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LABOUR PRODUCTIVITY, ICT AND COMPLEMENTARY FACTORS IN THE CEE REGION[1]

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A b s t r a c t

The paper discusses the role of Information and Communication Technologies for labour productivity in the Central and Eastern European countries, taking into account the consequences of the latest global economic crisis. It focuses on the factors (ICT complementarities) influencing the ICT diffusion trajectories, and thus having impact on labour productivity. The fixed effects models and least squares dummy variable (LSDV) regression was implemented with the use of panel data for 21 European Union member countries. The analysis revealed that only some complementary factors to ICT investments appeared significant to affect labour productivity in the CEE Region. It also showed that sources of labour productivity are sensitive to cyclical changes in the economy.

WYDAJNOŚĆ PRACY, TIK I CZYNNIKI KOMPLEMENTARNE W KRAJACH EUROPY ŚRODKOWO-WSCHODNIEJ

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S ł o w a k l u c z o w e: wydajność pracy, TIK, czynniki komplementarne, kraje Europy Środkowo-Wschodniej.

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Abstrakt

W artykule przeanalizowano wpływ technologii informacyjnych i komunikacyjnych (TIK) na wydajność pracy w krajach Europy Środkowej i Wschodniej (EŚW), z uwzględnieniem skutków ostatniego globalnego kryzysu gospodarczego. Szczególną uwagę poświęcono czynnikom komplementarnym wobec TIK, które oddziałują na ich procesy dyfuzji, mając tym samym wpływ na wydajność pracy. Analizę ilościową przeprowadzono z wykorzystaniem estymacji modeli z efektami stałymi za pomocą metody najmniejszych kwadratów ze zmiennymi sztucznymi (LSDV), dla danych panelowych dla 21 państw członkowskich Unii Europejskiej. Wyniki analiz wykazały, że jedynie niektóre czynniki komplementarne wobec TIK miały istotny statystycznie wpływ na wydajność pracy w krajach EŚW. Okazało się również, że źródła wydajności pracy są wrażliwe na zmiany koniunktury gospodarczej.

Introduction

The role of Information and Communication Technologies (ICT) concerning economic growth and productivity has been widely discussed since Solow (1987) stated "You can see the computer age everywhere but in the productivity statistics". Nowadays, there is a broad consensus among researchers that ICT are of key importance for productivity performance. Although recent research studies point towards a positive relationship between ICT investments and productivity, even in developing (or emerging) economies, there are still a lot of questions that remain unanswered. The most important are related to the hypothesis of the leapfrogging effect and the factors influencing the ICT diffusion trajectories (ICT complementarities), which have an impact on labour productivity. Both questions are crucial; however, we will focus on the latter in this paper. Our goal is to identify which complementarities to ICT investments have been significant to labour productivity growth in Central and Eastern European (CEE) countries since the second half of 1990s. A macroeconometric analysis has been conducted for three periods: 1995–1999, 2000–2007 and 2008–2011, describing different stages of transition of CEE countries to a market economy, the last period including the effects of the world financial crisis. Thusly, we were able to assess whether economic cycles influence the impact of ICT complementarities on labour productivity.

Towards ICT complementarities – a synthetic literature review

The ICT influence on economy can be described by two types of effects (JUNG, MERCENIER 2014). The first-order effect captures the impact of investments in ICT infrastructure on the stock of capital. The growth of ICT capital, as models of economic growth predict, positively influences GDP growth and labour productivity. The second-order effect (spillover effect) is a result of

complementary changes that are induced by ICT investments. This refers to outcomes of theoretical and empirical studies that were focused on "solving" the productivity paradox puzzle. The most accepted explanations include: mismeasurement of inputs and outputs related to ICT (BRYNJOLFSSON, SAUNDERS 2010, HALTIWANGER, JARMIN 2002, MOULTON 2002, YANG, BRYNJOLFSSON 2001), lags – ICT investments may not have an immediate impact on a company's productivity, as this requires a learning-by-doing form of experience (DAVID 1990, 2002, KLING, LAMB 2002), and finally the complementarity hypothesis, which argues that utilisation of the full potential of new technologies (including ICT) requires complementary changes (investments) related to work organisation, human capital or changes in business processes within companies (BRYNJOLFSSON 2005, MILGROM, ROBERTS 1990, 1995, MILGROM et al. 1991). These complementary changes affect Total Factor Productivity (TFP) and, as a result, productivity and economic growth. Literature provides many examples of adoption of organisational changes, new human resource management practices and the growing importance of human capital, which are treated as complementary factors.

BRESNAHAN et al. (2002) have shown evidence of a positive correlation between ICT use and workplace organisation and skilled labour that have affected productivity in the United States. They concluded that with the growing spread and access to ICT, investment in complementarities is crucial, particularly in skilled labour. BLACK and LYNCH (2001, 2004) showed, also for the US, that productivity growth during the 1990s had its source in changes in workplace organisation and innovations (employee involvement, team work, incentive pay and decision-making autonomy) along with the dissemination of computers. BRYNJOLFSSON (2005) described seven pillars of digital organisation, which in fact are ICT complementarities that enhance productivity and the market value of a company.

Research studies in other developed countries followed the path of analysis initiated in the Unites States. Analysis of panel data for British and French firms (CAROLI, VAN REENEN 2001) revealed that skilled workers adapt more easily to changes in organisation. Having this in mind, the authors presented empirical evidence of the relationship between workplace innovation and human capital, as well as its influence on productivity. Another comparative study of Swiss and Greek firms (ARVANITIS, LOUKIS 2009) shows the positive effects of physical capital, ICT, human capital and new organisational practices on labour productivity. It appeared that Swiss firms were more efficient in combining and implementing these factors, while in the Greeks firms, physical capital played a crucial role in relation to labour productivity.

The role of ICT complementarities has also been emphasised in macro-level research studies conducted in developing countries. PIATKOWSKI (2004) and

VAN ARK and PIATKOWSKI (2004) showed that ICT noticeably contributed to GDP and labour productivity growth in the CEE region in the second half of 1990. DEDRICK et al. (2013) found that in developed countries, ICT complementarities encompass foreign investments and cellular penetration, while in developing countries, these were the quality of human capital, foreign investments and the cost of communication services. NIEBEL'S (2014) analysis also indicates the existence of spillover effects and complementarities related to ICT investments in developed as well as in developing countries.

The interaction between ICT and complementary factors is a complex one. Access to technology is determined by the trade openness of an economy, which influences the transfer of know-how. The ability of a company to implement a given technology depends on whether it already possess adequately trained employees or is able to recruit them from the labour market. In order to bring about the expected results (e.g. increase in labour productivity), it also requires the introduction of changes in work organisation in connection with the redefinition of business processes that were performed with the use of previous-generation technology. Concurrently, the pace and scope of these changes are dependent largely upon the human capital of employees. Moreover, the institutional milieu plays an important role – it may support or hinder the implementation of this comprehensive process of changes in the organisation (e.g. more restrictive labour code regulations could hamper the introduction of changes in work organisation, while higher labour market flexibility should encourage greater openness to change among employees).

It should be emphasised that factors complementary to ICT are also reliant upon each other – changes in work organisation require access to modern technologies and suitably qualified human resources, while innovativeness and the scale of foreign investments are conditioned by the dissemination of technology and the quality of human capital.

ICT – driven productivity in the CEE countries

Statistical data shows that since 2000, the first- and second-order effects of ICT implementation have been more evident in the CEE region[2] than in the EU-15 countries. ICT capital grew 17.9% between 2000 and 2014 in the seven CEE countries, while in the EU-14, it reached 10.75%. As a result, the average contribution of ICT capital to GDP growth in the CEE region was above that of the EU-14, especially in Hungary, Bulgaria and Slovakia. TFP also played an

[2] Due to a lack of data on ICT capital in the Conference Board 2015 database for Estonia, Latvia, Lithuania, Croatia and Luxembourg, there is no possibility to assess the magnitude of the first-order effect.

important role, especially in the CEE region, where its contribution to economic growth was, on average, positive[3] (Tab. 1).

However, there were perceptible differences between individual countries. In Romania, Poland and Slovakia, TFP was the main driver of GDP growth. A smaller, but still positive, TFP contribution was recorded in Estonia, Lithuania, Latvia, Czech Republic and Slovenia. At the same time, Bulgaria, Croatia and Hungary witnessed a negative TFP contribution to GDP growth – unfortunately, it is not possible to estimate to what extent this effect was caused by ICT, though it seems that other factors played a primary role.

Table 1

Sources of GDP growth in EU-15 and CEE countries in 2000–2014

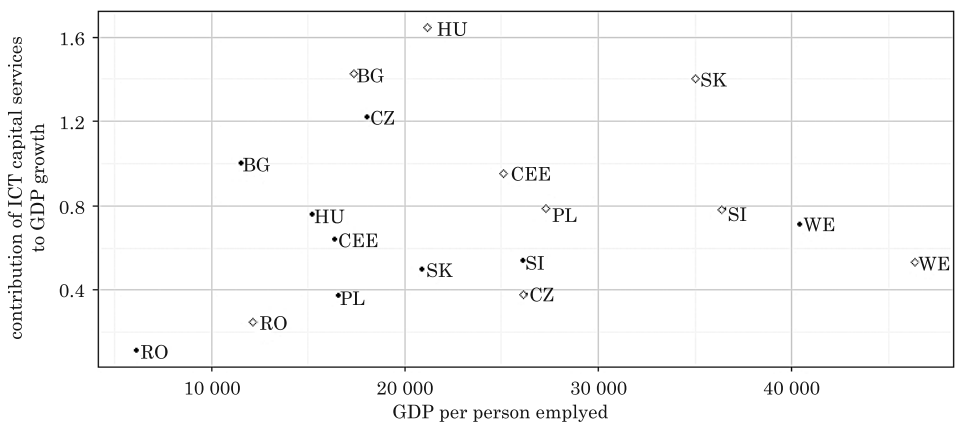
Country	Labour Quality	Labour Quantity	ICT capital services	Non-ICT capital services	TFP growth
EU-15	0.24	0.18	0.50*	0.74	-0.26
CEE (11)	0.24	-0.20	–	1.59	0.91
CEE (7)	0.28	-0.20	0.92	1.19	0.78
Bulgaria	0.34	0.01	1.40	3.06	-1.44
Croatia	0.22	0.17	–	1.41	-0.73
Czech Republic	0.22	-0.09	0.41	1.41	0.58
Estonia	0.17	-0.03	–	1.91	1.86
Hungary	0.33	-0.4	1.53	0.72	-0.22
Latvia	0.14	-0.70	–	3.22	1.38
Lithuania	0.16	-0.19	–	2.13	2.07
Poland	0.21	0.09	0.71	1.20	1.40
Romania	0.25	-1.11	0.47	0.23	3.67
Slovak Republic	0.13	0.11	1.30	0.83	1.40
Slovenia	0.48	-0.02	0.61	0.86	0.06

* Average for EU-14 excluding Luxembourg.
Source: own elaboration based on the Total Economy Database. Average for 2000–2014.

In spite of rapid labour productivity growth, the gap in the level of productivity between CEE and EU-15 (Western European – WE) countries is still quite large. Comparing average levels of productivity for the periods between 2000 and 2014, it is clear that CEE countries experienced strong productivity improvement. Productivity in the CEE region increased, on average, by 48.4%, while in WE countries, it was only 7.7%. As a result, the labour productivity gap between the two regions was reduced by 25.5%.

[3] It should be emphasised that the contribution of TFP to GDP growth in 2000–2014 in the EU-15 countries was negative.

Romania and Lithuania gained most – the increase in productivity levels in 2000–2014 accounted for 105% and 92%, respectively. However, productivity levels in all CEE countries are still much lower than in other European economies. Taking as a reference the year 2014, only Slovenia and the Slovak Republic had higher labour productivity levels when compared to the least performing EU-15 country – Portugal. The gap within the CEE region is significant, e.g. labour productivity in Bulgaria in 2014 was 35% lower than the average for the region. The productivity patterns in CEE countries resemble those of advanced market economies and are mainly driven by efficiency gains within individual firms. Rapid microeconomic progress in adoption of ICT innovations proves the potential of the technological revolution for transition countries (VAN ARK, PIATKOWSKI 2004). Figure 1 shows that in 2008–2014, CEE countries, apart from Romania and the Czech Republic, have higher levels of ICT capital contribution to GDP growth on average. However, in the case of Romania, there is no clear relation between these two variables – Romania is characterised by low ICT capital contribution and low GDP per employee. Nevertheless, all countries improved labour productivity. It is evident that CEE countries made a huge step after transition to restructure their economies and have entered a convergence path towards that of Western Europe. However, the convergence processes have been affected by the crisis to a larger degree.



• – 1995-1999 average
◊ – 2008-2014 average

Fig. 1. Contribution of ICT capital services to GDP growth and GDP per person employed: 1995–1999 and 2008–2014

Source: own elaboration based on the Total Economy Database.

Identification of ICT complementarities

Macroeconometric modelling, used for quantitative analysis, is based on the Solow growth model (SOLOW 1957) and its extension by Jorgenson and GRILICHES (1967). This approach enabled us to measure the impact of ICT complementarities on labour productivity and to assess whether the role of these complementarities changed over time. The econometric analysis encompassed the years 1995–2011 due to the unavailability of more recent data.

The aggregate production function takes the form:

$$Y_{ti} = A_{ti}K_{ti}^{\alpha}L_{ti}^{1-\alpha} \tag{1}$$

where at any given time t, for a given country i, Y is Gross Domestic Product; A is Total Factor Productivity (TFP); K is input of physical capital; L is input of labour. After decomposition of capital and labour, equation (1) can be expressed as:

$$Y_{ti} = A_{ti}f(K_{ti}^{NOICT}, K_{ti}^{ICT}, L_{ti}^{U}, L_{ti}^{S}) \tag{2}$$

where K is decomposed to K^{NOICT} – non-ICT capital and K^{ICT} – ICT capital; and L to L^{S} – skilled labour and L^{U} – unskilled labour. Total Factor Productivity can be presented in the following functional form:

$$A_{ti} = \exp(\delta_0 Trade.Openness + \delta_1 Edu + \delta_2 INTuse + \delta_3 Patents + \\ + \delta_4 RDS + \delta_5 HRST) \tag{3}$$

After logarithm transformation, the final model takes the following form:

$$\ln LP = \beta_1 \ln GFCF + \beta_2 \ln EduS + \beta_3 \ln RDS + \beta_4 \ln ICTS + \beta_5 \ln Trade.Openness + \\ + \beta_6 Edu + \beta_7 INTuse + \beta_8 \ln Patents + \beta_9 HRST \tag{4}$$

Equation (4) describes four sources of labour productivity: non-ICT capital (GFCF), ICT capital (ICTS), human capital (EduS) and Total Factor Productivity, represented by different variables (Tab. 2). These variables were selected taking into account the findings discussed in literature on productivity. It has been argued that productivity improvements in transition countries should be linked to the components of knowledge economy: ICT usage and knowledge, human capital development, workplace organisation and research and innovation (ARVANITIS, LOUKIS 2009, BRESNAHAN et al. 2002). There is also empirical evidence that investment in research, development and innovation affects TFP (JORGENSON, VU 2005). Domestic research and development is

needed for understanding and absorption of knowledge developed internationality, for improvement of local research and development (R&D) skills and active participation in international R&D networks.

A better quality of human capital can help countries to develop their technologies, as well as increase a country's ability to absorb high technology knowledge from abroad (CASELLI, COLEMAN 2001, POHJOLA 2000). Human capital derived from university education, but also from training and accumulated through learning by doing, can increase the efficiency of labour and also enhance TFP (ARVANITIS 2005, BLACK, LYNCH 2001). Moreover, human resource management within companies, organisations and institutions is an important factor in knowledge economy and one of the determining elements which enable the increase of competitiveness and improve individual and aggregated productivity (BRYNJOLFSSON, HITT 2003).

Finally, liberalised trade positively influences productivity and economic growth. This is particularly important for dissemination of knowledge and

Table 2

Variables and indicators used in econometric analysis

Name	Description	Source	Indicator
LP	Labour productivity per hour worked in 2012 USD (converted to 2012 price level with updated 2005 EKS PPPs)	Total Economy Database	Productivity
GFCF	Gross fixed capital formation as a percentage of GDP	World Bank (WDI)	Non-ICT capital
ICTS	Total ICT spending (computer hardware, software and services, and communications) as a percentage of GDP	WITSA Digital Planet	ICT capital
EduS	Total public expenditure on education per total annual hours worked	World Bank (WDI)/ Total Economy Database	Human Capital
RDS	Research and development expenditure as a percentage of GDP	World Bank (WDI)	Innovation capability
Trade. Openness	Net export as a percentage of GDP	World Bank (WDI)	Technology diffusion
Edu	Gross enrolment ratio	UNESCO UIS database	Adaptive capacity of technology
HRST	Human resources in science and technology percentage of active population from 25–64 years old	Eurostat	Adaptive capacity of technology
INTuse	Internet users per 100 people	World Bank (WDI)	Adaptive capacity of technology
Patents	Resident patents per 1000000 people	World Bank (WDI)	Technology creation

Source: own elaboration.

innovation. Open borders allow for international spillover effects, contributing to economic growth in developing countries and enhancing their catching-up process through adaptation of advanced foreign technologies. Openness to import makes different varieties of capital goods more accessible, which increases efficiency (BARRO, SALA-I-MARTIN 2004).

The econometric analysis was based on panel data for 21 European Union member countries divided into two groups: CEE countries (7 economies)[4] and WE countries (14 economies). We treat WE countries as a point of reference.

Equation (4) was estimated with the use of fixed effects models and least squares dummy variable (LSDV) regression. The results clearly indicate changes in the sources of labour productivity and the impact of ICT complementarities in CEE countries, as well as the influence of the economic crisis on changes in the relationship between ICT and productivity (Tab. 3).

Table 3
Influence of ICT and complementarities on labour productivity in CEE and WE countries in 1995–2011

Specification	Central and Eastern Europe			Western Europe		
	1995–1999	2000–2007	2008–2011	1995–1999	2000–2007	2008–2011
log(EduS)	0.000 (0.013)	0.050 (0.028)	-0.006 (0.017)	0.015 (0.010)	**0.077***** (0.019)	0.019 (0.015)
log(GFCF)	**0.333***** (0.073)	**0.160**** (0.046)	-0.017 (0.053)	**0.378***** (0.074)	0.021 (0.042)	**-0.093*** (0.044)
log(RDS)	-0.072 (0.051)	0.011 (0.026)	0.012 (0.016)	-0.007 (0.014)	0.003 (0.027)	**-0.041**** (0.015)
log(ICTS)	-0.183 (0.051)	**0.125***** (0.026)	-0.051 (0.127)	-0.083 (0.084)	**-0.038*** (0.019)	-0.169 (0.099)
log(Trade.Openness)	-0.183 (0.109)	0.021 (0.070)	**0.119**** (0.035)	0.167 (0.094)	**0.120**** (0.036)	**0.180***** (0.045)
Edu	-0.003 (0.003)	**0.012***** (0.002)	0.000 (0.002)	-0.001 (0.001)	0.000 (0.000)	0.000 (0.001)
INTuse	**0.017**** (0.006)	**0.003***** (0.001)	0.002 (0.002)	**0.002*** (0.001)	**0.002***** (0.000)	0.000 (0.001)
log(Patents)	0.049 (0.053)	0.063 (0.044)	0.038 (0.058)	0.009 (0.044)	-0.023 (0.020)	-0.042 (0.034)
HRST	0.005 (0.003)	**0.013**** (0.004)	0.004 (0.007)	0.001 (0.002)	**0.005*** (0.002)	0.003 (0.002)
R^2	0.838	0.947	0.757	0.753	0.823	0.622
Adj. R^2	0.455	0.676	0.324	0.506	0.654	0.367
Num. obs.	35	56	28	98	112	56
P-value	0.000	0.000	0.0125	0.000	0.000	0.000

Source: own elaboration.

[4] Countries for which data on ICT capital is available in the Total Economy Database.

In the first sub-period (1995–1999), only gross fixed capital formation (β=0.333, p<0.001) and Internet usage (β=0.017, p<0.01) appeared to be significant and positively affected labour productivity in CEE and WE countries. In the years 2000–2007, ICT spending (β=0.125, p<0.001), gross enrolment ratio (β=0.012, p<0.001) and human resources in science and technology (β=0.013, p<0.01) also become significant in explaining the growth of labour productivity in Central and Eastern European countries. In WE countries, at that time, two other complementarities – human capital, measured by total public expenditure on education per total annual hours worked (β=0.077, p<0.001) and trade openness (β=0.12, p<0.01), along with human resources in science and technology (β=0.005, p<0.01) and Internet usage (β=0.002, p<0.001), positively influenced productivity. Interestingly, ICT capital had a significant but negative impact on labour productivity in Western European countries (generally, in all analysed sub-periods, the relationship between ICT spending and labour productivity in WE countries was negative). This may imply that new ICT investments in WE countries were too low to positively affect productivity. In contrast, it appears that CEE countries took advantage of the favourable economic situation in order to catch up to West European countries by investing in ICT capital. Unfortunately, the economic crisis reversed this trend – the impact of ICT capital on labour productivity in CEE countries in 2008–2011 became insignificant and negative.

Estimated models clearly show that in the recession period (2008–2011), explanatory power dropped significantly (to 32% in the case of CEE countries, and to 37% in the case of WE countries). Variables that previously explained changes of labour productivity became insignificant, and even some coefficients acquired negative numbers. The only significant variable (ICT complementarity), explaining labour productivity in CEE countries, was trade openness (β=0.119, p<0.01). This variable was also significant for WE countries (β=0.18, p<0.001), along with non-ICT capital and R&D expenditures (but in this case, the coefficients had negative numbers).

This leads to the conclusion that the relationship between ICT and productivity, and the importance of given ICT complementarities, are strongly dependent upon the economic situation and the phase of the economic cycle. Macroeconomic stability seems to be a crucial factor enhancing labour productivity through the use of Information and Communication Technologies in Western and Central and Eastern European countries. Thus, the convergence processes between CEE and WE countries are hampered during economic slowdown, not only because of a decrease of capital investments (in non-ICT and ICT capital), but also due to the diminished influence of ICT complementarities.

Conclusions

It has been widely acknowledged that Information and Communication Technologies play a crucial role concerning economic growth and productivity performance, not only in highly developed countries, but also in developing or emerging economies – e.g. CEE countries. Theoretical and empirical research studies on the relationship between ICT and labour productivity and TFP growth emphasises the importance of complementary factors enhancing the measurable effects of ICT implementation. The analysis presented in this paper focuses on identifying these complementarities in CEE and Western European countries.

Empirical research at the macroeconomic level, based on the Solow growth model, showed that ICT complementarities played an important role in enhancing labour productivity in CEE (and WE) countries, especially in the years 2000–2007. It also revealed that the global economic crisis had a significant and unfavourable impact on the relationship between ICT complementarities and labour productivity. The following conclusions, stemming from the analysis, seem exceptionally interesting.

Firstly, although there are a couple of potential ICT complementarities at the macro level, econometric modelling revealed that only some complementary factors to ICT investments appeared significant to affect labour productivity in CEE countries – almost all of them are related to human capital (gross enrolment ratio, human resources in science and technology and Internet usage determined by the digital skills of the users). At the same time, variables used as indicators of innovativeness turned out to be statistically insignificant.

Secondly, sources of labour productivity (including ICT complementarities) proved to be sensitive to cyclical changes in the economy. These are significant in explaining productivity when the economic situation is relatively stable, but during a recession, the relationship becomes insignificant. Obviously, this issue requires further examination. This conclusion is quite important, taking into account that CEE countries are still attempting to converge to the performance levels of the more developed Western European countries, and ICT seem to be an important factor in this process.

Thirdly, ICT contribution to labour productivity in CEE countries was significant only in 2000–2007 – a period when the economic situation was relatively good and stable in these countries. If companies invest in ICT mainly in times of promising financial prospects, the role of ICT complementarities shall be even more important when enhancing ICT-driven productivity.

Fourthly, trade liberalisation and openness to foreign investment appears to be an important factor determining the implementation of new technologies

and dissemination of knowledge and innovation to all European economies in times of crisis. Open borders allow for an international spillover effect that contributes to economic growth in developing countries and enhancement of their catching-up process through adaptation of advanced foreign technologies.

The obvious limitation of this research study is the relatively small sample of countries included in the estimation. We also keep in mind the existing disparities in labour productivity caused by heterogeneity across the analysed countries. Although there are more factors influencing labour productivity, we could not take all of them into consideration. Regarding the importance of this topic, especially for transition economies, there is a need to conduct further research studies in this area. This includes macro-level analyses (with more countries, improved indicators and more reliable longitudinal data taken into account), as well as micro-level studies. This company-level approach (requiring collection of primary data from small, medium and large enterprises) seems especially promising, as CARDONA et al. (2013) argue that differences between countries concerning ICT effects are much less significant at the micro-level than at the macro and sectoral level.

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