

# Global Flows, Local Conditions and Productivity Spillovers: The Case of the Central and Eastern European Countries

## *Flujos globales, condiciones locales y spillovers de productividad: el caso de los países de Europa Central y Oriental*

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### **Abstract**

*The evolution of labour productivity in an economy can be affected by technology transfer through international linkages, as this permits the incorporation of innovation and automation intensive capital goods into the local productive system. Globalization may be an opportunity to promote sustainable growth –within the industry 4.0 framework– in economies with low levels of innovation or automation. In this paper, we analyse the role of global flows and local conditions for a sustainable productivity growth in the EU member states of Central and Eastern Europe. We focus on the imports of capital goods and foreign direct investment (FDI) inflows as main drivers of technology diffusion and productivity spillovers. As productivity also depends on the local capacity for technology adoption, in this work, we control for domestic factors, such as the domestic investment, R&D expenditure, levels of human capital and the quality of local institutions. Our estimates based on panel data models for 2000-2018, confirm that capital imports have been productivity enhancing in Central and Eastern European countries. Evidence that FDI inflows have a positive influence in the transmission of technology is vague or insignificant according to our model. Finally, our estimates show that countries with higher R&D spending, stronger institutions and higher physical and human capital endowments enjoy higher productivity gains.*

**Keywords:** imports of capital goods, FDI, productivity, CEE countries, local conditions.

**JEL Classification:** C23, F14, F21, O33.

### **Resumen**

*La productividad laboral en una economía puede verse afectada por la transferencia de tecnología a través de vínculos internacionales, en tanto que estos movimientos transnacionales permiten la incorporación al sistema productivo local de bienes de capital intensivos en innovación y automatización. La globalización puede contemplarse, así, como una oportunidad para favorecer un crecimiento sostenible en el marco de la industria 4.0 en economías con poca innovación o automatización. En este artículo, analizamos el papel de la globalización y las condiciones locales para un crecimiento sostenible de la productividad en los países miembros de la UE de Europa*

*Central y Oriental. Concretamente, nos centramos en las importaciones de bienes de capital y los flujos de inversión directa extranjera (IED) como principales impulsores de la difusión de tecnología y las mejoras de productividad. Dado que la productividad depende también de las capacidades locales de adopción de nuevas tecnologías, en este trabajo controlamos por factores como son la inversión doméstica, el gasto en I+D nacional, el nivel de capital humano y la calidad de las instituciones locales. Mediante la estimación de un conjunto de modelos de datos de panel para el periodo 2000-2018, nuestros resultados confirman que las importaciones de capital están mejorando la productividad en los Estados miembros de Europa Central y Oriental. Sin embargo, la evidencia de una influencia positiva de las entradas de IED en la transmisión de tecnología, aunque positiva, se muestra poco robusta. Por último, nuestras estimaciones muestran que aquellos países con un mayor gasto en I+D, instituciones más fuertes y una mayor dotación de capital físico y humano disfrutaron de mayores ganancias de productividad.*

**Palabras clave:** importaciones de bienes de capital, IED, productividad, condiciones locales.  
**Clasificación JEL:** C23, F14, F21, O33.

## 1. Introduction

Assessing how the transfer of technologies may affect long-term growth and employment via international linkages has long been at the centre of economic debates. This question is of particular interest for economies with relatively low level of domestic R&D expenditures, as it is the case of the Central and Eastern European (CEE) countries. The diffusion of technology from the most advanced economies to these countries offers them the opportunity to approach the world technological frontier, increasing their innovation capacity and long-term growth (Fatima, 2017). This refers also to clean, environment friendly technologies, which have become increasingly important for companies and policy makers. Technology flows across international borders through numerous channels. Among these external factors, we concentrate on imports of capital goods and inward foreign direct investment (FDI) as the main drivers of international technology diffusion and productivity growth. Following the recent literature,<sup>1</sup> we make a special mention on automation and industry 4.0, but we focus on productivity gains that stem from the imports of capital goods.

Apart from the mentioned factors, we emphasize the significance of local capacity to adopt new technologies, referring to domestic investment in physical capital, R&D and to political (institutional) stability and quality of human resources. Along these lines, we construct an empirical model, the results of which confirm the importance of capital imports, foreign and domestic investment, R&D expenditure, institutional stability, and human skills.

The rest of the paper is organized as follows: Section 2 provides an overview of the theoretical and empirical literature analysing international technology diffusion. In Section 3, we present the evolution of productivity and some contributing factors in the CEE region. The econometric model and estimation results are described in the next section. The final section concludes with a policy discussion and suggestion for future research on the topic.

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<sup>1</sup> See, for instance, Domini et al. (2019).

## 2. Brief theoretical and literature review

After the changes in the political system and integration into the EU (and before the economic crisis), labour productivity grew spectacularly in the new EU member states. The increase in this kind of competitiveness was the main stimulus to economic growth and the driving force 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) wrote, the innovation effort in CEE countries had been modest and differences in knowledge creation between CEE and EU had been even greater than the differences in income. External sources of productivity such as foreign investment and trade had been crucial in their economic catching-up process by stimulating knowledge transfers and innovation (IBRD, 2008).

International technology diffusion through capital imports has been broadly studied in the economic literature. The transfer of knowledge embodied in the trade of capital goods was already underlined by Rivera-Batiz and Romer (1991). Since then, there 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 spread around the world through trade and patenting. Similarly, Keller's model (2004) predicts that the import patterns of countries are relevant to their productivity behaviour. Specifically, it shows how a country that imports primarily from a leader country receives more technology embodied in intermediate goods than another country that imports from follower countries. Coe and Helpman (1995), and Coe et al. (2009) confirm this hypothesis showing empirically that countries which are more open to machinery and equipment imports from the world's technology leaders have also experienced faster growth. Similarly, Cuadros and Alguacil (2014) find that imports of capital goods have a positive influence on productivity growth in developing economies. Some empirical works investigated the links between foreign transactions and productivity in the CEE countries (Holland & Pain, 1998 and Bijsterbosch & Kolasa, 2010). These papers analyse the impact of capital imports on economic performance across countries using aggregate data (Kutan & Yigit, 2009) or firm-level data, but concentrating on one specific country (such as Halpern et al., 2015, for Hungary). Meriküll et al. (2013) apply industry-level data, investigating the effect of foreign R&D stock on the productivity level for six CEE countries between 1995 and 2007. Alguacil et al. (2015) provide additional evidence on the linkages between the international transfer of technology and productivity in the CEE member states, considering the stock of knowledge embodied in capital goods imports from advanced countries to be the main driver of technology diffusion. In this work, there is a special focus on the role played by local conditions in the assimilation of foreign technology, and particularly on the level of physical and human capital, domestic R&D, and institutional stability.

The article of Békés and Harasztosi (2020) focuses on machine import and technology adoption. Their results suggested that an additional local importer in the firm's vicinity increases the probability of importing that particular machine considerably. The analysis found that the specific nature of machine, even within a type of imported machine, and the origin of the product matter in the extent of spillovers.

In the past years, with the spreading of industry 4.0 concept and the decrease of robot prices, installation of imported robots incremented in CEE countries (see later). In the recent literature, the benefits in productivity from a higher robot intensity has been revealed as a robust finding in both developed and less developed countries (see, among others, Graetz & Michaels, 2018, and De Backer et al., 2018). According to Domini et al. (2019) imports of goods embedding automation technologies are positively correlated with growth in employment.

A broad number of studies have also addressed the productivity benefits of the entry of FDI. Comprehensive surveys about empirical evidence on the FDI efficiency spillovers for both developed and developing countries can be found in Bijsterbosch and Kolasa (2010) and Cuadros and Alguacil (2014). The different mechanisms through which the diffusion of technology by FDI occurs are well documented in the literature. Some explanations on the positive effects of FDI as technology source are related with the fact that multinational subsidiaries tend to be larger and more technologically intensive than the average firms in the host country (Cuadros & Alguacil, 2014). Foreign firms bring superior technology, providing domestic firms the opportunity to learn and upgrade their technologies. The presence of foreign firms can also induce greater competition within the industry forcing some local firms to improve efficiency (Byungchae et al., 2019). An alternative mechanism refers to the transfer of workers' skills. The staff of foreign firms with advanced technology or those sent to their domestic subsidiaries can bring their new skills and knowledge to domestic firms (see Park et al., 2016 and Seck, 2012).

Recent papers have also related FDI with the industry 4.0. For Horváth and Szabó (2019), multinational enterprises are in better position to adopt the technologies that comprise the industry 4.0 than small and medium firms. Multinationals have higher driving forces and lower barriers for the industry 4.0 implementation. The driving forces of this phenomenon are related, among other things, with the capacity to increase innovation and opportunities for business, and with higher efforts to save energy and improve sustainability. The barriers are more linked with financial constraints and limits of coordination or human skills endowments.

However, productivity spillovers from capital imports and FDI may be constrained by the limited ability of countries to adopt new technologies, as pointed out by Cuadros and Alguacil (2014) and Bijsterbosch and Kolasa (2010). 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 & Spiegel, 1994; Coe et al., 2009; Seck, 2012). According to Benhabib and Spiegel (1994), for instance, human capital facilitates

the adoption of technology from abroad and enhances the creation of domestic technology. Similarly, Smith and Thomas (2017) show that regions with higher level of human capital benefit more from the FDI related spillovers. According to Griffith et al. (2004) and Keller (2004) domestic research and development expenditure is a key factor for successfully adopting foreign technology.

Other authors such as Alguacil et al. (2011), Manca (2010), Coe et al. (2009) and Seck (2012) emphasize the role played by the institutional framework in providing the necessary background for technology adoption. According to Manca (2010), institutional quality differences largely explain the differences in the speed at which countries imitate and adopt technologies. Thus, a favourable institutional environment may increase spillovers from FDI (Cuadros & Alguacil, 2014). Institutional development captures factors such as rule of law, the degree of corruption, the quality of public management, and the protection against property rights infringements and discretionary government interference (Nunnenkamp & Spatz, 2004). In certain CEE countries, corrupt political elite captured the state that distorts the functioning of institutions. In a captured state, rent seekers are prone to look for the grace of government in forms of regulation, practices or judiciary system, instead of being involved in a fair competition. Corruption happens with a systemic and partial redistribution of resources (Martin, 2020).

For Papaioannou and Dimelis (2019), the impact of FDI on total factor productivity growth depends also on regulatory conditions in the network industries of energy, transport, and communications. Considering a set of OECD countries, these authors find a significant positive influence on the FDI-productivity growth relationship as the upstream regulation decreases.

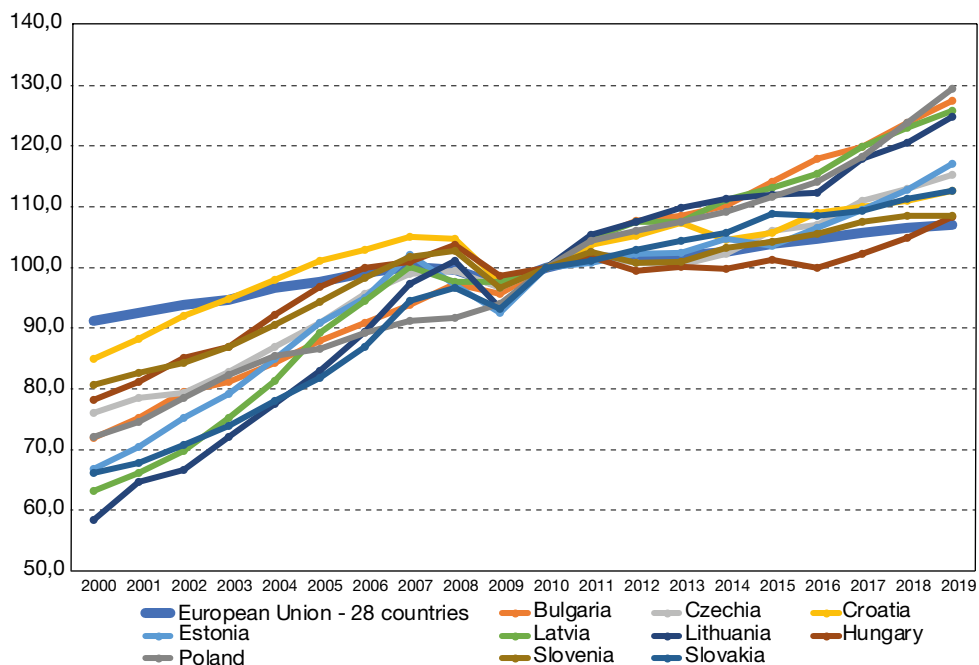
### **3. Productivity development of CEE economies and some contributing factors**

The ten CEE countries started from a considerably lower level of productivity than the EU average in 2000. However, from this year onward –as seen in Figure 1– the increase of real labour productivity<sup>2</sup> had been very high. After the financial crisis, the CEE group seems to be divided into two parts: Poland, Latvia, Lithuania and Bulgaria have experienced rapid growth of productivity, because of a catch-up process starting from a lower base and because of structural changes in the economy (shift from agriculture to services, high productivity of export sector, increasing employment). The other groups' productivity increase has been more modest. Still, all CEE countries (except for Hungary) could outpace the EU average rate.

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<sup>2</sup> GDP/total employment, basic data in PPS.

**FIGURE 1**  
**REAL LABOUR PRODUCTIVITY PER PERSON, 2010= 100**

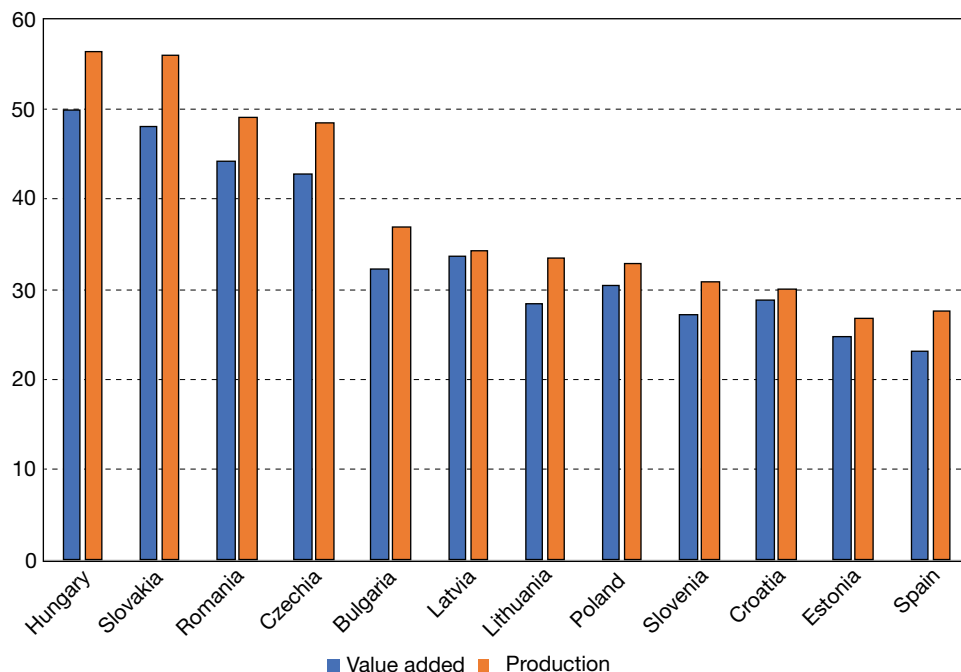


**SOURCE:** Eurostat.

The Hungarian (almost stagnating) productivity rate after 2010 called the attention of some researchers. Baksa and Kónya (2019) concludes that mostly the slowdown in total factor productivity (TFP) convergence is responsible for the sustained sluggish growth of Hungarian productivity. As Murakózy et al. (2018) analyse, there are large productivity differences within industries and between small and large firms. A comparison to the global frontier suggests that even top Hungarian firms are significantly behind top global firms in terms of productivity.

The behaviour of productivity in these economies had been influenced by foreign direct investment, the activity of foreign multinationals and technology spillovers. The massive inflow of FDI and its role in Central and Eastern European development is well known. Foreign-owned companies, affiliates of multinationals have a determining role in production, employment, and export of these countries. Figure 2 shows that their shares in production and value-added is around 30 % in most cases (extremely high in Hungary and Slovakia).

**FIGURE 2**  
**SHARE OF FOREIGN CONTROLLED ENTERPRISES IN VALUE ADDED**  
**AND PRODUCTION, 2017**



NOTE: Spain figure is given for the sake of comparison.

SOURCE: Own calculations based on Eurostat FATs and SBS statistics.

As mentioned, the import of modern machinery also contributes to the increase of productivity. In the past years, the price of industrial robots decreased and robotisation has spread worldwide. Together with other modern and digital technologies, the concept of industry 4.0 has been introduced and has become widespread.

According to Rüßmann et al. (2015) industry 4.0 has nine pillars: big data, autonomous robots, simulation, horizontal and vertical system integration, industrial internet of things, cybersecurity, cloud, additive manufacturing, and augmented reality. The real novelty of industry 4.0 is the smart decision support systems, production planning and scheduling that optimise capacity utilisation, maintenance and energy management and communication with faraway team members.

Robotisation is spreading in the CEE countries at a large pace (see Table 1), but robot density is still not high in this region compared to core-EU members.

**TABLE 1**  
**INDUSTRIAL ROBOTS PER 10,000 EMPLOYEES**

	<b>2016</b>	<b>2018</b>	<b>% growth</b>
Germany	309	338	9.39
Sweden	223	247	10.76
Denmark	211	240	13.74
Italy	185	200	8.11
Belgium	184	188	2.17
Spain	160	184	15.00
Netherlands	153	182	18.95
Austria	144	175	21.53
Slovenia	137	174	27.01
Slovakia	135	165	22.22
France	132	154	16.67
Finland	138	140	1.45
Czech Republic	101	135	33.66
United Kingdom	71	91	28.17
Hungary	57	84	47.37
Portugal	58	68	17.24
Poland	32	42	31.25
Greece	17	23	35.29
Romania	15	21	40.00
Estonia	11	19	72.73
Croatia	5	7	72.73

**SOURCE:** International Federation of Robotics (World Robotics 2019).

The severe labour shortage in certain CEE countries can be an incentive for automation of the production process and digitalisation of services. A kind of indicator for labour shortage is the job vacancy rate (see Table 1 in the Annex). It can be seen that job vacancies in the Czech Republic are the most acute and in Latvia and Hungary labour shortage also has, become serious.

The CEE countries have sound industrial base, but their progress in introducing industry 4.0 elements provides a mixed picture. Naudé et al. (2019) analyse the industry 4.0 readiness of the Central and Eastern European countries and find that the best performers are the Czech Republic, Slovenia and Hungary while the lowest ranked ones are Romania, Bulgaria and Poland.

Regarding industry 4.0 technologies there is a kind of dichotomy in the CEE countries, foreign multinational affiliates (and large domestic firms too) are more able and willing to introduce these technologies than domestic SMEs (small and



medium enterprises). This is partly because SMEs are different from large firms anyway in several aspects (financial constrain, informal organizational structure, less collaboration with R&D and educational centres, etc.). The other reason of the duality is the attitude and weak capabilities of most SME-managers. Companies still lack their own industry 4.0 strategy and they have not assigned responsible personnel to take care of that. Benefits of industry 4.0 are unclear and in many cases, high costs are associated with its application (Éltető, 2020).

Although industry 4.0 has an impact on productivity, we cannot include properly this concept to our model. The reason is that industry 4.0 is a very complex decision, support and production organisation system, consisting in several elements from cybersecurity to virtual reality, real time machine-to-machine communication, etc. Data for all these elements are simply not available (especially not on aggregate country level).

#### **4. Local conditions enhancing productivity: domestic investment and innovation, human capital and political stability**

The experiences of implementation of industry 4.0 in the CEE region prove the opinion of Bijsterbosch and Kolasa (2010). The authors claim that FDI inflows as such may not necessarily be sufficient to ensure an increase in productivity. The extent to which these flows are translated into technological progress and productivity growth depends on the absorptive capacity of the sector and the country and on the levels of basic technological literacy and advanced skills. Regarding local technological advances, there has been a growing convergence in the research and development efforts of CEE countries with respect to the EU average level, however, this convergence is heterogeneous in its pace and degree (see Table 2). Slovenia, Czech Republic and Estonia are the best performers, showing the highest level in per capita R&D spending. By contrast, Romania and Bulgaria are those with the lowest spending on R&D (per person) of all CEE countries.

Research and development can be financed by the business sector, by the government, and from abroad. The share of the business sector financing is similar to the EU average in Czechia, Poland and Romania and higher than average (more than 70 %) in Hungary, Bulgaria, Slovenia.<sup>3</sup> Following the transition period, CEE countries exhibited rising innovative activity either in own inventions or co-inventions. Regarding the number of patent applications relative to million inhabitants until 2019, Slovenia, and Estonia have outstanding results and at the other end, Romania, Bulgaria, Croatia show very low figures.<sup>4</sup>

Concerning the human capital, the economic literature describes its endowment as a direct determinant of productivity, as well as one of the main factors of absorptive capacity. Based on Coe et al. (2009), many empirical works include human capital as a

<sup>3</sup> Eurostat data for 2018.

<sup>4</sup> Eurostat data on patent application to the European Patent Office.

**TABLE 2**  
**RATIO OF TOTAL R&D EXPENDITURE (GERD) PER CAPITA, (EU28 = 100)**

	2004	2007	2010	2013	2016	2018
Bulgaria	3.2	4.0	5.9	6.7	8.8	9.2
Croatia	20.3	17.5	15.9	15.3	16.1	18.6
Czechia	27.4	38.1	48.0	52.5	47.0	57.5
Estonia	15.3	28.0	35.6	45.5	34.4	42.2
Latvia	5.2	12.4	10.4	12.7	9.4	14.7
Lithuania	10.2	15.5	14.2	20.6	19.0	23.1
Hungary	18.1	21.1	22.9	26.3	23.3	31.9
Poland	7.6	10.1	14.0	16.6	18.6	24.1
Romania	2.8	6.7	5.7	5.1	6.9	8.0
Slovenia	48.2	54.1	74.2	83.7	65.8	65.7
Slovakia	8.2	10.2	15.7	20.8	19.8	21.0

**SOURCE:** Own calculations based on Eurostat data.

source of productivity growth (Seck, 2012). The quality of human capital depends on education, skills and creativity, and it is not easy to measure. Conventional indicators of education graduation and enrolment rates, PISA results and state expenditure on education are used to qualify the available human capital of a country. Certainly, most indices have their drawbacks (Kwon, 2009) and occasionally new or composite indicators are invented. In this article, we employ “human resources in science and technology” covering those people who have successfully completed a tertiary level education and/or are employed in a science and technology occupation. As shown in Table 3, the Baltic countries and Slovenia have the highest shares in this respect and Romania, Bulgaria have the lowest ones.

Similarly, to tertiary education, there is a heterogeneity in the quality of education and knowledge among CEE countries. Table A2 in the Annex shows the share of those students who are underachieving (below basic skill level) in mathematics, reading and science fields. Again, Bulgaria and Romania have the worst results and Estonia, Poland, Slovenia have the best ones.

Quality of human capital has been declining in the CEE countries because of the emigration of talented youth. Not only financial motivations can be triggers for emigration but also the local political situation and instability of democracy –as lately in Hungary and Poland. A prominent feature of this is the institutionalised corruption. According to the Transparency International’s Corruption Perception Index<sup>5</sup>, Bulgaria, Romania and Hungary are in the worst position (rank 70 or below) and Estonia, Lithuania and Slovenia have the least extent of corruption (rank 18, 35).

<sup>5</sup> [https://images.transparencycdn.org/images/2019\\_CPI\\_Report\\_EN\\_200331\\_141425.pdf](https://images.transparencycdn.org/images/2019_CPI_Report_EN_200331_141425.pdf)

**TABLE 3**  
**PERCENTAGE OF ACTIVE POPULATION WITH TERTIARY EDUCATION**  
**AND/OR EMPLOYED IN SCIENCE AND TECHNOLOGY,**  
**FROM 25 TO 64 YEARS**

	<b>2000</b>	<b>2004</b>	<b>2008</b>	<b>2012</b>	<b>2016</b>	<b>2019</b>
Bulgaria	29.7	31.2	31.4	32.8	36.8	36.6
Czechia	31.5	32.8	37.1	36.6	38.7	39.8
Estonia	39.5	42.1	44.4	49.2	49.1	53.6
Croatia	–	27.9	29.0	31.5	37.4	40.1
Latvia	31.4	30.7	39.4	40.1	43.3	46.8
Lithuania	47.7	34.9	42.3	43.9	49.1	51.9
Hungary	29.6	31.8	33.3	35.6	36.3	38.2
Poland	25.1	28.3	33.4	37.7	42.8	46.0
Romania	18.4	21.2	23.8	25.5	27.6	28.2
Slovenia	30.6	35.8	40.1	42.8	46.5	48.2
Slovakia	27.7	28.8	32.0	32.5	34.2	38.1

**SOURCE:** Eurostat.

## 5. Empirical strategy

In order to investigate empirically the various channels through which foreign technology affects productivity in the CEE countries, we estimate a set of panel data models for the period 2000-2018.<sup>6</sup> We focus on the eleven CEE countries that are members of the European Union: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. Table 4 presents detailed information about the sources and definition of variables.

In these models, we employ two alternative endogenous variables: labour productivity index and valued added per capita. As our main regressors, we have imports of machinery and transportation equipment (*IMP\_K*) and the inflows of foreign direct investment (*FDI*). We also include net investment expenditure in nonfinancial assets to capture domestic capacity to invest. In an extended model, we consider also other control variables as human capital, domestic R&D, and the quality of institutions that capture the country's capability to adopt foreign technology and to improve productivity. We examine how the skills of workers in the home country and the process of technology adoption may enhance productivity growth, by adding the variable Human Resources in Science and Technology as a share of the active population (*HK*). The domestic source of new technology is measured

<sup>6</sup> The period of analysis was selected due to the availability of data.

**TABLE 4**  
**DEFINITION AND SOURCES OF VARIABLES**

Variable	Definition	Source
<i>Labour productivity</i>	Real labour productivity (GDP per total employment), 2010 = 100	EUROSTAT statistics
<i>Value added per capita</i>	Total value added in millions (US dollars at constant prices, 2015) /- Total population in thousands (log values)	UNCTAD database
<i>IMP_K</i>	Imports of machinery and transportation equipment, as a percentage of GDP (log values)	EUROSTAT statistics
<i>FDI</i>	FDI inflows in millions, deflated by CPI 2010 (log values)	UNCTAD database
<i>HRST</i>	Human resources in science and technology as a percentage of the active population in the age group 25-64 (log values)	EUROSTAT statistics
<i>INV</i>	Net investment in nonfinancial assets (% of GDP)	International Monetary Fund, Government Finance Statistics.
<i>CC</i>	Worldwide Governance Indicator of Control of Corruption, percentile rank	World Bank. (Kaufmann et al. 2010)
<i>RD</i>	Research and development expenditure (% of GDP)	UNESCO Institute for Statistics

here by the R&D expenditure as a percentage of GDP (*RD*). Finally, to capture the role of the institutional framework, following Morrissey and Udomkerdmongkol (2012) and Cuadros and Alguacil (2014), we use the Worldwide Government Indicators. In this article, we employ the Control of Corruption (*CC*) indicator, because corruption can basically undermine the functioning of many institutions.<sup>7</sup> Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as “capture” of the state by elites and private interests. Percentile rank indicates the country’s rank among all countries with 0 the lowest rank (highest corruption), and 100 the highest rank (lowest corruption).

<sup>7</sup> Under the Hungarian political regime, for example, since 2010 an informal network of politicians and oligarchs have captured the institutions with the aim of ensuring their power and channeling resources towards cronies and clients. The control institutions have been eliminated, which increased corruption risks. The public procurement system works differently on paper and in practice. Favouritism and resource reallocation concerns also the distribution of EU funds, state aid to big companies, strategic partnership agreements and the unorthodox spending of the Hungarian central bank (Martin, 2020).

Accordingly, we estimate the following econometric model:

$$Y_{c,t} = \beta_0 + \beta_1 IMP\_K_{c,t} + \beta_2 FDI_{c,t} + \beta_3 INV_{c,t} + \beta_4 HK_{c,t} + \beta_5 RD_{c,t} + \beta_6 CC_{c,t} + \eta_c + \tau_t + \varepsilon_{c,t}$$

where  $c$  stands for each country and  $t$  denotes time.  $Y_{c,t}$  represents labour productivity or total valued added per capita. The disturbances  $\eta_c$ ,  $\tau_t$  and  $\varepsilon_{c,t}$  that represent time-invariant differences across countries, time effects and the random error, respectively, are assumed to have the standard properties.

Tables 5 and 6 below present the estimate coefficients of the previous model for labour productivity and total valued added per capita, respectively. In the first two columns, we present the outcomes for the basic model, and in the last two columns for the extended model.

**TABLE 5**  
**ESTIMATION RESULTS OF LP ON FOREIGN TECHNOLOGY TRANSFER.**  
**CEE COUNTRIES (2000-2018)**

<b>Dep. Variable: Labour productivity (LP)</b>	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>
<i>IMP_K</i>	0.384*** (0.040)	0.174*** (0.031)	0.127*** (0.329)	0.134*** (0.027)
<i>FDI</i>	0.004 (0.013)	0.003 (0.007)	0.009* (0.005)	0.0133* (0.008)
<i>INV</i>	0.024* (0.13)	0.011* (0.006)	0.017** (0.009)	0.009* (0.005)
<i>HK</i>	—	—	0.188*** (0.017)	0.028* (0.013)
<i>RD</i>	—	—	0.124*** (0.031)	0.044* (0.021)
<i>CC</i>	—	—	0.006*** (0.002)	0.006*** (0.001)
<i>Intercept</i>	5.174*** (0.122)	4.526*** (0.082)	3.374*** (0.180)	4.003*** (0.114)
Country effects	YES	YES	YES	YES
Time effects	NO	YES	NO	YES
n. obs.	174	174	174	174
<i>F</i> -test [p-value]	8.42 [0.000]	65.90 [0.000]	67.96 [0.000]	81.42 [0.000]

NOTE: Robust standard errors are in parentheses. \*, \*\*, \*\*\* denote significance at the 10 %, 5 % and 1 % levels, respectively. The *F*-test statistic test the whole significance of the model.

**TABLE 6**  
**ESTIMATION RESULTS OF VA ON FOREIGN TECHNOLOGY TRANSFER.**  
**CEE COUNTRIES (2000-2018)**

Dep. Variable: value added per capita (VA)	(1)	(2)	(3)	(4)
<i>IMP_K</i>	0.388*** (0.038)	0.155*** (0.031)	0.190*** (0.316)	0.102*** (0.030)
<i>FDI</i>	0.0094 (0.013)	0.006 (0.007)	0.011* (0.005)	0.005* (0.006)
<i>INV</i>	0.029* (0.13)	0.010 (0.007)	0.013 (0.009)	0.007 (0.006)
<i>HK</i>	–	–	0.176*** (0.017)	0.029** (0.014)
<i>RD</i>	–	–	0.116*** (0.030)	0.042* (0.023)
<i>CC</i>	–	–	0.006*** (0.002)	0.005*** (0.001)
<i>Intercept</i>	3.683*** (0.121)	3.052*** (0.089)	2.022*** (0.173)	2.552*** (0.125)
Country effects	YES	YES	YES	YES
Time effects	NO	YES	NO	YES
n. obs.	174	174	174	56.33
<i>F</i> -test [p-value]	37.94 [0.000]	56.35 [0.000]	61.92 [0.000]	81.42 [0.000]

NOTE: Robust standard errors are in parentheses. \*, \*\*, \*\*\* denote significance at the 10 %, 5 % and 1 % levels, respectively. The F-test statistic test the whole significance of the model.

Our estimations verify that, once domestic local conditions are considered, imports of machinery and transport equipment exert a beneficial influence on labour productivity and on value added per capita in the CEE countries. The positive influence of imports of capital goods (*IMP\_K*) is clear and very robust in all regressions, confirming the relevance of this channel of technology transfer to enhance productivity growth in these economies.

We also obtained the predicted positive coefficient on *FDI*. However, this variable is barely or not significant. The weak results of *FDI* variable can be explained by the specificities of *FDI* inflow data. These net inflows of investment are the sum of equity capital, reinvested earnings and other long-term and short-term capital as shown in the balance of payments. The data show net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors. *FDI* data registered at the national banks are in most cases distorted by the financial transactions of special purpose entities, capital in transit or portfolio manipulations of companies. These kind of capital flows do not have effects on the real economies (Antaloczy & Sass, 2015).

Our estimations further support the positive relationship between domestic human skills and productivity growth. The coefficient on human capital variable is positive and significant (although its significance is abruptly reduced when we consider time effects). In the case of domestic investment, although the coefficient on *INV* is positive and significant in the explanation of labour productivity, its significance in the valued added per capita regressions is not robust.

With highly significant and positive coefficients on *CC* and *RD* in all regressions, the above estimates confirm that good governance and domestic R&D expenditure are positively related with productivity behaviour. These outcomes corroborate the productivity augmenting effect of strongly controlled corruption and domestic technology advances.

In sum, the findings in this work verify our hypothesis of the existence of important spillovers from foreign transactions, and particularly from capital imports, that benefit domestic productivity. However, to implement incentives to stimulate foreign transactions it is not enough to enhance productivity, since improving the quality of institutions, domestic technology and the level of skilled workers should also be viewed as a prime guideline for policy makers.

## 6. Conclusion

During the decade before the international economic crisis, productivity in CEE countries increased spectacularly, driving economic growth and a process of convergence with advanced industrial countries. As others have shown, foreign sources of technology and R&D spillovers have played an extremely important role for these countries in their productivity growth.

We focused on foreign technology diffusion through capital imports and FDI inflows as the main determinants of productivity growth, factoring for the local conditions that influence productivity spillovers. In particular, we considered human capital and institutional quality as the main factors that contribute to the absorption of new technologies and to productivity gains in our empirical analysis.

Our sample consisted of eleven CEE countries over the period of 2000-2018. The results from a set of panel data models support our initial hypothesis that foreign transactions, and particularly capital imports, lead to sustainable gains in productivity, since these entries allow the incorporation of innovation and automation intensive capital goods into domestic production processes. In addition, the outcomes confirm our initial idea that human capital, domestic R&D and institutional development (strong containment of corruption in our model) have a direct positive effect on productivity. It also manifested that the CEE region is not homogeneous, certain countries perform similarly to core-EU members while some have much worse indicators. The gap can be large between the most and least advanced countries.

FDI –meaning the investment activity of foreign firms– clearly has important spillover effects in CEE economies. It impacts technology transfer and productivity,

but this is not captured by general BoP FDI inflow data. The traditionally highly skilled Central European human capital had been an important factor attracting foreign companies, but this advantage is receding in certain countries due to labour shortages and declining education. Similarly, worsening corruption and increasing political instability can deteriorate FDI in certain CEE countries, which can negatively affect productivity in the future.

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## ANNEX

**TABLE A1**  
**JOB VACANCY RATE - ANNUAL DATA**

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU 28	:	:	1.2	1.4	1.4	1.4	1.5	1.6	1.8	2.0	2.2	2.3
Bulgaria	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.9	0.8	0.9	0.9
Czechia	3.2	1.1	0.8	0.9	1.0	0.9	1.3	2.2	2.9	3.8	5.5	6.2
Estonia	2.5	0.9	1.0	1.3	1.4	1.4	1.4	1.5	1.7	2.1	1.9	1.9
Croatia	:	:	:	:	1.0	0.8	0.9	1.1	1.6	1.7	1.7	1.5
Latvia	1.6	0.9	0.9	1.3	1.4	1.6	1.4	1.5	1.6	1.9	2.5	3.1
Lithuania	1.7	0.5	0.6	0.9	0.9	0.9	1.0	1.1	1.3	1.6	1.5	1.4
Hungary	1.3	0.9	1.0	1.1	1.0	1.3	1.4	1.6	1.9	2.3	2.7	2.5
Poland	1.5	0.6	0.6	0.6	0.4	0.4	0.5	0.6	0.8	1.0	1.2	1.1
Romania	2.0	0.9	0.6	0.6	0.6	0.7	0.9	1.1	1.3	1.3	1.3	1.1
Slovenia	1.0	0.7	0.7	0.8	0.8	0.8	1.2	1.3	1.7	2.2	2.5	2.3
Slovakia	1.3	1.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.2	1.1

NOTE: The job vacancy rate (JVR) is the number of job vacancies expresses as a percentage of the sum of the number of occupied posts and the number of job vacancies:  $JVR = \text{number of job vacancies} / (\text{number of occupied posts} + \text{number of job vacancies}) \times 100$ .

SOURCE: Eurostat.

**TABLE A2**  
**UNDERACHIEVING 15-YEAR-OLD STUDENTS - PISA SURVEY**

<b>Mathematics</b>					
	<b>2006</b>	<b>2009</b>	<b>2012</b>	<b>2015</b>	<b>2018</b>
Bulgaria	53.4	47.1	43.8	42.1	44.4
Czechia	19.3	22.4	21.0	21.7	20.4
Estonia	12.1	12.7	10.5	11.2	10.2
Croatia	28.7	33.2	29.9	32.0	31.2
Latvia	20.8	22.6	19.9	21.4	17.3
Lithuania	23.1	26.4	26.0	25.4	25.6
Hungary	21.2	22.3	28.1	28.0	25.6
Poland	20.0	20.5	14.4	17.2	14.7
Romania	52.9	47.0	40.8	39.9	46.6
Slovenia	17.8	20.4	20.1	16.1	16.4
Slovakia	21.0	21.0	27.5	27.7	25.1
<b>Reading</b>					
	<b>2006</b>	<b>2009</b>	<b>2012</b>	<b>2015</b>	<b>2018</b>
Bulgaria	51.1	41.0	39.4	41.5	47.1
Czechia	24.8	23.1	16.9	22.0	20.7
Estonia	13.6	13.3	9.1	10.6	11.1
Croatia	21.5	22.4	18.7	19.9	21.6
Latvia	21.2	17.6	17.0	17.7	22.4
Lithuania	25.7	24.4	21.2	25.1	24.4
Hungary	20.6	17.6	19.7	27.5	25.3
Poland	16.2	15.0	10.6	14.4	14.7
Romania	53.5	40.4	37.3	38.7	40.8
Slovenia	16.5	21.2	21.1	15.1	17.9
Slovakia	27.8	22.2	28.2	32.1	31.4
<b>Science</b>					
	<b>2006</b>	<b>2009</b>	<b>2012</b>	<b>2015</b>	<b>2018</b>
Bulgaria	42.6	38.8	36.9	37.9	46.5
Czechia	15.5	17.3	13.8	20.7	18.8
Estonia	7.7	8.3	5.0	8.8	8.8
Croatia	17.0	18.5	17.3	24.6	25.4
Latvia	17.4	14.7	12.4	17.2	18.5
Lithuania	20.3	17.0	16.1	24.7	22.2
Hungary	15.0	14.1	18.0	26.0	24.1
Poland	17.0	13.1	9.0	16.3	13.8
Romania	46.9	41.4	37.3	38.5	43.9
Slovenia	13.9	14.8	12.9	15.0	14.6
Slovakia	20.2	19.3	26.9	30.7	29.3

**SOURCE:** OECD [educ\_outc\_pisa]