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THE DIGITAL ECONOMY, ICT AND ECONOMIC GROWTH IN THE CEE COUNTRIES

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Key words: ICT, digital economy, economic growth, CEE countries.

Abstract

This paper focuses on the relationship between Information and Communication Technologies, GDP growth and productivity in the Central and Eastern European (CEE) countries. It elaborates on measures of the digital economy/information society, emphasizing the role of complementary factors to ICT that are crucial for the productive use of these General Purpose Technologies. The paper discusses the impact of technical progress, induced by the development of ICT, on sources of economic growth by describing changes in the contribution of ICT capital and non-ICT capital, labour and TFP to GDP growth in the CEE and EU-15 countries.

GOSPODARKA CYFROWA, TIK I WZROST GOSPODARCZY W KRAJACH EUROPY ŚRODKOWO-WSCHODNIEJ

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Słowa kluczowe: TIK, gospodarka cyfrowa, wzrost gospodarczy, kraje Europy Środkowo-Wschodniej.

Abstrakt

Artykuł koncentruje się na zależnościach między technologiami informacyjnymi i komunikacyjnymi (TIK), wzrostem PKB i produktywności w krajach Europy Środkowo-Wschodniej (EŚW). Omawia różne mierniki rozwoju gospodarki cyfrowej/społeczeństwa informacyjnego, podkreślając rolę czynników komplementarnych wobec TIK, które są najważniejsze dla produktywnego wykorzystania tych technologii ogólnego zastosowania. W artykule przedstawiono wpływ postępu technicznego, indukowanego rozwojem TIK, na źródła wzrostu gospodarczego, opisano zmiany we wkładzie kapitału TIK, pozostałego kapitału, nakładów pracy i TFP we wzrost PKB w krajach EŚW i UE-15.

Introduction

Information and Communication Technologies (ICT) have become ubiquitous in the modern world – they are present in virtually all areas of economic and social life, noticeably changing how people behave and interact with each other, how companies run their businesses and how governments provide public services. It has been emphasized that ICTs are assumed to be, through the channel of technical progress, one of the major determinants of economic changes in the developed and developing countries. These profound changes in work organization, the structure of labour demand, in enterprise business processes, should ultimately result in productivity increases, thus enhancing GDP growth. This in turn, may play a crucial role in the convergence processes between developing and developed economies, by creating a leapfrogging effect related to ICT utilization in developing countries.

The aim of this paper is to elaborate on the sources of economic growth in selected Central and Eastern European (CEE) countries that are Member States of the European Union, to identify in which countries the potential of ICT has been utilized in the most productive way to enhance economic growth. The paper refers to the concept of the digital economy and ICT-driven convergence processes. A special focus was put on human capital, which is a complementary factor required to unlock the potential of ICT. The analysis was conducted at the macro-level, however some remarks also concern micro and meso levels as well.

ICT, productivity and economic growth – literature review

The impact of ICT on economic growth and productivity has often been analyzed with the use of growth accounting methodology as proposed by SOLOW (1957), which was further developed by JORGENSON and GRILICHES (1967), OLINER and SICHEL (2000), and JORGENSON and STIROH (2000). In this approach, the aggregate production function takes the form:

$$Y = Af(K^{NOICT}, K^{ICT}, L^{U}, L^{S}) \tag{1}$$

where:

Y – Gross Domestic Product (GDP),

A – an index of the aggregate state of technology – Total Factor Productivity (TFP),

K – input of physical capital decomposed to K^{NOICT}: non-ICT capital and K^{ICT}: ICT capital,

L – the input of labour decomposed to L^{U}: unskilled labour and L^{S}: skilled labour.

GDP increases when capital accumulation and labour inputs are growing, or when TFP comes into play[1]. Changes in TFP indicate shifts in the relation between measured aggregate inputs (K and L) and outputs (Y), which are assumed to be caused by changes in technology (technical progress) (LIPSEY, CARLAW 2001, pp. 7–11).

ICT may influence GDP (in line with equation 1), in different ways. Firstly, investments in ICT (software, hardware, and infrastructure) lead to capital deepening and growth of the stock of ICT-capital. Secondly, according to the Skill-biased Technical Change hypothesis, implementation of ICT requires highly qualified personnel – as demand for highly educated employees is increasing, the skill structure of the labour force is changing towards a growing share of high quality human capital. This influences the stock of labour, as well as the TFP. Thirdly, technical progress in the ICT-producer sectors (exogenous to the rest of the economy) is transferred to the other sectors (ICT-users) in the form of lower prices (financial external effects) – this in turn should cause higher efficiency of all the production factors and the growth of Total Factor Productivity. Fourthly, ICT is regarded as a General Purpose Technology (GPT) – it generates significant non-financial external effects – the spillover effects, which influence TFP. And finally, higher capital stock, with a better quality of labour resources and technical progress should enhance labour productivity.

Although this framework from neoclassical growth theory provides a solid theoretical background to explain the relationship between technical progress, caused by ICT development, and productivity and economic growth, the statistical data up to the mid 1990s did not confirm it. Discussion and analysis of this phenomenon (called the Solow paradox or productivity paradox) emerged when Robert SOLOW (1987) stated *You can see the computer age everywhere but in the productivity statistics*. The results of research studies on the productivity paradox brought important insights into the mechanism of ICT diffusion, explaining the potential reasons for the paradox. One of the explanations focuses on the concept of complementary factors to ICT investments[2]. It refers to seminal work of MILGROM and ROBERTS (1990), who

[1] The growth accounting methodology, based on this neoclassical framework and widely used in the research studies analysing ICT impact on GDP and productivity growth, enables calculating contribution of each production factor inputs to the economic growth. Technically, the growth rates of production factors are weighted with their respective share in total costs. For example, the contribution of ICT capital to GDP growth is measured as the speed with which ICT capital input grows, multiplied by the share of ICT capital in total costs (for detailed description on the growth accounting methodology see: *Productivity and growth...* (2011) or DE VRIES, ERUMBAN (2015). The review of literature and analysis based on data from the Total Economy Database presented in this paper relates to this methodological approach.

[2] The other explanations emphasise the measurement issues, problems of lags, redistribution and dissipation of profits, and mismanagement of ICT – see (BRYNJOLFSSON, SAUNDERS 2010, YANG, BRYNJOLFSSON 2001).

developed the conceptual model of interrelated changes connected with the introduction of CAD/CAM technology in one of the American companies. In general, the complementarity hypothesis states that utilization of the full potential of new technologies (including ICT) requires complementary changes (investments) at the micro-level (work organization, investing in employees' skills, introducing changes into business processes) as well as at the macro-level (increasing the stock of available human capital, introduction of institutional changes supporting the flexibility of the markets and thus, the diffusion of new technologies). Consequently, the introduction of these complementary changes to ICT takes time – thus the positive outcomes of ICT investments may be recorded in the statistics with some delay, which is consistent with the „lags" argument explaining the Solow paradox.

Provided that these arguments are correct, we could expect that a positive relationship between ICT and productivity would be confirmed at first in highly developed economies, which are leaders in ICT implementation, and then in developing countries. Indeed, the first research studies pointing out the positive impact of ICT on productivity and economic growth were focused on the highly developed economies – mainly the United States (see: JORGENSON, STIROH 2000, JORGENSON 2001, OLINER, SICHEL 2000, STIROH 2002).

This positive relationship has been revealed relatively recently also for developing countries, including CEE economies. PIATKOWSKI (2003, 2004) proved that ICT had a noticeable contribution to GDP and labour productivity growth in Central and Eastern European countries[3] between 1995 and 2001. His analysis showed that the contribution of ICT capital to GDP growth was higher by 0.61 pp than the EU-15 average in five CEE countries that joined the EU in 2004 (Czech Republic, Hungary, Poland, Slovakia and Slovenia). These countries (except Slovenia) were also characterised by a higher than EU-15 average total contribution of ICT to economic growth. VAN ARK and PIATKOWSKI (2004) demonstrated that ICT capital contributed to the labour productivity growth in CEE countries to the same extent as in EU-15 countries. Consequently, a significant role for the convergence of ICT and for labour productivity between CEE and EU-15 countries was confirmed. DIMELIS and PAPAIOANNOU (2010) found a positive and significant impact of ICT on productivity growth in 42 developed and developing countries (albeit larger in the group of developed countries) in the period 1993–2001. Finally, JORGENSON and VU (2010)[4] found that exceptionally high GDP growth rates between 2000–2004 in Eastern Europe was a result of dynamic TFP growth

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[3] The analysis covered Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, and Russia (CEE countries), EU-15 and the US.

[4] They analyzed the impact of ICT equipment and software on the resurgence of world economic growth in 122 economies between 1989 and 2008, distinguishing seven regions and 14 major world economies.

– in this period TFP contribution to GDP growth was estimated at 5.2% ppa. This value was unreachable for the other regions of the world, even to Developing Asia („only" 2.64% ppa). While in 2004–2008, the contribution of capital and labour to GDP growth increased substantially (to 1.1% ppa and 0.91% ppa respectively), and changes in TFP were still the main source of economic growth. Moreover, research studies on the relationship between ICT, productivity and GDP growth (in developed as well as developing countries) have been focusing more and more on the role of ICT complementarities that may enhance productivity. It became evident, that the productive utilization of ICT is dependent on a wide availability of skills – or more broadly, human capital (BRESNAHAN et al. 2002, ARVANITIS, LOUKIS 2009, ACEMOGLU 2002).

Taking into consideration the specific situation of the formerly centrally-planned economies, PIATKOWSKI (2004, p. 27), stressed the ICT potential would not be fully utilised in CEE countries without changes in the institutional and regulatory environment (macro scale), as well as without changes in the structure, organization and business model of companies – especially an improvement of the digital skills of the labour force (micro scale). Similar conclusions were presented by VAN ARK and PIATKOWSKI (2004, p. 238).

Measuring the digital economy and the role of ICT complementarities

Although there are a number of approaches to measuring the digital economy/information society, we will focus on two indexes: NRI and DESI. The first one – Networked Readiness Index (NRI) – covers around 140 countries and measures the extent to which the economy is prepared to apply the benefits of ICT to promote economic growth and well-being (including the ICT impact on productivity). NRI comprises 4 sub-indexes which are known as the: environment, readiness[5], usage and impact sub-indexes. The overall value of the NRI (between 1 and 7) is calculated as the average of these four sub-indexes. The ranking created on this basis enables researchers to analyse the distance travelled by each country in real and relative terms.

The relative changes are measured by the position of each country in terms of the ranking in consecutive years. From this point of view, we may distinguish three groups of economies within the CEE countries. The first group consists of Lithuania, Slovenia, Czech Republic and Poland, which maintained

[5] Within this subindex, one pillar is devoted to the skills readiness that is measured by four variables: quality of the educational system, quality of math and science education, secondary education gross enrolment rate and adult literacy rate. The detailed description of the NRI methodology may be found in (*The Global Information*... 2014, p. 3–8, 323–328).

their positions in the ranking. The second group – countries that improved their relative situation – includes Latvia (moved from 41st to 33rd place), Slovakia (64th to 59th), Romania (67th to 63rd) and Estonia (the best performing CEE country in this ranking, at 22nd place in 2015). In the third group – countries which lost some ground – we find Hungary (moved down by 10 positions to 53rd place), Croatia (dropped 9 positions to 54th place), and Bulgaria (from 70th to 73rd place).The real changes may be calculated as the difference between NRI values in 2015 and 2012. From this perspective, it should be emphasised that all CEE countries improved their performance[6], however perceptible differences between countries are noticeable. The biggest steps forward were achieved by Latvia (an increase in NRI of 0.4) and Slovakia (0.29), the slightest steps forward were by Slovenia (0.06) and Hungary (0.04). Relatively high increases of NRI were reported in Estonia and Romania (0.25), and in Poland (0.22). Although we witnessed slow convergence in NRI numbers between the CEE and EU-15 countries, the NRI value in 2015 for almost all CEE economies was still below the EU-15 average – except for Estonia (Fig. 1). Estonia was the only CEE country with an NRI exceeding 5 points. Next to Estonia, in the group of best performing CEE countries we may include Lithuania, Latvia, Slovenia and the Czech Republic. By contrast, Bulgaria and Romania, which together joined the EU in 2007, are classified as the worst performing CEE economies.

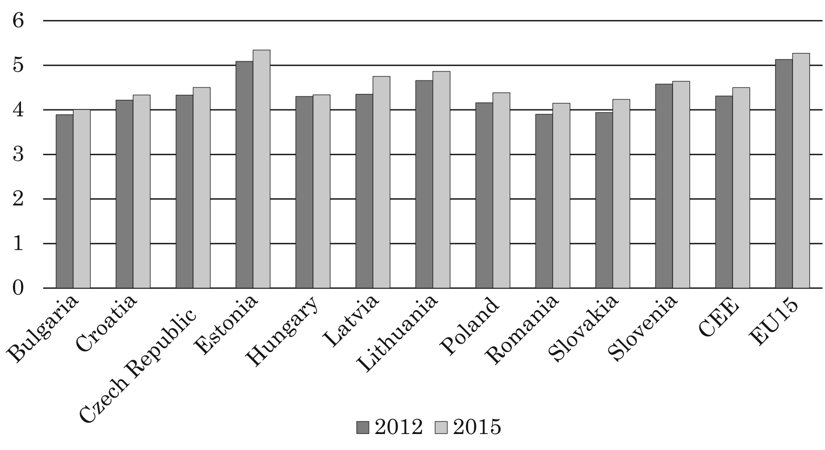
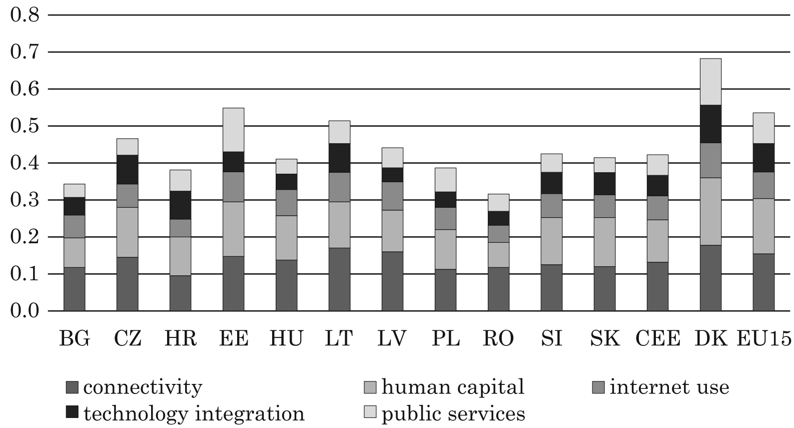


Fig. 1. NRI indexes in selected countries (2012, 2015)
Source: own elaboration based on NRI data.

[6] The average growth of NRI for CEE countries amounted to 0.19, while in EU-15 it was 0.14.

The other index – DESI – is related to the Digital Agenda for Europe (DAE). The DAE (2010) adopted in March 2010 is an EU-wide initiative within the framework of Europe 2020 Strategy. DAE consists of 7 pillars – each one defines goals and actions required to meet these goals[7], ranging from typical technological issues (e.g. development of fast, broadband infrastructure) to soft, but crucial ICT complementarities (e.g. development of digital literacy and ICT skills). To inform stakeholders about the progress of DAE, a tool – the Digital Agenda Scoreboard – was developed. However, in February 2015 the European Commission presented the Digital Economy and Society Index (DESI), that captures 30 indicators on EU digital performance within 5 dimensions: connectivity, human capital, use of Internet, integration of Digital Technology, and Digital Public Services[8]. The results show that although the individual Member States made progress towards a digital economy, there are still perceptible differences between countries. Analysis of DESI leads to similar conclusions as in the case of the NRI index. The best performing CEE country is Estonia – the only one with a DESI higher than the EU-15 average (Fig. 2).



BG – Bulgaria, CZ – Czech Republic, HR – Croatia, EE – Estonia, HU – Hungary, LT – Latvia, LV – Lithuania, PL – Poland, RO – Romania, SI – Slovenia, SK – Slovak Republic

Fig. 2. DESI 2015 by dimensions

Source: own calculations based on DESI results: https://ec.europa.eu/digital-agenda/en/progress-country.

[7] 101 specific policy actions altogether: 78 taken by the European Commission, 23 proposed to the Member States.

[8] DESI is a weighted average of performance scores in these five dimensions, where connectivity and human capital account for 25% of the total score (each), technology integration for 20%, and the use of Internet and digital public services for 15% (each). It is measured on a scale of 0–1, with higher values representing better performance. Up to now, DESI covers two years: DESI 2014 (based on data available mostly from 2013) and DESI 2015 (based on data available mostly from 2014).

The reason behind this is twofold: Estonia is one of the best in Europe in terms of the utilization of digital public services (they are second place in the EU-28 as a leader in the availability of pre-filled online forms and the use of ePrescriptions) and Estonians make wide use of the Internet (fourth place in EU-28). The least performing CEE country – Romania – is the last one in the EU-28 ranking, with a score less than half of Denmark (the best EU-28 country). It shows the scale of the gap from one side, and the unexploited potential of the digital economy in countries like Romania, Bulgaria or Croatia, from the other side. Most of the CEE countries (Latvia, Slovenia, Hungary, Slovakia, Poland, Croatia, Bulgaria and Romania) have been categorised as low-performing economies. Only Estonia, Lithuania and the Czech Republic have entered the group of medium-performing countries. The biggest gap between the CEE and EU-15 counties is related to the availability of digital public services (0.18 difference in scores), which is a crucial factor from the point of view of businesses and individuals. The other important ICT complementarity – human capital – is also not a strong asset of CEE countries (a 0.14 difference in scores). It seems, that connectivity is still weaker in CEE countries, which combined with low digital skills translates into relatively low levels of business digitalization and e-commerce readiness.

Sources of economic growth in CEE countries – the role of ICT

Impact of ICT on economic growth was analyzed in selected CEE countries[9] for two periods: 1995–2003, and 2004–2014. The first period covers the post-initial stage of transition of the CEE to a market economy that took place after introducing the main reforms, and the recession of early 2000. The other period starts in the year of the accession of 5 CEE countries into the EU (on the 1st of May 2004, Bulgaria and Romania joined on the 1st of January 2007) and captures the effects of the financial crisis and the global recession[10].

Although between 1995 and 2003 average GDP growth in CEE countries was slightly below the EU-15 average, this situation reversed in the next period. Nevertheless, there were perceptible differences between CEE countries – Hungary and Slovenia faced relatively slow GDP growth, while Poland, Slovakia and Romania registered exceptionally high growth rates (Tab. 1).

[9] The analysis covers Bulgaria (BG), Czech Republic (CZ), Hungary (HU), Poland (PL), Romania (RO), Slovak Republic (SK), Slovenia (SI) in the group of CEE countries, and EU-15 countries (as a point of reference). Estonia, Latvia, Lithuania and Croatia were excluded from analysis due to lack of data on ICT capital in the Conference Board 2015 database.

[10] Years 1990–1994 (the very beginning of the transition process) were intentionally excluded from the analysis, because of the remarkable instability of CEE economies at that time and the low reliability of available statistical data for that period.

Changes in labour quality were quite similar in the EU-15 and CEE countries in both periods, while changes in labour quantities followed different patterns. Between 1995 and 2003 employment rose in the EU-15, while CEE countries witnessed shrinking labour numbers (an increase in employment was registered only in Hungary).

In 2004–2014 the average growth in employment was comparable in the EU-15 and CEE countries, with large discrepancies within the CEE (a relatively high increase in Poland and Slovakia, and a decrease in Romania and Hungary). The characteristic feature of the CEE countries is much higher growth of ICT capital in both periods in comparison with the EU-15, which shows that CEE countries focused on investing in ICT infrastructure to catch up to the more developed economies. The growth of non-ICT capital was also higher in the CEE during both periods[11].

Table 1

Growth rates (log change) in EU-15 and CEE countries

Specification	EU-15	CEE	BG	CZ	HU	PL	RO	SK	SI
GDP rate of growth 1995–2003	3.14	3.10	1.01	2.56	3.12	4.35	2.39	4.08	4.17
GDP rate of growth 2004–2014	0.93	2.67	2.85	2.32	1.23	3.89	3.12	3.83	1.48
Growth of Labour Quality 1995–2003	0.50	0.44	0.60	0.36	0.46	0.24	0.35	0.27	0.80
Growth of Labour Quality 2004–2014	0.34	0.43	0.63	0.29	0.60	0.32	0.39	0.30	0.51
Growth of Labour Quantity 1995–2003	1.30	-0.90	-1.05	-0.72	0.25	-0.44	-3.11	-1.05	-0.19
Growth of Labour Quantity 2004–2014	0.14	0.12	0.33	0.32	-0.68	1.12	-0.99	1.04	-0.33
Growth of ICT capital 1995–2003	13.36	22.14	17.62	22.18	20.54	30.29	23.93	22.81	17.61
Growth of ICT capital 2004–2014	10.24	16.85	19.05	8.98	15.49	18.12	24.02	21.12	11.16
Growth of non-ICT capital 1995–2003	2.77	3.03	4.59	4.43	3.72	2.95	-1.82	2.29	5.04
Growth of non-ICT capital 2004–2014	1.80	3.21	7.79	3.74	1.55	3.34	1.51	1.53	3.03

Source: own elaboration based on the Total Economy Database. Average for each period.

The main source of economic growth in CEE countries between 1995 and 2003 was TFP – its average growth accounted for half of GDP growth in that period (for the EU-15 it was „only” 17%), which means that spillover effects, including those connected with ICT, played an important role in the development of CEE economies. However, this process was not distributed evenly – in Romania large relative TFP growth balanced the negative contribution of labour and non-ICT capital, while in Bulgaria TFP contribution was large, but negative. A positive impact of TFP on economic growth was present in Poland, Slovakia and Slovenia (Tab. 2).

[11] Romania is an interesting example – it registered the highest growth of ICT capital in years 2004–2014, and was the only CEE country with negative growth of non-ICT capital between 1995 and 2003.

As a result of the high dynamics of ICT investments in the years 1995–2003, the average contribution of ICT capital to GDP growth in CEE countries exceeded EU-15 results. However, non-ICT capital was still more important for economic growth than ICT capital (even in Bulgaria, where the contribution of both types of capital was extraordinarily high). Although in 2004–2014 TFP did not contribute as much to GDP growth as in the previous period, it was still positive in CEE countries (with the exception of Bulgaria and Hungary), while in the EU-15 it became negative. The main drivers of economic growth in the EU-15 countries were non-ICT and ICT capital. The same happened in CEE countries – the contribution of ICT capital to GDP growth was crucial in Hungary and highly important in Bulgaria, Slovenia and Slovakia.

Table 2

Contribution of production factors to GDP growth in EU-15 and CEE countries

Specification	EU-15	CEE	BG	CZ	HU	PL	RO	SK	SI
1995–2003									
Labour Quality	0.31	0.27	0.3	0.21	0.27	0.16	0.22	0.11	0.59
Labour Quantity	0.81	-0.54	-0.54	-0.45	0.14	-0.29	-2.02	-0.42	-0.19
ICT capital services	0.61	0.72	1.09	1.00	0.94	0.44	0.36	0.65	0.55
Non-ICT capital services	0.92	1.10	1.97	1.77	1.27	0.96	-0.64	1.32	1.05
TFP growth	0.52	1.55	-1.82	0.03	0.50	3.08	4.46	2.42	2.17
2004–2014									
Labour Quality	0.21	0.25	0.34	0.17	0.36	0.18	0.25	0.11	0.37
Labour Quantity	0.07	0.00	0.1	0.19	-0.41	0.65	-0.66	0.39	-0.26
ICT capital services	0.48	0.93	1.43	0.26	1.63	0.75	0.39	1.48	0.59
Non-ICT capital services	0.62	1.18	3.07	1.36	0.46	1.31	0.52	0.83	0.73
TFP growth	-0.42	0.30	-2.09	0.33	-0.82	1.00	2.62	1.01	0.05

Source: own elaboration based on the Total Economy Database. Average for each period.

Positive changes in labour quality were often counterbalanced by the negative contribution of shrinking employment numbers – as in the case of Hungary, Romania and Slovenia. Generally, the contribution of labour quality to GDP growth was higher in the EU-15 than in CEE countries.

Human capital and labour productivity

The modern, technology-savvy economies require high and strong qualifications in science and technology. Thus, the concept of Human Resources for

Science and Technology (HRST)[12] seems to be an appropriate approach to assess the potential of human capital in the CEE and EU-15 countries, treated as complementarity to ICT investments[13]. Data shows that although HRSTE levels in the group of CEE countries were lower than in the EU-15[14] both in 2003 and 2013, the convergence process was in place. The best performing CEE countries are Estonia and Lithuania (the only countries above the EU-15 average). Poland, Slovakia and the Czech Republic registered a dynamic increase in the percentage of individuals who completed tertiary education (by 86%, 72% and 71% respectively). However, Slovakia and the Czech Republic, along with Bulgaria and Romania, were still the worst performing CEE countries in 2013 when taking the HRSTE into account (Fig. 3*a*).

Analysis of HRSTO reveals the existence of a divergence processes between the EU-15 and CEE countries, which may imply that demand for highly skilled individuals grew faster in the EU-15 than in CEE economies[15], as a consequence of weaker ICT readiness in the latter group of countries. The best performing CEE countries in 2013 were Lithuania, Slovenia, Estonia and the Czech Republic, but none of these economies reached the average of the EU-15 (Fig. 3*b*). The lowest share of individuals working in S&T occupations was registered in Slovakia, Bulgaria and Romania[16]. A large gap between the EU-15 and CEE countries remains in the case of HRSTC. The share of individuals who have completed third level education and are employed in S&T occupations in the EU-15 was 5.8 pp higher than in CEE economies in 2013[17]. A significant increase of this statistical share was recorded in Latvia, Lithuania and Poland between 2003 and 2013 (Fig. 3*c*). Even in the best performing CEE countries (as well as in the EU-15) a relatively large part of the S&T positions

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[12] *Canberra Manual* (1995) presents concepts, methods and definitions related to Human Resources in Science and Technology. From the point of view of this paper, the following categories are most important: HRST – persons who successfully completed third level education or are employed in S&T occupations (the broadest category); HRSTE – people who successfully completed third level education (since 2014, according to ISCED 2011 – levels 5 to 8); HRSTO – persons who are employed in science and technology occupations as „Professionals" or „Technicians and associate professionals" (ISCO-08 major groups 2 and 3), HRSTC – individuals who have successfully completed a tertiary level education and are employed in S&T occupations.

[13] Skorupinska and Arendt (2015) argued that human capital in CEE countries is the main complementary factor to ICT investment enhancing ICT-driven labour productivity.

[14] The percentage of the population in the age groups 25–64 years in 2003 and 2013 is taken into account in the analysis. The age group is consistent with the employment goal of Europe 2020. Differences between 2003 and 2013 (2003 is the last year of the first period used in the analysis of sources of GDP growth, 2013 is the last year in the other period, for which data is available in the Eurostat database) describe developments in each country.

[15] Growth of HRSTE and HRSTO led, by definition, to an increase in HRST in the EU-15 and CEE countries (Fig. 3*d*).

[16] The dynamics between 2003 and 2013 were also poorest in these three countries, especially in Slovakia, where the percentage of people working in S&T occupations dropped from 19.9% to 19.6%.

[17] Only Lithuania reached the EU-15 average.

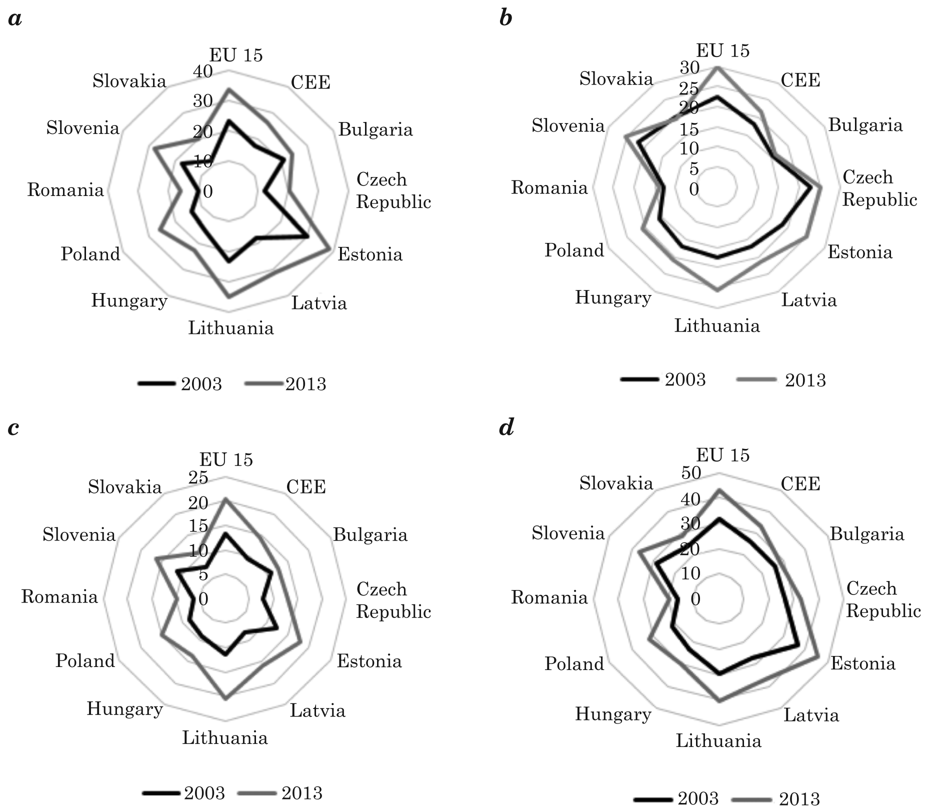

Fig. 3. Human Resources in Science and Technology: *a* – HRSTE, *b* - HRSTO, *c* – HRSTC, *d* - HRST
Source: Eurostat database.

are occupied by individuals who do not possess tertiary education, which means that some portion of highly educated people were (formally) underemployed.

Although CEE countries are still lagging behind the EU-15, as far as the HRST measures are concerned, undoubtedly the quality of human capital (at least formally) has improved in recent years, which shall (in line with theoretical assumptions) result in an increase of labour productivity. Simultaneously, the growing importance of ICT utilization for economic growth in these countries also should, as growth theory argues, enhance labour productivity. Indeed, labour productivity data shows a significant improvement of GDP per person employed in CEE countries between 1995–2003 and 2004–2015 (Fig. 4).

Productivity in CEE economies increased on average by 47%, while only by 10% in the EU-15 countries. As a result, the productivity gap between the two

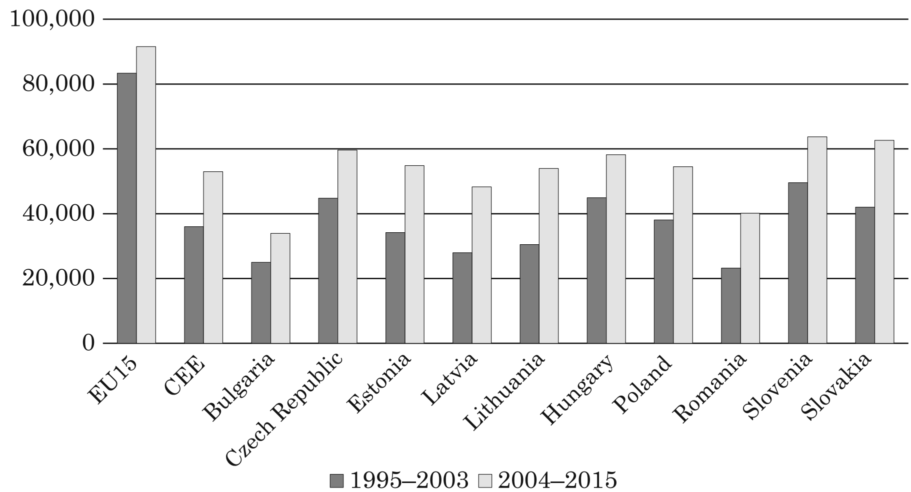

Fig. 4. Labour productivity per person employed (in 2014 US$ – converted to 2014 price level with updated 2011 PPPs)
Source: Total Economy Database. Average for each period.

regions was reduced by 8,756 USD. Lithuania, Latvia, Romania and Estonia gained most (productivity growth by 77%, 73%, 73% and 61%, respectively). However, even the best performing CEE countries – Slovenia and Slovakia did not reach the EU-15 average (63,704 USD and 62,616 USD compared to 91,551 USD respectively[18]), while in the worst performing CEE economies – Bulgaria and Romania – labour productivity was more than two times lower than the EU-15 average (2.7 and 2.3 times respectively). Undoubtedly, we can see a positive relationship between the growth of ICT-capital and human capital as an important complementarity to ICT. Furthermore, it should provide an improvement in labour productivity for CEE countries.

Conclusions

Since the beginning of the transition, ICT investments and utilization of these modern technologies have had a positive impact on the economic growth of CEE countries – directly through the contribution of ICT capital, and indirectly through spillover effects captured by TFP. Leaving aside the differences between the analyzed CEE economies, we may conclude that the stock of ICT capital grew faster in these countries in comparison to the EU-15

[18] Taking as the reference year 2015, only these two CEE countries had higher labour productivity levels than Portugal, which was the worst performing economy in the EU-15.

average, which means that the CEE tried to close the existing ICT-infrastructure gap. ICT-capital was also an important factor contributing to GDP growth in CEE countries, especially between 1995 and 2003. Moreover, TFP growth reached extraordinarily high levels in these economies, enabling them to maintain a high rate of GDP growth, even during the time of the latest world economic crisis.

However, the analysis of different measures of the digital economy shows that although investments in ICT infrastructure are crucial, complementary investments that create a digital friendly environment in which ICT may be used more efficiently are even more important. The underperformance in the area of ICT complementarities may be perceived as the main weakness of CEE countries, as it hampers their readiness to become a digital economy. The NRI and DESI indexes unequivocally point to Estonia as the best performing CEE country, that is followed by (depending on the index) Lithuania, Latvia, Slovenia and the Czech Republic. By contrast, Bulgaria and Romania are classified as the worst performing CEE economies. Similar conclusions stem from the analysis of HRST indexes that describe the quality of human capital. The best performing CEE economies are Estonia and Lithuania, while the worst performers are Bulgaria and Romania.

This relatively poor performance of most CEE countries (in comparison with the EU-15 average) translates into the less efficient use of available ICT and potentially lower enhancement of GDP and productivity growth. Although it was not possible to assess the ICT contribution to economic growth in Estonia, Lithuania and Latvia, where theoretically ICT should have been utilized more efficiently than in other CEE countries, there is no doubt that Bulgaria and to some extent Romania did not take full advantage of what ICT had offered to their countries.

This paper focused on these macro-level ICT complementarities, which are usually analyzed in the literature. It seems, however, that other determinants may play an important role regarding the enhancing of ICT-driven GDP and productivity growth (in developed and developing countries). One of those is a Business Digital Divide, defined as disparity between the effective use of ICT for productivity gains between small and medium-sized enterprises (SMEs) and large companies (WIELICKI 2008, WIELICKI, ARENDT 2010). Some research studies have shown that the use of ICT-based solutions at too low and at insufficient levels by SMEs is one of the main reasons for their relatively low performance when compared to large corporations, especially in the less developed countries (ITC 2015). While SMEs generate a substantial part of GDP, the Business Digital Divide may have a major macroeconomic effect; with its scale related to the size of the economy (this could explain to some extent, why Estonia and Slovenia achieved better results than Bulgaria or Romania). Obviously, this problem requires thorough research.

In summary, ICT-capital has become an important production factor in the CEE countries, and although there is still a gap between the EU-15 and CEE economies as far as ICT infrastructure is concerned, CEE countries have recently witnessed a perceptible development in this area. However, more productive utilization of available ICT is limited by an insufficient level of ICT complementarities, which is especially noticeable in lower-performing countries such as Bulgaria, Romania and Hungary. Without further investment in ICT complementarities, CEE countries will continue to lag behind the EU-15 economies.

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