary). The closest analysis to ours is the paper of Meriküll et al. (2013) that using a industry-level panel data investigate the effect of foreign R&D stock on the productivity level for six Central and Eastern European countries between 1995-2007. In our paper, we go a little further; studing the links between capital imports and productivity growth (and in levels) for more countries, applying country-groups and cross-sector analysis and covering data until 2009, so including crisis effects.

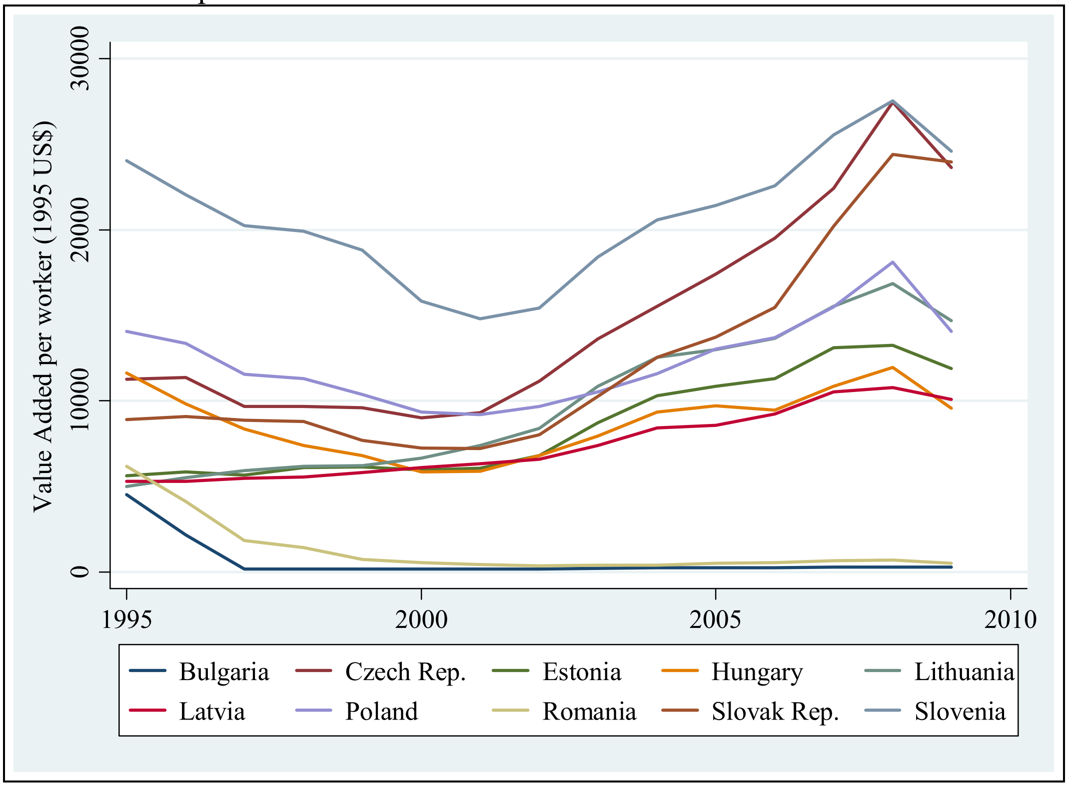
Our findings suggest the following conclusions. Capital imports from developed countries are a significant channel of technology diffusion and productivity growth in the CEE member states. These benefits are even more substantial in the less advanced countries than in the more advanced countries. However, the differences in the benefits from international spillovers between manufacturing and services sectors appear almost negligible. Finally, our estimates suggest that countries with a larger stock of human capital and a greater technology gap enjoy more productivity gains.

The structure of the article is the following: in the first section, the development of productivity, domestic R&D development and features of human capital in CEE region are described. In the second section, we present our theoretical model and its implications. The database and the econometric methodology are described in the next section. The fourth section presents the estimation results and the final section concludes.

I. Productivity growth in the CEE countries

Before and after the adhesion to the EU the CEE region experienced considerable growth. Between 2000 and 2007 average EU real GDP growth was 2.3% while for the ten CEE countries it reached 6.2%, reaching the highest level at the Baltic States[4]. A major factor behind this growth was the growth of total factor productivity. Benkovskis et al (2013) found that even between 1996 and 2007 productivity growth was generally higher in CEE countries than in Western Europe. However, there are differences among CEE countries themselves. Contribution of total factor productivity to total growth of value added had been the highest in the Baltic States, Slovakia and Slovenia.

Figure 1. Value Added per worker.



Source: Own elaboration

Figure 1 exhibits country specific dynamics of labour productivity. At a first glance, two different patterns may be distinguished. On the one hand, Bulgaria and Romania show a downward slope over the period. We must however be cautious when interpreting these trends since it is affected by a number of variables from which the exchange rate against the US$ may have a special relevance. In the case of Bulgaria it went from 14.89 US$ per Lev in 1995 to 0.71 in 2009 while for Romania it went from 4.97 US$ per Leu to 0.32. On the other hand, the rest of the countries show a positive trend, specifically after 2001/2002 where we can highlight the evolution of Slovenia (after the significant drop up to 2001), Slovakia and the Czech Republic. The financial crisis of 2008 is also present in this figure through the breaking point in the labour productivity evolution.

[4] Calculations from Eurostat data.

Table 1. Value Added per worker. Period average. (Country's average=100)

	BGR	CZE	EST	HUN	LTU	LVA	POL	ROM	SVK	SVN
AtB	293.1	97.9	115.8	175.4	162.0	108.4	331.4	290.6	137.8	237.3
C	132.6	87.7	126.0	59.3	178.8	110.1	82.6	66.7	116.7	121.0
D15t16	90.3	94.8	101.2	51.0	122.1	110.6	100.2	188.9	119.5	79.8
D17t18	43.6	62.0	55.9	37.6	55.8	66.7	48.0	36.0	44.9	50.9
D19	63.0	30.3	41.4	28.5	80.7	40.6	53.3	29.0	38.9	46.3
D20	37.9	108.2	101.7	54.2	80.8	103.3	78.9	34.1	120.6	64.3
D21t22	91.5	138.7	124.8	132.1	160.8	149.5	166.1	112.4	165.1	111.1
D23	606.1	83.0	111.7	566.5	237.5	35.8	543.7	86.4	448.9	27.3
D24	115.8	167.1	206.3	97.1	274.0	158.3	172.8	144.2	246.2	190.0
D25	56.3	129.6	220.7	111.4	142.2	121.0	122.6	110.5	151.8	95.3
D26	61.8	120.2	131.4	129.4	146.4	122.2	119.3	82.3	145.9	92.0
D27t28	77.1	77.6	117.7	93.9	113.7	138.3	97.7	69.6	147.3	84.2
D29	69.4	92.0	157.3	104.6	124.0	93.6	109.4	42.1	115.6	79.7
D30t33	46.0	126.2	117.8	261.1	121.8	124.9	125.3	100.8	109.6	106.7
D34t35	100.9	144.4	120.0	207.3	160.8	86.0	100.2	58.5	207.6	103.9
D36t37	23.2	80.8	95.5	55.1	98.7	86.5	70.5	435.8	165.5	76.8
E	228.7	233.8	86.6	94.2	162.3	184.9	116.9	97.5	119.2	136.6
F	72.8	63.7	93.9	71.1	74.5	76.7	82.5	93.6	83.7	83.8
G50	79.4	109.1	73.3	84.8	102.0	94.3	156.0	78.0	97.5	127.9
G51	79.4	188.5	285.4	180.9	212.3	150.8	156.0	105.6	140.3	86.8
G52	79.4	106.7	60.6	58.1	91.1	43.8	156.0	72.5	98.7	73.8
H	53.4	42.9	50.1	53.1	59.9	41.1	62.6	130.6	53.3	68.1
I60	138.0	112.4	92.2	64.4	81.4	93.6	97.2	75.9	71.6	74.3
I61	138.0	56.6	153.8	34.5	148.4	285.6	42.9	95.4	36.0	376.9
I62	138.0	418.2	68.5	45.2	150.1	285.6	39.7	84.3	355.6	153.3
I63	138.0	218.3	96.9	141.3	260.9	245.0	68.5	889.9	114.2	129.5
I64	138.0	175.1	262.7	195.3	102.2	256.4	120.6	104.2	156.7	155.0
J	485.7	244.5	508.2	105.9	135.1	235.4	190.2	516.3	109.0	280.2
K70	473.7	495.0	625.8	1454.8	868.9	288.2	160.4	2538.9	641.6	2121.5
K71t74	473.7	94.7	109.6	162.1	76.5	112.8	160.4	101.8	77.3	77.1
L	41.6	66.4	69.7	95.2	136.3	76.5	108.2	98.0	90.9	97.5
M	27.4	60.0	40.2	57.2	29.5	41.9	38.6	28.2	36.2	68.0
N	30.0	35.3	37.5	64.7	27.6	50.0	29.6	23.1	39.9	76.1
O	30.7	69.9	47.5	106.5	60.2	73.8	93.4	81.2	69.9	106.0

Source: Own elaboration. Sector names may be found in table A2 in the appendix.

Going down to the sectoral level, Table 1 shows the value added per worker indices of the countries that may shed light on where the labour productivity is allocated within these countries. In general terms, financial intermediation (J) and real estate activities (K70) are those with the highest productivity in most of the countries. On the other hand, textile manufactures (D17t18), leather products (D19) and hotels and restaurants (H) are among the sectors with the lowest figures. In the meantime, the primary sector (AtB) is especially well situated in Bulgaria, Poland, Romania and Slovenia, showing figures well above the country's average. It is also worth to mention, in the case of Bulgaria, Hungary and Poland, that coke, refined petroleum and nuclear fuel (D23) sector show high labour productivity. For most countries, capital goods manufacturing, groups D30t33, D34t35 and D36t37, are situated well in the middle of the labour productivity ladder being, Hungary and Slovakia the economies where these sectors are more productive.

Total factor productivity and labour productivity are complex phenomena that may be influenced by several factors. In this paper, we focus on two main factors: technology (research and development activity from foreign and from domestic sources) and human capital.

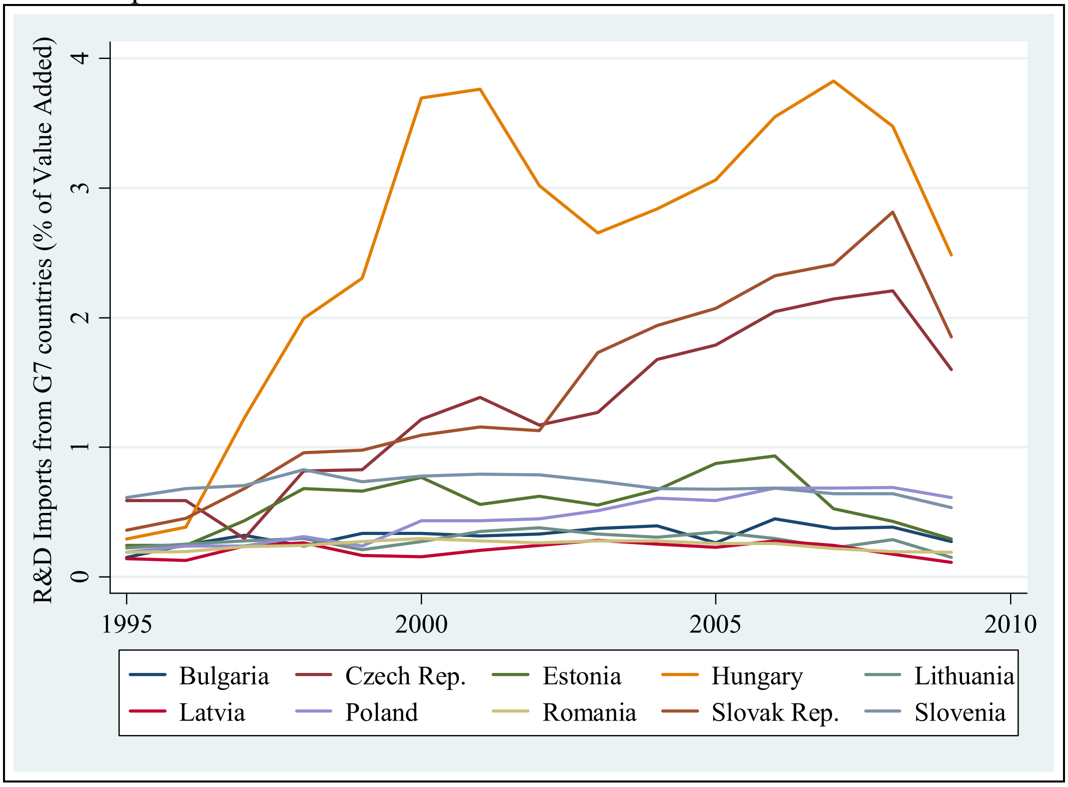
Technology development seems to be the main engine for productivity gains. In large and "capital-strong" developed countries domestic R&D activity is especially significant, financed by the state and by the enterprise sector too. In the case of the CEE countries, however, the lack of domestic capital has been substituted by foreign capital from the nineties. Electronic, automotive and machinery branches are in general foreign controlled. Apart from manufacturing, however, foreign capital imports are important in the service sector too. In certain countries and sectors, foreign firms have been financing R&D activity to a large extent or almost entirely. Foreign multinational companies established affiliates and transferred knowledge and technology to CEE economies, thus enhancing productivity. As mentioned, the productivity effects and transmission of technology linked to foreign direct investments have been widely described by the literature. In general, the measurement of these spillover effects is difficult; these can be country or sector-specific and they will depend on the used methodology or dataset (Barrios, et al. 2009). Officially registered data in CEE countries on FDI flows capture less and less real effects on the economy.[5] That is why we have decided not to include foreign direct investment in our analysis and rather focus on imports of capital goods as the main factor of technology diffusion and productivity growth.

Since the seminal paper by Rivera-Batiz and Romer (1991), the important role that imported capital goods plays as a foreign source of technology diffusion and productivity growth has been highlight in many theoretical and empirical works (see, for instance, Coe and Helpman, 1995; Coe et al. 1997; Keller, 2004; Acharya and Keller, 2009; Seck, 2011). According to these works, a country's productivity depends on its own R&D capital stock, but also on the R&D capital stocks of its trade partners. As new technology is embodied in capital and intermediate goods, the direct import of these goods is a channel of transmission (Keller, 2004 and Acharya and Keller, 2009). Indeed there are also studies according to which the impact of foreign intermediate imports is more important for smaller countries than larger ones (Barba Navaretti and Tarr, 2000, Keller, 2004). Similarly, Coe and Helpman (1995) find that foreign R&D may have a stronger effect on domestic productivity the more open an economy is to international trade. In general many authors also suggest a positive relationship between openness to trade and technology adoption (Balasubramanyam et al 1996 and Cuadros et al. 2004). In most of the smaller countries the elasticity of factor productivity is larger with respect to the foreign R&D capital stock than with respect to domestic one. In the case of CEE countries, imports are one of the most important foreign R&D transmission channels as shown by Meriküll et al. (2013).

In this paper we adopt a particular way of measuring foreign R&D. Similar to Meriküll (2013) we only apply capital goods imports as a transmission channel of foreign R&D. Particularly we compute imports from G7 countries and for sectors: machinery, nec (D29), electrical and optical equipment (D30t33) and transport equipment (D34t35). Additionally we weight them by the R&D intensity of the exporter country (measured as R&D expenditure over value added). Figure 2 shows the evolution of these R&D imports for the ten CEE countries considered. As in the case of the labour productivity, again two different groups may be distinguished: those who increased their R&D imports during the period –Hungary, the Czech Republic and Slovakia– and those who did not.

[5] In recent years there are unusually large FDI inflows and outflows in the same quarter of the year or short term in certain CEE countries. This phenomenon is defined as *capital in transit*. These are transactions within a multinational enterprise group that pass through the compiling economy without making an impact, do not finance development projects, but they distort the statistics on the components of foreign direct investment. Capital in transit is not easy to distinguish, as the affected companies are organically integrated into the economy.

Figure 2. R&D imports form G7 countries.



Source: Own elaboration

In the case of the allocation of R&D imports within the CEE countries, machinery, electrical and optical equipment, and transport equipment sectors are those who receive the majority of foreign R&D, far above the rest[6] (see table 2). Transport sector (I60 to I63) are also among the receivers of R&D for abroad. In the bottom of the R&D ladder are financial intermediation (J), hotels and restaurants (H) and real estate activities (K70).

The magnitude of the spillovers also depends on the local capacity to successfully adopt foreign technology. This was shown previously in Cuadros and Alguacil (2014) where 28developing economies were analysed in a period of a decade. Apart from others, the results demonstrated the importance of socioeconomic and institutional development of the host countries. The assimilation of knowledge spillovers will be greater the higher the absorptive capacity of the host country. Two major determinants have been emphasised as the main local factor that facilitate technology adoption: domestic R&D and human capital (Benhabib and Spiegel, 1994; Borenzstein et al, 1998; Griffith et al, 2004; Keller, 2004; Henry et al., 2009).[7] According to Griffith et al. (2004), domestic R&D and human capital are key factors for the success in adopting foreign technology when these are employed in “imitative” or “adaptative” research activities. Keller (2004) and Henry et al. (2009) also emphasizes the role played by research and development expenditures and human capital in providing the necessary skills for technology adoption.

[6] A portion of these imports correspond to intermediate parts and components that are assembled and exported back or re-exported to third countries as effect of global value chains.
[7]Crespo and Fontoura (2007) provide a survey of absorptive literature.

Table 2. R&D imports from the G7. (Country's average=100).

	BGR	CZE	EST	HUN	LTU	LVA	POL	ROM	SVK	SVN
AtB	21.3	22.4	29.7	14.2	27.3	58.4	17.1	11.7	9.6	10.4
C	64.7	30.5	30.3	36.6	13.3	76.1	34.5	92.3	11.6	31.2
D15t16	42.5	5.8	15.6	10.3	31.0	19.3	16.6	20.4	5.8	8.9
D17t18	37.7	15.3	14.2	18.2	11.6	17.2	11.6	22.9	5.5	9.5
D19	47.0	13.7	14.1	14.1	32.6	20.9	11.2	16.9	13.0	7.6
D20	68.1	14.8	17.5	15.5	32.9	75.5	18.8	35.6	5.1	13.0
D21t22	51.9	16.3	19.0	16.4	16.9	9.9	9.9	31.9	9.5	12.1
D23	73.5	50.8	31.5	16.6	39.7	211.8	18.6	19.8	1.2	13.6
D24	85.5	18.1	15.6	15.7	15.2	15.5	19.5	65.8	13.3	8.4
D25	49.3	43.4	69.2	61.0	18.7	71.7	21.6	30.4	18.4	31.8
D26	30.9	23.8	26.7	17.2	27.5	91.9	20.8	47.3	12.2	19.5
D27t28	107.1	41.6	40.0	40.1	80.4	218.7	56.1	82.3	24.5	32.4
D29	142.1	204.6	116.0	180.1	198.0	187.4	157.3	190.8	125.0	215.4
D30t33	757.1	1070.3	1541.5	769.0	590.9	735.4	423.8	508.3	432.3	353.7
D34t35	396.5	934.9	358.4	1255.7	527.0	458.0	1271.1	409.7	1983.1	2015.6
D36t37	46.1	21.5	21.7	18.7	88.9	38.7	31.5	26.5	40.5	25.1
E	78.8	36.7	42.3	23.6	143.1	91.0	34.2	112.5	27.1	51.8
F	111.2	50.1	50.1	33.8	76.6	141.2	47.2	52.9	25.7	82.1
G50	131.2	166.5	141.2	85.0	241.3	223.7	64.4	227.1	153.1	130.8
G51	24.8	18.5	22.4	13.3	25.1	13.1	12.9	17.7	23.5	18.5
G52	112.3	10.8	11.5	11.4	17.3	22.4	13.1	18.7	12.4	9.4
H	58.0	5.9	9.2	4.4	7.2	10.5	7.9	15.7	2.1	4.0
I60	79.7	30.8	106.0	67.6	274.7	107.5	106.3	135.8	36.2	58.9
I61	58.2	215.2	113.9	76.1	320.7	128.3	247.0	249.9	31.7	2.7
I62	121.2	174.3	342.0	476.3	207.7	157.9	496.4	552.7	296.2	105.4
I63	100.8	6.5	29.3	19.0	58.4	25.3	45.7	5.0	7.7	12.4
I64	170.5	45.5	32.6	21.4	104.9	37.6	72.7	62.6	23.0	8.4
J	6.6	7.8	6.2	1.8	12.6	5.3	10.6	21.1	2.6	5.8
K70	1.0	11.0	2.9	4.8	17.7	9.0	4.7	39.9	1.6	2.1
K71t74	28.1	21.6	33.4	12.0	26.3	34.3	22.0	99.8	20.4	28.4
L	91.8	10.8	28.0	13.8	49.9	17.6	29.5	30.3	6.6	34.8
M	10.2	10.3	6.2	3.4	2.1	8.6	4.4	13.7	1.8	2.2
N	73.0	35.4	40.1	19.7	18.0	32.3	15.3	95.1	10.1	24.2
O	121.3	14.7	21.7	13.2	44.6	27.6	25.6	37.1	7.5	9.8

Source: Own elaboration. Sector names may be found in table A2 in the appendix.

As pointed out in previous literature, the extent of technology diffusion can depend also on the technological gap (see, for instance, Benhabib and Spiegel, 1994; Glass and Saggi, 1998 and Crespo et al., 2002). In recent years, there has been a growing convergence in the research and development efforts of CEE countries with respect to the EU average level (see Table 3). However, this convergence is heterogeneous in its pace and degree. Slovenia, Czech Republic and Estonia are the best performers, showing the highest increase and level in per capita R&D spending. By contrast, Romania, Poland and Bulgaria are those with the lower spending on R&D (per person) of all CEE countries.

Table 3. Ratio of total R&D expenditure (GERD) per capita, (EU27 = 100).

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bulgaria	2,9	3,2	3,3	3,5	3,9	4,6	5,2	5,8	5,7	6,5
Czech Rep.	25,6	27,1	30,5	34,0	37,9	40,1	38,8	40,6	47,1	51,7
Estonia	12,6	15,3	18,6	25,5	27,9	32,2	31,0	35,3	55,7	53,8
Latvia	4,2	5,1	7,8	11,5	12,2	13,4	8,2	10,3	13,1	13,5
Lithuania	8,3	10,1	11,3	13,2	15,4	16,6	14,7	14,1	17,9	18,6
Hungary	17,6	17,9	20,1	20,4	20,9	21,8	22,4	22,8	23,3	23,9
Poland	7,0	7,5	8,8	9,0	10,0	11,9	11,5	13,8	14,2	16,8
Romania	2,4	2,7	3,7	4,7	6,6	8,1	5,7	5,7	6,3	5,2
Slovenia	42,3	47,9	50,2	55,1	53,7	63,7	68,0	73,9	84,5	90,8
Slovak Rep.	8,1	8,1	8,8	9,2	10,1	11,7	11,8	15,6	16,8	20,4

Source: Own elaboration based on Eurostat data.

Research and development is mainly financed by the business sector, by the government and from abroad. Regarding the CEE countries the share of business sector is similarly high to the EU average in Estonia, Hungary and Slovenia. In general, every country has much higher share (10-50%) of finance from abroad than the EU average (9%)[8].

A typical measurement of research and development activity is the number of patents submitted or acquired. Compared to the US, Japan or EU, CEE countries certainly perform poorly in this area. Following the transition period, however, CEE countries show rising innovative activity either in own inventions or co-inventions. Regarding the number of patents (granted by US office) relative to inhabitants until 2012, Hungary and the Czech Republic have significantly higher results than other CEE countries.[9] Concerning the number of patent applications filed (relative to inhabitants) Slovenia, Estonia, Hungary and the Czech Republic are the leaders.[10] However, patenting is costly and not so frequent in the CEE region as in Western Europe. Apart from that, as Veugelers (2010) puts it, for catching-up, emerging countries patents are inadequate to measure innovation activity, because this indicator is biased in favour of countries at the technology frontier.

Altogether, based on more than twenty innovation indicators certain CEE countries (Estonia, Slovenia, Czech Republic) belong to the “moderate innovators” group and all the others belong to “catching-up countries” (Veugelers and Mrak, 2009). The former countries have a potential for knowledge-based growth in the near future and the latter are falling short of this kind of growth (Veugelers, 2010).

Economic literature describes human capital as a direct determinant of productivity, as well as one of the main factors of absorptive capacity. Based on Coe et al. (1997)’s many empirical works include human capital as a source of productivity growth (Seck, 2012). The quality of human capital depends on education, skills, creativity and not easy to measure (see box 1).

[8] Eurostat data for 2011.

[9] United States Patent and Trademark Office, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_all.htm

[10] World Economic Forum: Global Information Technology report. http://reports.weforum.org/global-information-technology-report-2013/

Box 1.

The World Economic Forum published in 2013 its Human Capital Index (HCI) which is a comprehensive index based on four pillars containing 51 indicators in total[11]. The HCI is constructed considering that human capital is a multidimensional and a long term concept and depends also on individual life courses. The first pillar is education, where access, quality and attainment are taken into consideration. Here CEE countries occupy the 20th-57th place (led by Estonia up to Romania) among 122 countries. The second pillar of human capital is health and wellness that captures different physical and mental factors from childhood. Survival rates, well-being indices and health services are considered here. Here the dispersion of ranking is larger, CEE countries are ranked from 22th place (Estonia) to 73th place (Hungary). The third pillar is workforce and employment including labour force participation and unemployment rate, training and talent. Here CEE countries are placed between 36th and 100th place (being the Czech Republic the best and Bulgaria the worst). Generally worse ranking is caused by high unemployment and low participation rates in several countries. The fourth pillar is "enabling environment" including infrastructure, legal framework, social mobility and collaboration of business with universities. CEE countries are ranked between 26th and 83th place by this pillar (see Annex, table A1).

Regarding primary education, indices of CEE countries are around the EU average. At the secondary level, Estonia shows outstanding qualities and other countries are also usually above the EU-average[12]. However, if we look at higher education, universities had been underfunded in the transition countries, as significant higher education reform started only after the EU adhesion (Kwiek, 2014). The Bologna Declaration was signed by most countries in the region and its implementation began, not without problems[13]. The EU and OECD had influence on national educational policies. Higher education expanded in the past 20 years in the CEE countries (see table 4) and the role of vocational training decreased. In the case of Poland and Latvia, the proportion of vocational students among all dropped by more than 25% and in Lithuania and Slovenia by more than 10% between 1993 and 2007 (West, 2013). As large state-owned enterprises disappeared, also their links with vocational schools were broken. The significance and proportion of vocational students varies largely in the CEE countries: from 72% in the Czech Republic to 27% in Hungary[14].

Table 4. Tertiary education indicators.

Gross graduation ratio from first degrees in tertiary education (%)*				Enrolment in tertiary education per 100000 inhabitants			
	2000	2005	2011		2000	2005	2011
Bulgaria	18,5	23,6	31,6	Bulgaria	3325,6	3151,5	3990,0
Czech Rep.	14,1	24,7	42,0	Czech Rep.	2520,7	3354,8	4322,6
Estonia	9,7	30,1	Na	Estonia	4014,6	5232,9	5464,0
Hungary	27,8	44,1	32,0	Hungary	3068,2	4411,8	3929,1
Latvia	42,6	47,2	43,4	Latvia	3928,0	6003,6	5152,0
Lithuania	22,0	39,2	42,5	Lithuania	3555,7	6062,2	6316,8
Poland	35,7	42,5	63,8	Poland	4196,8	5645,4	5589,2
Romania	16,2	30,0	46,7	Romania	2065,9	3396,8	4090,4
Slovakia	21,0	29,7	45,7	Slovakia	2569,4	3423,9	4258,5
Slovenia	16,2	22,4	42,3	Slovenia	4305,2	5718,9	5350,0

Source: UNESCO Institute for Statistics http://data.uis.unesco.org/.

Note: *All graduates in first degree programs expressed as a percentage of the population of the age where they theoretically finish the most common first degree programme in the given country.

[11] http://www3.weforum.org/docs/WEF_HumanCapitalReport_2013.pdf

[12] EBRD Transition Report 2013: „quality of education and human capital".

[13] See: Trends 2010 report of European University Association http://www.eua.be/Libraries/Publications_homepage_list/Trends2010.sflb.ashx

[14] Eurostat data for 2012.

The above picture on the state of R&D and human capital in CEE economies justifies that we included them as explanatory variables in our model. It is also evident that there are considerable differences among the observed countries. These countries are also diverse in their level of economic development (which is a complex concept but most popularly it is measured by GDP per capita). Table 5 shows that these differences do not coincide with the geographic location of the countries.

Table 5. Nominal GDP, Purchasing Power Standard per capita, euros.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
EU 28	21 600	22 400	23 600	25 000	25 000	23 500	24 400	25 100	25 500	25 700
Bulgaria	7 500	8 200	9 000	10 000	10 900	10 300	10 800	11 700	12 100	12 000
Czech Republic	16 900	17 800	18 900	20 600	20 200	19 400	19 700	20 300	20 700	20 600
Estonia	12 400	13 800	15 600	17 500	17 200	14 900	15 600	17 400	18 200	18 600
Latvia	10 100	11 100	12 500	14 300	14 600	12 700	13 500	15 000	16 400	17 300
Lithuania	11 100	12 300	13 600	15 500	16 100	13 600	15 100	16 900	18 300	19 100
Hungary	13 600	14 200	14 900	15 300	15 900	15 300	16 100	16 900	17 000	17 200
Poland	10 900	11 500	12 300	13 600	14 100	14 200	15 400	16 400	17 100	17 500
Romania	7 500	8 000	9 200	10 700	12 200	11 700	12 400	12 900	13 500	na
Slovenia	18 700	19 600	20 700	22 100	22 700	20 200	20 600	21 200	21 400	21 300
Slovakia	12 300	13 500	14 900	16 900	18 100	17 000	18 100	18 900	19 400	19 600

Source: Eurostat.

It can be seen that although the Baltic countries share strong common ties in history and regionally, in terms of GDP per head Estonia is more developed than the other two economies. Bulgaria and Romania are the less and Slovenia and the Czech Republic are the most developed countries. Using these facts and the already described characteristics of the R&D and human capital – being most relevant to our study – we constructed two groups of countries in our sample. To one group belong the relatively well advanced CEE countries with relatively more intensive R&D activity: Slovenia, Czech Republic, Estonia, Slovakia and Hungary (this latter is a border-line case, but because of its relatively high R&D expenditure we included Hungary into the more advanced group). To the other group belong the less advanced economies with less R&D effort: Bulgaria, Romania, Latvia, Lithuania and Poland.

II. Theoretical considerations

As mentioned before, the importance of technology diffusion through foreign transactions has been recognised widely by the economic literature (Keller, 2004). The major channels for technology diffusion across countries may include foreign direct investments, but also international trade. According to Acharya and Keller (2009) and Keller (2004), the technology is embodied in capital and intermediate goods, so the direct import of these goods is a channel of transmissions. Capital imports may involve the transfer of superior technologies, which can then spread over the entire economy leading to productivity gains in domestic firms.

Following the endogenous growth literature, Liu (2008) extends the Ehrlich et al. (2004)'s model by incorporating technology spillovers to the production function at the firm level. This model suggests that the spillovers related to foreign capital lead to a decline in the short-term productivity but an increase in the long-term rate of productivity growth of domestic firm.

On the basis of these works, we present here (with an illustrative purpose) a simple model of international technology diffusion. Concretely, we adapt the above models considering both the transferred (adopted) technology as an intermediate good which increase the aggregate productivity of all its inputs, and the initial conditions in the host economies for both the creation of new technologies and the absorption of the spillovers associated with foreign transactions.

In our model, the transfer of superior technologies through foreign transactions, and concretely through imports of capital goods, spreads over the entire economy leading to productivity gains in domestic firms. Similar to the standard knowledge production function, we include the stock of knowledge as a separate input in the Cobb-Douglas production function (*T*). Concretely, assuming that foreign countries have a more advanced technology, we specify the home country production function as,

$$Y_{it} = A_i L_{it}^{\alpha} K_{it}^{\beta} T_{it}^{\gamma}$$

Where Y_{it} is total output and K_{it} and L_{it} denote capital and labour in country *i* at time *t*, respectively. T_{it} represents the average technical knowledge stock of the home country that it is subject to continuous accumulation. A_i is a technical factor. In this model, this factor is treated as exogenous to focus on the impact of the spillovers associated with foreign transactions.

The stock of knowledge serves as a specific input for the home country production that augments productivity of all factors, as in Lucas (1988) and Romer (1990). However, in our model, technical progress associated with knowledge emerges from foreign transactions rather than from R&D activities or human capital.[15] If the technology associated with foreign transactions, in the form of managerial skills as well as new products and processes, are partially public, this may be used by other firms as an unpaid input factor, increasing hence the growth rate of the technology input in the home economy.[16]

The accumulation of new technology, g_T, follows here the law of motion (similarly than in Lucas 1988´s for human capital). The production of additional technological inputs requires a stock of knowledge that may come from two sources: (i) The technology stock of the home country and, (ii) the knowledge spillovers associated with foreign transactions. Concretely, the accumulation of new technology will depend on both the current level of domestic technology, *T*, and the spillovers that occur through the technology transfer from the most advanced economies, *G*. That is,

$$g_{T_{it}} = r_{it} T_{it} G_{it}^{\varphi} \qquad (1)$$

where $\varphi \geq 0$ is the intensity of spillovers and r_i is an efficient factor that represents the fraction of technological input employed in the adoption of new technology.[17] For attaining any unit of knowledge, a country needs $r>0$ new units of technical knowledge. All countries are not equally efficient in adopting foreign technology. The extent to which the new technology obtained through foreign transactions is translated into domestic technological progress and productivity growth depends on the capacity of the sector and the country to maximise foreign spillovers (Bijsterbosch and Kolassa, 2010; Cuadros and Alguacil, 2014). Thus, the value of this parameter will rely on the technology absorption capacity, such as the level of domestic skills or the level of basic technology

[15] In our model, domestic R&D activities and human capital facilitate the absorption of the new technology, but they are not their engine. The observed CEE countries are not among the strong innovators in the world and their technology is less developed.

[16]As in Romer (1986), spillovers are non-appropriable by firms and affecting the whole economy.

[17] This equation is inspired in the specification suggested by Benhabib and Spiegel (1994) which indicates that technical change depends both on innovation and imitation.

literacy. The domestic capacity to benefit from potential spillovers of foreign transactions may be also measured as the distance to the technological frontier (Nelson and Phelps, 1966). According to these authors, a larger development gap entails a poorer transfer of foreign technology.

From Eq. (1), we can write the home country's total factor productivity, at time *t* as,

$$TFP_{it} = \frac{Y_{it}}{L_{it}^{\alpha} K_{it}^{\beta}} = A_i H_{it}^{\gamma}$$

Taking natural logs, the above equation can be also be expressed as,

$$\ln tfp_{it} = \ln y_{it} - \beta \ln k_{it} - (\alpha + \beta - 1) \ln L_{it} = \ln A_i + \gamma \ln H_{it}$$

where lowercase letters denote per worker values. Then, assuming constant returns to scale with respect to domestic capital and labor, and taking first differences, we can express the growth rate of labor productivity (*lp*) in terms of output per capita growth (g_y) and capital per worker growth (g_k),

$$lp_{it} = g_{y_{it}} - \beta g_{k_{it}} = \gamma g_{h_{it}} \qquad (2)$$

According to this expression, the productivity growth is an increasing function of the accumulation of knowledge of the economy, as $\gamma > 0$.[18]

In short, we can say that the growth rate of labor productivity is influenced by foreign transactions through the transfer of a superior technology that raises the productivity of all other factors. This technology factor is assumed to be greater, the greater is the exposure of the home country to the international transactions and the greater the country capability to domestically adopt foreign technology. Both domestic conditions (the absorptive capacities and the average knowledge stock) and foreign spillovers contribute to productivity growth, facilitating the adoption of new technology. Concretely, we assume that capital imports lead to a sustainable growth in productivity in the home economy as domestic technology increases. In accordance with the endogenous growth models, knowledge is viewed here as the ultimate engine of economic growth.[19]

III. Empirical analysis

Data

The main data source of which this paper makes use is the new WIOD database, which provides a time-series of world input–output tables (WIOTs) from 1995 onwards. It covers 40 countries, including all EU 27 countries and 13 other major advanced and emerging economies namely Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and the United States. Data disaggregation includes 35 industries and 59 product groups. The 35 industries cover the overall economy and are mostly at the 2-digit NACE rev.1 level or their groups. They include agriculture, mining, construction, utilities, 14 manufacturing industries, 8 trade and transport services, telecommunication, finance, business services, personal services, and 3 public services. WIOD database provides information on the source (domestic industries and imports) and destination (intermediate use by domestic industries, domestic final demand or

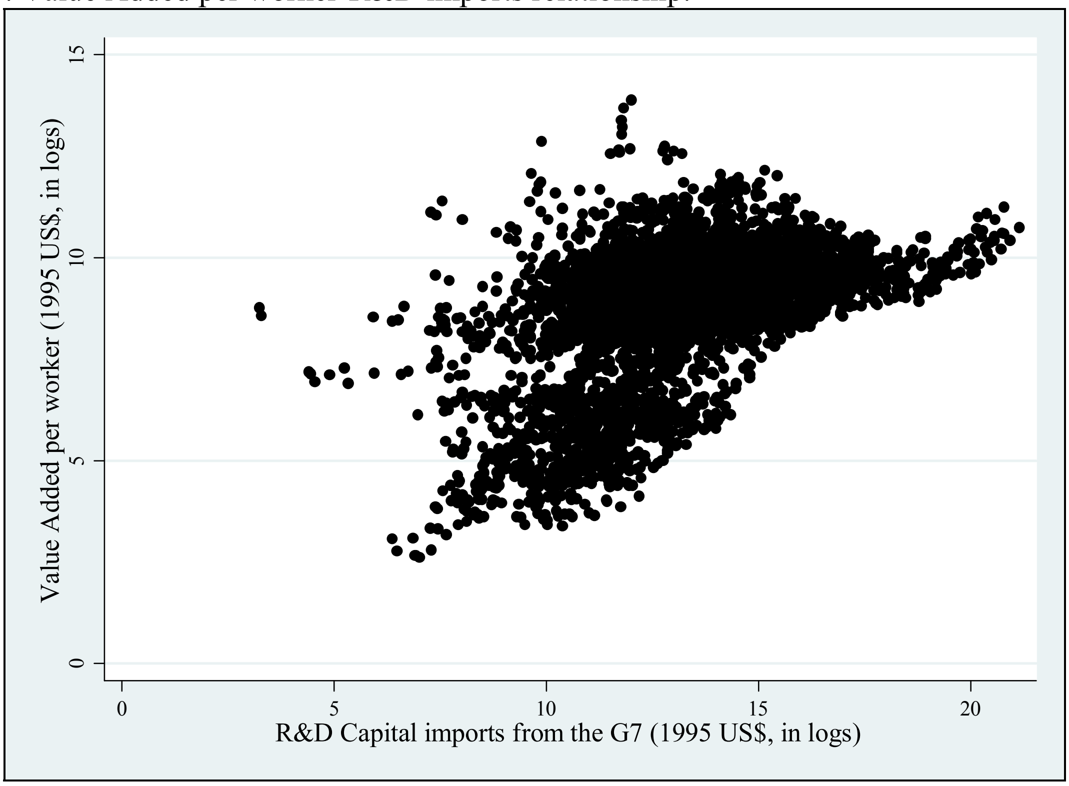
[18] The increasing return to the production of technology drives the accumulation of technology and the economy grows indefinitely.
[19] See Liu (2008).

exports) of each product. For the purpose of this paper a sample of thirty-four industries[20] for ten Central and Eastern European countries[21] for the period 1995 to 2009 have been considered.

The main objective of this work is to analyze the role of capital imports, as a technology diffusion channel, and local conditions on the productivity of Central and Eastern European countries. In order to do that, we define productivity as the value added per person employed. As mentioned earlier, foreign R&D will refer to the capital imports weighted by the exporter sector's R&D intensities. Capital imports accounts for the bilateral imports of industries Machinery, NEC; Electrical and Optical Equipment; and Transport Equipment (Groups 29 to 35 according to the NACE rev.1) that come from the G7 countries[22] while exporter R&D intensities are constructed as the R&D expenditure over the value added for each capital aforementioned sector extracted from the OECD Science, Technology and Patents database.

Figures 3 and 4 display scatter plots of value added per worker (measured in constant US$ and natural logarithms) against the R&D capital imports from the G7 countries (also in constant US$ and natural logarithms). Each point accounts for the pair labour productivity–R&D imports for a country in a certain year. For the whole sample Figure 3 suggests a positive correlation between both variables. Once we divide the sample into two groups of More Advanced (MA hereafter) and Less Advanced (LA hereafter) the conclusion may be the same while it is clearer for the case of the less advanced countries.

Figure 3. Value Added per worker-R&D imports relationship.



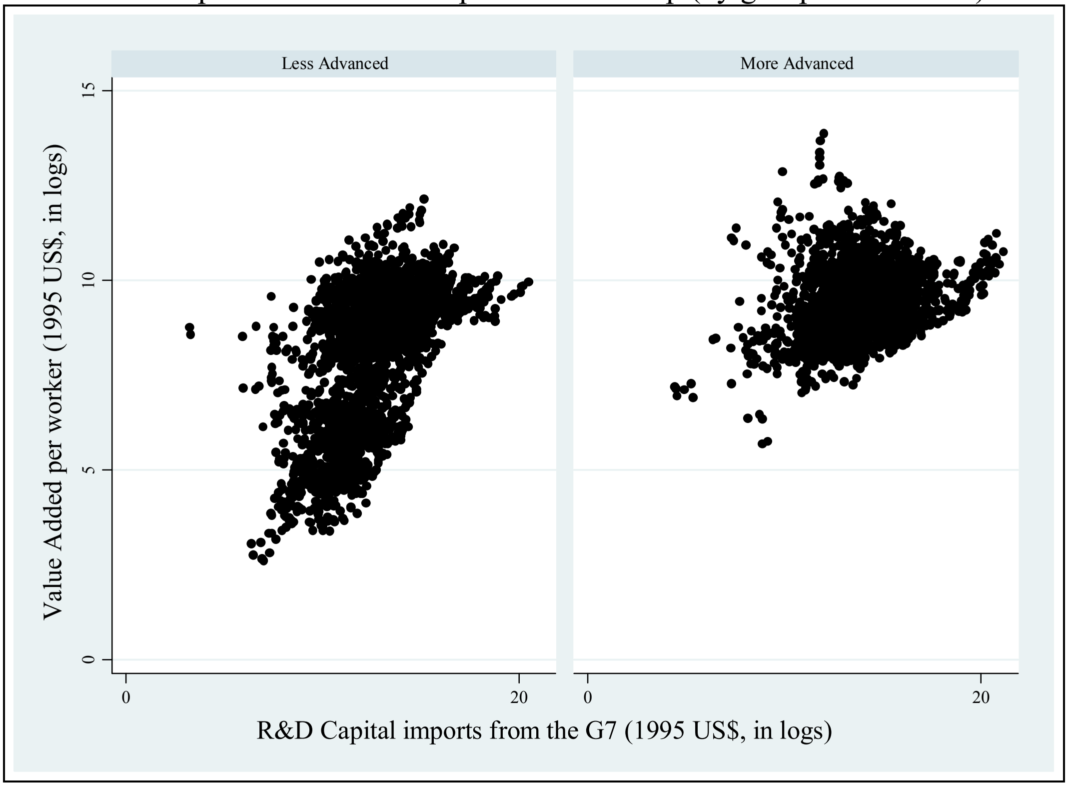
Source: Own elaboration

[20] See table A2 in Appendix.

[21] Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

[22] Canada, France, Germany, Italy, Japan, United Kingdom, and United States.

Figure 4. Value Added per worker-R&D imports relationship (by group of countries).



Source: Own elaboration

As mentioned earlier, many papers before have highlighted the importance of local conditions in order to succeed in technology diffusion. In this sense, domestic human capital, domestic R&D and distance to the technology frontier have been used widely in the literature to capture so-called local conditions. Analogously to foreign R&D, domestic R&D is defined as domestic intermediate capital inputs weighted by domestic sector's R&D intensities where domestic capital refers to the use of intermediate inputs from groups 29 to 35 (NACE rev. 1.1) by the 34 economic sector considered. The country's distance to the technology frontier is measured inversely by the ratio of its average productivity parameter to the global frontier parameter. Consistently, in this study we define the variable the GAP, which we will refer to "proximity" to the frontier, as the ratio of the sample countries' TFP to the US TFP for each sector.[23]

We apply a slightly different method to proxy the human capital. As we described, human capital can be rather defined as a composite index influenced by several factors. However, given the lack of human capital data at the sectoral level for these CEECs, we chose to create an indirect measure of human capital based on labour compensation. WIOD database provides statistics on total labour compensation and the shares of high, medium, and low-skilled compensation. With these statistics we have constructed our human capital (HK) variable as follows:

$$HK_{ijt} = \frac{LAB_{ijt} \times LABHS_{ijt}}{EMPE_{ijt}}$$

Where *LAB* is total labour compensation, *LABHS* is high skilled labour compensation share in total compensation and *EMPE* is total employees. Subscripts *i*, *j* and *t* stand for country, sector and time.

[23]See Inklaar, R. and Timmer, M. P. (2003) page 4.

All monetary variables have been deflated to constant 1995 prices and converted to US$ using the prince indexes and exchange rates delivered by WIOD database.

Model specification and estimation method

To empirically investigate the link between the transmission of foreign technology and productivity growth in the CEE countries, we adopt two strategies. First, we estimate the growth rate of labour productivity based on equation (2). As shown previously in Section 3, this equation reflects the productivity growth enhancing effects of foreign transactions within an economic growth framework. Concretely, the rate of labour productivity growth is explained in this work by the lag of the per capita value added (lp_{t-1}), as a proxy of the converge effect, the foreign source of technology (foreign R&D) and other control variables that capture the country capability to domestically adopt foreign technology: human capital, domestic R&D and technological gap.[24]
Secondly, in order to check whether the results are similar to those obtained in previous empirical works, we estimate the level of labour productivity. Concretely, we follow here the Coe and Helpman (1995) approach. Assuming a Cobb-Douglas function, Coe and Helpman (1995) show the level of productivity as a function of knowledge capital with a domestic and a foreign component. This last measured as foreign R&D embodied in capital goods from industrial countries (Coe et al. 1997).

For the estimation of the rate of productivity growth, we employ the system Generalized Method of Moments (GMM) approach for dynamic panel data proposed by Arellano and Bover (1995) and Blundell and Bond (1998). This dynamic panel method enables us to consider both the presence of unobserved country and sector specific effects and to deal with the problem of reverse causality or simultaneity. More productive sectors may also need to import more capital goods. Thus, the potential positive impact of foreign transactions on productivity growth, and the possibility of these flows to be attracted by a higher rate of productivity growth are both plausible.[25] Ignoring this effect might lead to overstate the impact of foreign capital inflows and to find spillovers where they do not exist. Moreover, this method does not require finding good instruments as it uses lags of the right hand side variables as instruments.

For the estimation of the level of labour productivity, we use the traditional within-group estimator. The fixed-effects model allows us to control for the unobserved country and sector specific effects although it omits the potential endogeneity problem. However, these estimations offer, on the one hand, an alternative evaluation of the role played by foreign capital imports. On the other hand, they allow us to check the robustness of our previous results. Any discrepancy between both strategies should be interpreted as a warning signal inviting us to interpret with caution the obtained results.

[24] In the endogenous growth models, the past income is usually employed as a proxy of initial efficiency that captures the convergence effect.
[25] The endogeneity or reverse causality of R&D stocks has also been pointed out in other empirical works (see, for instance, Meriküll et al, 2013).

IV. Econometric results

As a benchmark point, we start with estimating simple regressions using only labour productivity (growth rates and levels) and foreign R&D. These preliminary estimations provide an initial valuation of the role played by machinery and equipment imports on productivity. Next, to empirically investigate the channels through which foreign technology diffuses to the productivity, we estimate baseline and extended models, in order to control for the local conditions and technology gap, respectively.

Productivity growth regressions

The results of the preliminary regressions for productivity growth are reported in Table 6. In these estimations, the lag of value added (as a proxy of initial income) and capital imports are the unique explanatory variables. In column 1, we present the aggregate effect of capital imports on productivity growth. Later, in column 2 and 3, we analyze the differential impact of foreign technology in manufacturing and services sector, respectively. Finally, in order to check if countries at different development stages benefit from different sources of foreign technology, we distinguish between less advanced (LA) and more advanced (MA) countries, in columns 4 and 5, respectively. As mentioned previously, we have divided here the sample into two groups according to the per capita GDP and R&D expenditure. Concretely, the group of more advanced countries comprises those CEE countries with a relatively high GDP per capita data and with a per capita R&D expenditure (GERD) in 2012 above the 20% of the EU27average (100%): Czech Republic, Estonia, Hungary, Slovenia and Slovakia. The other group contains the less advanced countries with a per capita R&D expenditure in 2012 below the 20% of the EU27 average: Bulgaria, Latvia, Lithuania, Poland and Romania.

Table 6. Preliminary results. Growth of value added per worker. GMM estimation.

Variable	Total (1)	Manufacturing (2)	Services (3)	LA countries (4)	MA countries (5)
va(-1)	-.075 ***	-0.063 ***	-.061 ***	-.080 ***	-.129 **
	(.013)	(.016)	(.015)	(.0214)	(.053)
foreign R&D	.086 ***	.073 ***	.064 ***	.102 ***	.039 ***
	(.012)	(.016)	(.014)	(.021)	(.008)
N obs	4752	1956	2516	2374	2378
SOSC test	0.20	-1.61	1.91	-0.05	0.28
	[0.84]	[0.11]	[0.06]	[0.96]	[0.78]

Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All regressions include a constant term and time dummy variables. For Second Order Correlation tests the p-values are reported in square brackets.

As can be appreciated, these preliminary estimations confirm our hypothesis that imports of machinery and equipment from more advanced economies exert a positive and significant influence on productivity growth in the CEE countries. Moreover, the beneficial influence of foreign technology seems to be independent on the analyzed sector. The coefficients on foreign R&D, although slightly greater for the manufacturing sector, are positive and significant across industries. However, comparing the results reported in columns 4 and 5, we observe that despite the impact of capital imports is positive and significant in both country groups; the coefficient on foreign technology is noticeably higher for LA countries than for MA countries. We also obtain the predicted negative and significant coefficient on the log of the value added in all regressions, indicating the existence of a converge effect.

These preliminary results however are not taking into consideration other potential sources of productivity growth nor the local capacity to adapt the technology available in more advanced economies. Since the omission of these local factors could lead to an overestimation of the impact of international transmission of technology on productivity, we next present the results of the basic regressions that include domestic R&D and human capital as additional explanatory variables (see Table 7).

Table 7. Basic model. Growth of value added per worker. GMM estimation.

Variable	Total (1)	Manufacturing (2)	Services (3)	LA countries (3)	MA countries (4)
va(-1)	-.366 ***	-.290 ***	-.388 ***	-.311 ***	-.290 ***
	(.063)	(.060)	(.090)	(.047)	(.092)
foreign R&D	.041 ***	.060 ***	-.009	.065 ***	.035 ***
	(.015)	(0.016)	(.029)	(.022)	(.013)
domestic R&D	.007	-.025	.041	-.043	.006
	(.016)	(.016)	(.027)	(.028)	(.015)
hk	.270 ***	.231 ***	.287 ***	.254 ***	.201 ***
	(.043)	(.039)	(.066)	(.032)	(.055)
N obs	3328	1372	1760	950	2378
SOSC test	0.32	-1.01	1.05	1.27	0.03
	[0.75]	[0.31]	[0.29]	[0.20]	[0.97]

Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All regressions include a constant term and time dummy variables. For Second Order Correlation tests the p-values are reported in square brackets.

The estimates obtained in the basic models verify the beneficial influence of foreign technology on productivity, once domestic R&D and human capital have been considered. In the case when the coefficients on foreign R&D are found to be significant, they show a positive sign. Only for the service sector, we obtain a negative and insignificant coefficient on foreign technology. The above regressions also confirm the positive relationship between human capital and productivity growth, with a high significant and positive coefficient on HK in all regressions. However, in the case of domestic R&D there is a lack of significance in these estimates. It seems therefore that domestic technology is does not provide considerable stimulus for productivity growth in the - generally small - countries of Central and Eastern Europe.

As mentioned before, the local capacity to learn and absorb new technology is also related to productivity gap. To explore the extent to which the success of knowledge diffusions is influenced by technological differences, we estimate an extended model including the interaction effects between technology gap with both human capital, as proposed by Nelson and Phelps (1966), and foreign technology, as suggested by Glass and Saggi (1998). The results of these extended models are presented in Table 8.

Table 8. Extended model. Growth of value added per worker. GMM estimation.

Variable	Total (1)	Manufacturing (2)	Services (3)	LA countries (3)	MA countries (4)
va(-1)	-.111 ***	-.059 ***	-.122 ***	-.177 ***	-.249 ***
	(.019)	(.020)	(.026)	(.029)	(.036)
foreign R&D	.034 **	.019 **	.057 **	.078 ***	.029 **
	(.015)	(.027)	(.027)	(.031)	(.012)
domestic R&D	.001	.006	-.017	-.018	-.005
	(.011)	(.009)	(.017)	(.024)	(.010)
hk*gap	.148 **	.211 ***	.119	.302 **	.112 **
	(.014)	(.080)	(.093)	(.124)	(.055)
foreign R&D*gap	.063 ***	.030 ***	.064 ***	.099 ***	.068 ***
	(.014)	(.008)	(.023)	(.023)	(.012)
N obs	3124	1288	1652	882	2242
SOSC test	0.80	-0.99	1.98	1.83	-0.89
	[0.42]	[0.32]	[0.05]	[0.07]	[0.37]

Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All regressions include a constant term and time dummy variables. For Second Order Correlation tests the p-values are reported in square brackets.

Again the initial productivity level and foreign R&D are statistically significant and with the expected signs, showing a strong convergence effect and an important role of capital imports in accounting for productivity growth in CEE countries. As in the previous estimations, domestic R&D shows positive but insignificant effect on productivity growth in all regressions.

Besides, the results in the extended model confirm the Glass and Saggi hypothesis according to which a larger productivity gap would limit the transfer of foreign technology. In other words, being closer to the technology frontier fosters the transfer of foreign technology. This result is highlighted by the positive and significant value of the interaction between foreign R&D and gap variables. However, our results would be contrary to the Nelson-Phelps catch-up hypothesis. With the exception of the services sector, we find a statistically positive significant effect of the interaction between human capital and productivity proximity, indicating that the productivity in countries closer to the technology frontier increases more and that the speed of the technology catch-up rise with the level of human capital.

Productivity level regression

In this section, we perform regressions for the level of productivity using the fixed effect estimation method. The main results are reported in tables 9, 10 and 11. The estimates presented in these tables confirm the existence of a positive influence of capital imports on productivity in the CEE countries, once industry and country specific effects have been considered. As in the GMM regressions, in the fixed-effect model foreign R&D has a positive and significant coefficient that is marginally greater in the manufacturing sector (than in the services sector) and substantially higher for LD countries (than for MD countries). The beneficial impact of a higher human capital endowment seems also to be a robust result, as *hk* is positive and highly significant in all productivity level regressions (see Table 10). However, contrary to the growth productivity regressions, in the fixed effect model an increase in the industry (of a country)'s domestic knowledge stock appears to enhance the level of productivity in that industry. Domestic R&D is positive and strongly significant in the all regressions of the basic model (Table 10).

Table 9. Preliminary results. Value added per worker. Fixed effects estimation.

Variable	Total (1)	Manufacturing (2)	Services (3)	LA countries (4)	MA countries (5)
foreign R&D	0.516 ***	0.588 ***	0.421 ***	0.678 ***	0.247 ***
	(.036)	(.049)	(.053)	(.045)	(.039)
N. obs	5095	2097	2698	2546	2549

Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All regressions include a constant term and time dummy variables.

Table 10. Basic model. Value added per worker. Fixed effects estimation.

Variable	Total (1)	Manufacturing (2)	Services (3)	LA countries (4)	MA countries (5)
foreign R&D	.078 ***	.067 ***	.053 **	.172 ***	.076 ***
	(.017)	(.023)	(0.025)	(.058)	(.018)
domestic R&D	.039 ***	.036 **	.028 *	.010	.0183
	(.012)	(.018)	(.017)	(.036)	(.013)
hk	.741 ***	.820 ***	.709 ***	.705 ***	.637 ***
	(.028)	(.055)	(.024)	(.054)	(.043)
N. obs	3568	1470	1888	1019	2546

Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All regressions include a constant term and time dummy variables.

The introduction of the interactions terms reveals also some unexpected results (Table 11). While the Glass and Saggi hypothesis, showed by the positive estimates for the interaction foreign R&D*gap, holds in the level regressions; The Nelson-Phelps catch-up hypothesis is neither confirmed nor rejected at the standard significance levels.

Overall, our results confirm our hypothesis that imports of machinery and equipment from more advanced economies exert a positive and significant influence on productivity growth in the CEE countries. Moreover, the beneficial influence of foreign technology depends on the level of development and also, to a lesser extent, to the analyzed sector. They also corroborate the relevance of local conditions, and particularly of human capital and the technological distance to the frontier.

Table 11. Extended model. Value added per worker. Fixed effects estimation.

Variable	Total (1)	Manufacturing (2)	Services (3)	LA countries (4)	MA countries (5)
foreign R&D	.211 ***	.229 ***	.174 ***	.485 ***	.133 ***
	(.040)	(.050)	(.060)	(.069)	(.033)
domestic R&D	.206 ***	.238 ***	.179*** ***	.078	.084
	(.026)	(.047)	(.017)	(.050)	(.022)
hk*gap	-.162	-.173	-.186	-.143	-.128
	(.098)	(.261)	(.128)	(.192)	(.082)
foreign R&D*gap	.109 ***	.108 ***	.114 ***	.161 ***	.097 ***
	(.015)	(.029)	(.024)	(.034)	(.012)
N. obs	3364	1386	1780	951	2413

Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. All regressions include a constant term and time dummy variables.

Conclusions

During the decade before the international crisis, productivity at CEE countries has increased spectacularly, leading to an economic growth and a convergence process toward the income of advanced industrial countries. As it has already been shown by others, foreign sources of technology and R&D spillovers have been extremely important for these countries in their productivity growth. Basically, foreign technology can spill over to domestic sectors via FDI or via imported capital goods.

In our paper, we focused on foreign technology diffusion through capital imports as the main determinant of this productivity growth, as the effects of FDI have already been discussed broadly in the literature. In this study, we have taken into consideration the domestically capability to benefit from productivity spillovers. Concretely, in the empirical analysis, and in accordance with the vast relevant literature, we considered domestic technology development and human capital as the main factors that contribute to the absorption of new technologies. We also analyze how the technology catch-up process (technology gap) influences the role of human capital and technology diffusion on productivity enhancing.

Our sample consisted of ten CEE countries in the period of 1995-2009. As a novelty, we split the sample across sectors and into two country groups based on economic development and R&D activity: "less advanced" and "more advanced" countries. We believe that disaggregated estimations might provide more accurate results about the different patterns of technology absorption. Our outcome shows that foreign technology is a significant source for productivity growth in the less advanced countries, and also, although in small amount, in more advanced countries. We found also that industries in the manufacturing sector obtain a slightly higher profit in terms of productivity from foreign spillovers than industries in the services sector. Finally, our findings indicate a positive impact of human capital on productivity. The results also reinforce that the size of the technology gap counts when it comes to succeed in the absorption of foreign technology.

In sum, our findings confirm the idea of the existence of important spillovers from foreign R&D, and particularly from capital imports, that benefit domestic efficiency. However, to implement incentives to foreign transactions are not sufficient to enhance productivity, improving the level of skilled workers should be also viewed as a prime guideline for policy makers.

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Annex

Table A1: Human Capital Index in CEE countries

	Overall index	Education	Health & wellness	Workforce & employment	Enabling environment
Estonia	27	20	22	39	26
Slovenia	32	21	26	41	38
Czech Rep.	33	36	36	36	31
Lithuania	34	23	41	56	36
Latvia	38	30	48	54	43
Poland	49	42	47	63	57
Hungary	54	33	73	77	62
Bulgaria	56	46	33	100	74
Romania	69	57	61	85	83

Source: The Human Capital Report 2013, WEF
Note: Slovak data are not available in the report

Table A2: Economic sectors.

Code	Name	Code	Name
AtB	AGRICULTURE, HUNTING, FORESTRY AND FISHING	G	
C	MINING AND QUARRYING	50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
D		51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
15t16	FOOD , BEVERAGES AND TOBACCO	52	Retail trade, except of motor vehicles and motorcycles; repair of household goods
17t18	Textiles and textile products	H	HOTELS AND RESTAURANTS
19	Leather, leather products and footwear	I	
20	WOOD AND OF WOOD AND CORK	60	Other Inland transport
21t22	PULP, PAPER, PAPER , PRINTING AND PUBLISHING	61	Other Water transport
23	Coke, refined petroleum and nuclear fuel	62	Other Air transport
24	Chemicals and chemical products	63	Other Supporting and auxiliary transport activities; activities of travel agencies
25	Rubber and plastics	64	POST AND TELECOMMUNICATIONS
26	OTHER NON-METALLIC MINERAL	J	FINANCIALINTERMEDIATION
27t28	BASIC METALS AND FABRICATED METAL PRODUCTS	K	
29	MACHINERY, NEC	70	Real estate activities
30t33	ELECTRICAL AND OPTICAL EQUIPMENT	71t74	Renting of m&eq and other business activities
34t35	TRANSPORT EQUIPMENT	L	PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY
36t37	MANUFACTURING NEC; RECYCLING	M	EDUCATION
E	ELECTRICITY, GAS AND WATER SUPPLY	N	HEALTH AND SOCIAL WORK
F	CONSTRUCTION	O	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES

Source: Own elaboration.