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Marcin Piatkowski and Bart van Ark

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Summary

This paper investigates the role of information and communication technology (ICT) as a driver of improved productivity performance of Central and Eastern European (CEE) countries and Russia (CEER) relative to the EU-15 and the U.S. during the 1990s. The paper investigates how, and to what extent, ICT contributed to a narrowing in the productivity gap. Although investment in ICT capital has strongly increased, total factor productivity (TFP) growth has made the largest contribution to convergence during the 1990s. In a few CEER countries, notably the Czech Republic and Hungary, ICT production contributed more to productivity growth than the EU-15 average. Spillovers from a productive use of ICT in both CEER countries and the EU-15 are still considerably lower than in the U.S.. The paper argues that the convergence process between CEER countries and the EU-15 is characterized by two phases. In the first "restructuring" phase, convergence has been driven by enterprise restructuring in manufacturing, which was facilitated by rapid ICT investment in new plants, and by growth in ICT production in particular through FDI. In the second "expansionary" phase the sustained convergence has to rely more on productivity growth in sectors that make intensive use of ICT, in particular the service sector. While the first phase is dependent largely on openness and basic fundamental reforms, the second phase requires deeper structural reforms focused on product and labor market flexibility, business re-organization and investment in human capital and ICT skills.

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1. Introduction

The post-communist transition phase in Central and Eastern Europe (CEE) is almost over. The recent accession to the European Union of the eight post-communist economies marked the formal end of their transition from a socialist centrally planned to a market economy. The other two CEE countries (Bulgaria and Romania) are set to join the EU by 2007, too (as well as Croatia at a later stage).

However, the transition by itself has not led to a full convergence with the developed countries in Europe and the U.S., as was mistakenly assumed by some scholars when the process started a decade and a half ago[2]. After all, within the old EU-15 there are still large differences in average per capita income between, for example, southern and northern member countries, and these gaps only narrow very slowly. At present only the first part of the post-transition growth potential in the CEE countries (although less so in Bulgaria and Romania) has been realized. The question arises as to the future sources of convergence with the EU-15 and the U.S. More specifically, we ask ourselves which role information and communication technology (ICT) plays in the process.[3]

The purpose of this paper is to analyze the impact of ICT on labor productivity growth in CEE countries and Russia (CEER) in the framework of the catch-up and convergence hypotheses. We analyze how the investment, use and production of ICT contributed to the convergence (or even leapfrogging) of CEER countries towards the EU-15 average and the U.S. during 1995-2001. In this context, we also focus on the linkages between the diffusion and productive use of ICT in CEER countries with structural reforms, investment in human capital, and enterprise restructuring.

In the remainder of this paper we will argue that the ICT-led convergence process can be divided into two phases: in the first, "restructuring" phase, the convergence has been driven by rapid growth in ICT investment which has facilitated the restructuring process in manufacturing, and a rise in ICT production mainly through foreign direct investment. The completion of the first, restructuring phase is mostly dependent on some basic fundamental reforms: macroeconomic stability, open markets which allow for inflows of FDI, some basic labor and product market deregulations, infrastructural improvements, and an increase in the

[2] See Sachs (1993) and Aslund (1995) for the exposition of the optimistic view and Kolodko (2000) and Nuti (2003) for critiques.

[3] This paper builds on a previous paper by the same authors, which presented a detailed macro and industry-level analysis of the ICT-led convergence of CEE countries with the EU-15 and the U.S (Van Ark and Piatkowski, 2004).

basic quality of the human capital. At the end of the first convergence phase, productivity growth may slow down as the restructuring process in manufacturing nears completion. During the next "expansionary" phase period, the convergence will have to rely mainly on an intensive and productive use of ICT in non-ICT producing sector of the economy, particularly in services.[4]

The successful move to the second phase, however, requires ICT to be complemented with a more sophisticated deregulation of product markets, increased labor flexibility, organizational innovations in enterprises, improved management practices, access to financing and investment in a broader palette of human capital and ICT skills. These reforms are much harder to achieve than those required during the restructuring phase. Also, compared to the EU-15, CEER countries may or may not have an advantage in achieving this.

The paper proceeds as follows. In Section 2 we formalize the channels through which ICT impacts labor productivity growth. We first introduce a growth accounting model and a shift-share methodology which are jointly used to estimate the contributions of ICT to labor productivity growth at aggregate and industry level. We then provide a stylistic model that links the contributions of ICT to productivity with indicators of structural reforms ("structural indicators"). Although we do not have sufficient independent observations to statistically test the linkages between productivity and reforms, the following sections provide important empirical clues to how this relationship might work. In Section 3 we use the growth accounting methodology to estimate the contributions of investment in ICT capital and TFP to labor productivity growth. We also discuss the determinants of ICT investment and TFP during the restructuring phase and the type of structural reforms that were associated with it. In Section 4 we focus on the impact of the ICT production channel on labor productivity growth, and we identify the most fundamental reforms that were required to make this possible. In Section 5 we focus on the ICT use channel. We adopt an industry-level perspective to show the divergence in labor productivity growth rates between ICT-using and non-ICT industries in the CEER countries, the EU-15 and the US. We then link our results to indicators that measure progress in structural reforms, management skills and human capital which are crucial for a more productive use of ICT. Section 6 concludes by discussing the implications of our "two-phase" convergence hypothesis. We argue that further convergence

[4] As shown by Van Ark and Piatkowski (2004), labor shedding was also a major source of labor productivity growth in the CEE countries during 1993-2001. ICT contributed to restructuring mainly through increased investment in new equipment with embedded ICT and basic automatization of back-office operations (accounting, procurement, etc.).

of the CEER countries will depend on substantial changes in their economic environment, which would allow for productive implementation of ICT, particularly in services.

2. ICT, Labor Productivity Growth and Structural Reforms

The contribution of ICT to output and labor productivity growth can be measured within the extended growth accounting framework based on the original work by Solow (1957) and Jorgenson and Griliches (1968) and later extended by inter alia Oliner and Sichel (2000) and Jorgenson and Stiroh (2000).[5] Since ICT products and services are both outputs from the ICT industries as well as inputs into ICT-using industries, ICT can impact labor productivity through the following three channels:

1. Use of ICT capital as an input in the production of other goods and services;
2. Increase in total factor productivity (TFP) of production in ICT sector, which contributes to aggregate TFP growth in an economy;
3. Contribution to economy-wide TFP from increase in productivity in non-ICT producing sectors induced by production and use of ICT (spillover effects);

The growth accounting methodology can be summarized as follows. Gross domestic product (Y) is produced from aggregate factor inputs X, consisting of capital services (K), divided into ICT capital (K_{it}) and non-ICT capital (K_n) and labor services (L). Productivity is represented as Hicks-neutral augmentation of aggregate input (A). The aggregate production function takes the form:

$$Y = A * X(L, K_n, K_{it}) \quad (1)$$

with subscript *n* indicating services from non-IT capital and subscript *it* indicating services from information technology capital (including office and computing equipment, communication equipment and software). Under the assumption of competitive factor markets and constant returns to scale, growth accounting expresses the growth of output as a share weighted growth of inputs and total factor productivity, denoted by A, which is derived as a residual.

$$\Delta \ln Y = vL \, \Delta \ln L + vKn \, \Delta \ln Kn + vKit \, \Delta \ln Kit + \Delta \ln A \quad (2)$$

[5] For other countries than the U.S., see for example, Colecchia and Schreyer (2001) for OECD, Daveri (2002) and van Ark, Timmer and Ypma (2003) for the EU and Piatkowski (2004) for the CEER countries.

where v's denote the average shares in total factor income and because of constant returns to scale: $v_L + v_{Kn} + v_{Kit} = 1$, and Δ refers to first differences. By rearranging equation (2) the results can be presented in terms of average labor productivity growth defined as y = Y/L, the ratio of output to employment, k = K/L, the ratio of capital services to persons employed and TFP:

$$\Delta \ln y = v_{Kn} \Delta \ln k_n + v_{Kit} \Delta \ln k_{it} + \Delta \ln A \quad (3)$$

Section 3 measures the contribution of ICT capital deepening ($v_{Kit} \Delta \ln k_{it}$) to aggregate labor productivity growth.

Another useful distinction can be made between TFP growth originating in (manufacturing) industries producing ICT goods (A_{prod}) which represents the first channel above, in (mainly service) industries which are heavy users of ICT (A_{use}) representing the third channel, and TFP in other industries (A_{other}):

$$\Delta \ln y = v_{Kn} \Delta \ln k_n + v_{Kit} \Delta \ln k_{it} + \Delta \ln A_{prod} + \Delta \ln A_{use} + \Delta \ln A_{other} \quad (4)$$

However, without industry-specific data on investment we will not be able to separate TFP growth in ICT-producing industries ($\Delta \ln A_{prod}$), intensive ICT-using industries ($\Delta \ln A_{use}$) and other industries ($\Delta \ln A_{other}$).[6]

Some clues on the distinction between productivity growth from ICT production, ICT use and other sources of productivity growth can be obtained by decomposing aggregate labor productivity growth into the contributions of ICT-producing industries ($\Delta y_{prod} S_{prod}$), ICT-using industries ($\Delta y_{use} S_{use}$) and less-intensive users of ICT ($\Delta y_{other} S_{other}$) according to a shift-share methodology:

$$\Delta y = \frac{Y}{L} = \sum_{i=1}^{n} \left(\Delta \frac{Y_i}{L_i} \right) \left(\frac{L_i}{L} \right) = \sum_{prod} \left(\Delta y_{prod} S_{prod} \right) + \sum_{use} \left(\Delta y_{use} S_{use} \right) + \sum_{other} \left(\Delta y_{other} S_{other} \right) \quad (5)$$

with *S* denoting the share of each industry group in total employment.[7] In Section 4 we focus on the contribution of ICT-producing industries to labor productivity growth, and in

[6] Nonetheless, Timmer et al. (2003) and Piatkowski (2004) provide rough estimates of the contribution of ICT-producing sector to TFP growth in the EU-15 and CEE countries, respectively, during 1995-2001. Their estimates are based on TFP growth rates in the U.S. ICT producing industry.

[7] This equation can be further decomposed into contributions to labor productivity growth from productivity within each industry group (the 'intra-effect') and the effects of shifts of employment from one industry group to another (the 'shift-effect') (See Inklaar, McGuckin and van Ark, 2003). Here we do not make that distinction as it is less relevant for our primary distinction between the three channels by which ICT impacts productivity.

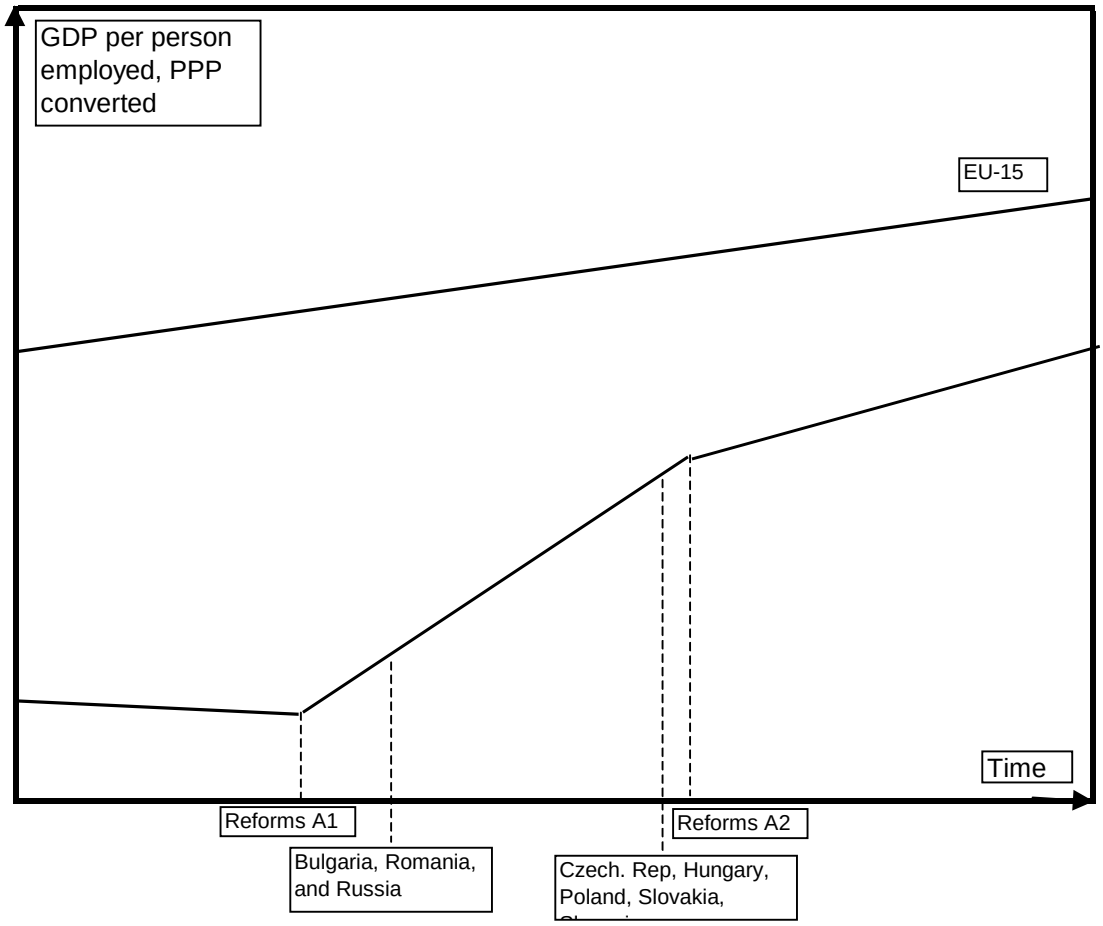
Section 5 on the contribution from industries which are typically classified as ICT-using industries.

The results of these two decomposition techniques may be used to analyze interactions between the contribution of ICT to average productivity growth and various structural indicators, reflecting the quality of the economic and institutional environment in the CEE countries. In this paper we work from a "two-phase convergence" hypothesis between CEER countries and the EU-15 (and the U.S.) which is based on an interaction of ICT production and use with restructuring of the economy and structural reforms.[8]

Figure 1 provides a stylized representation of this process. In the early stage of transition the primary reforms led to an immediate catch-up in productivity, in part supported by a strong – but temporary – negative effect on the labor market through labor shedding. This process has supported investment in ICT and a surge in ICT production in CEER countries. However, both effects are transitional. ICT investment is characterized by diminishing returns and markets for ICT goods have become saturated. Hence the first convergence phase peters out after a certain period of time. During the second phase, convergence may continue but will it depend mainly on the productivity effect from the use of ICT. As services industries are the biggest users of ICT, reforms will mainly need to target these industries.

[8] It should perhaps be stressed that ICT stands in general for the introduction of new technologies and modern equipment. As ICT emerged as the key general purpose technology driving accelerated growth in many countries during the 1990s, we use it as a symbol for the broader phenomenon of technological change that has also accompanied the growth process in the CEER countries.

Figure 1: Stylized representation of Two-Phase Convergence Process in CEER countries and the EU-15 since the beginning of Transition in 1989



Source: author's own

We can now build a simple stylistic model (equations 6 and 7), where changes in labor productivity growth ($\Delta Y/L$) in phase 1 are a function of ICT contribution to labor productivity growth through the contribution from ICT capital deepening ($v_{Kit}\ \Delta \ln k_{it,}$ see equation 4) and ICT production ($\Delta y_{prod} S_{prod}$), whereas labor productivity growth in phase 2 depends on ICT use ($\Delta y_{use} S_{use}$). These ICT contributions are in turn dependent on structural reform indicators (A1 and A2), which are linked with the two phases of convergence, respectively. The model can then be described as follows:

$$\Delta Y/L \text{ (phase 1)} = f\ (v_{Kit}\ \Delta \ln k_{it}\ ,\ y_{prod} S_{prod}) * A1 \quad (6)$$

$$\Delta Y/L \text{ (phase 2)} = f\ (y_{use} S_{use}) * A2 \quad (7)$$

where A1 represent structural indicators for phase 1, with A2 representing structural indicators for phase 2.

The crucial issue here is to identify the determinants of adoption and diffusion of ICT at both the aggregate and the industry level. There is a large literature on this subject for advanced countries. For these countries it shows that ICT use crucially depends on the level of competition in the product markets, flexibility of labor markets, quality of human capital, access to high-risk financing, spending on innovation, quality of law enforcement, trade openness, direct costs of ICT products, size of foreign direct investments and the level of liberalization of the telecom markets.[9]

Unfortunately there are much fewer studies that focus on the determinants of ICT adoption in developing and transition economies. Van Ark and Piatkowski (2004) provide a broad assessment of determinants of investment in ICT in CEER countries. They constructed a a new economy indicator, that measures various components related to the quality of the economic and institutional environment in CEER countries. The new economy indicator included, for example, trade openness, the development of financial markets, the quality of human capital, labor and product market flexibility, openness to macroeconomic stability and openness to foreign investment. This indicators shows a positive relation with the ICT capital contribution to labor productivity growth[10]

The key question, however, is whether all of the above determinants interact equally with the growth in ICT production, absorption of ICT in manufacturing and ICT use in the service sector, respectively. For instance, it seems unlikely that product market deregulation is equally important for the growth in ICT production, during the first convergence phase, as for the productive use of ICT in the service sector during the second, "expansionary" phase. The former is mostly dependent on FDI, which – as shown in the next section – is driven by open borders, existence of basic infrastructure and rule of law. Conversely, as argued by OECD (2003, 2004), ICT diffusion in the service sector seems to be strongly linked with competition (while, paradoxically, enhanced competition could even deter FDI). Hence some factors are more likely to interact directly with ICT investment, while others will mostly impact ICT production. In the next section we make a start in answering this question by analyzing the strength of interactions of ICT investment with a number of structural factors that can be identified for the two convergence phases.

[9] OECD (2003, 2004) provides a very useful review. See also Vu (2004), who presents results of his cross-country regression analysis of more than fifty developed and developing countries.

[10] Clarke (2003) provides evidence for the important role of FDI in ICT diffusion in CEE countries. Muller and Salsas (2003, 2004) argue that the use of Internet is closely linked with GDP per capita, openness, liberalization of the telecom market, costs of access to the Internet and the quality of the telecommunication infrastructure.

3. The Contribution of ICT Capital and TFP to Growth

Much of the attention for the role of ICT in growth has focused on the contribution of ICT production to growth. However, as shown by a number of studies, ICT capital has been a more important source of growth in the U.S., the G-7 and the EU-15 during the 1990s than ICT-related TFP growth.[11]

This also appears to be the case for transition economies. Piatkowski (2004) and Van Ark and Piatkowski (2004) provide growth accounting results comparing the contribution of ICT capital to labor productivity growth in CEER countries with the EU-15 and the U.S. during 1995-2001. **Table 1** shows that, in absolute terms, the contribution of ICT capital to labor productivity growth in most CEER countries (with the exception of Romania and Russia) was higher or comparable to that in the EU-15 (column 3).

Table 1: ICT capital contribution to labor productivity growth (GDP per person employed) in CEER countries, EU-15 and the U.S., 1995-2001, in %-points

	GDP per person employed (annual growth, %)	%-point contribution of:			Relative ICT capital share in LP growth (%)
		Non-ICT capital intensity	ICT capital intensity	Total factor productivity growth	
	(1)	(2)	(3)	(4)	(5)
CEE countries	**3.5**	**1.0**	**0.6**	**2.0**	**17%**
Slovakia	4.8	1.4	0.6	2.8	12%
Poland	4.4	1.8	0.6	2.1	13%
Slovenia	3.8	0.7	0.5	2.5	14%
Romania	3.5	1.4	0.3	1.8	7%
Hungary	3.3	0.2	0.7	2.4	22%
Czech Republic	2.8	1.4	0.8	0.6	27%
Bulgaria	1.9	-0.1	0.5	1.6	26%
Russia	**1.7**	**-0.6**	**0.1**	**2.2**	**8%**

[11] See, for example, Jorgenson (2004) for the G7, Colecchia and Schreyer (2001) for OECD; and Daveri (2002), van Ark, Timmer and Ypma (2003) for the EU, Piatkowski (2004) for the CEER countries.

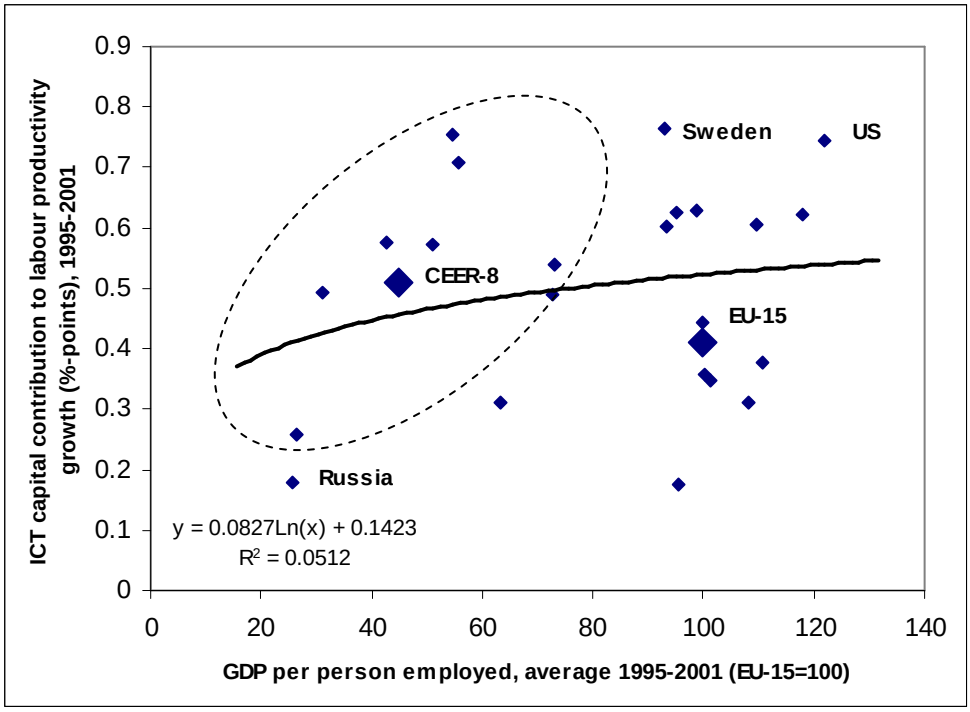
European Union	**1.1**	**0.4**	**0.4**	**0.3**	**36%**
Ireland	4.0	0.6	0.6	2.7	15%
Greece	3.2	1.1	0.5	1.7	15%
Austria	2.3	0.9	0.4	1.0	16%
Finland	2.2	-0.6	0.6	2.2	28%
Sweden	1.8	0.5	0.8	0.6	42%
Denmark	1.6	0.9	0.6	0.2	38%
United Kingdom	1.5	0.6	0.6	0.4	39%
Portugal	1.5	1.1	0.3	0.1	21%
Belgium	1.4	0.3	0.6	0.5	46%
Germany	1.2	0.3	0.3	0.5	30%
France	1.0	0.3	0.3	0.4	31%
Italy	0.8	0.5	0.4	0.0	46%
Netherlands	0.3	-0.2	0.4	0.0	164%
Spain	-0.3	0.1	0.2	-0.6	-51%
United States	**2.2**	**0.4**	**0.7**	**1.1**	**34%**

Source: Van Ark and Piatkowski (2004) for the CEE countries, EU-15 and the US. Piatkowski (2004) for Russia.

However, there are substantial differences across countries, and in fact only the Czech Republic and Hungary showed capital contributions which were significantly above those of the EU-15 (and close to Sweden and the U.S.). A glance at **Figure 2**, which relates the comparative level of GDP per person employed to the *absolute* ICT contribution to labor productivity growth, shows that ICT capital in itself has not been a direct source of convergence during the second half of the 1990s. However, lower labor productivity levels of the CEER countries also did not prevent them from benefiting from ICT capital to the same degree as the average for the EU, and it has therefore not been a cause for divergence either.[12]

[12] The final column of Table 4 shows that the relative contributions of ICT capital to labor productivity growth were much lower for the CEE countries than for the EU-15 average (17% and 36% respectively) because of the higher growth rates of labor productivity itself in the CEE countries.

Figure 2: Contribution of ICT Capital to Labor Productivity Growth versus average GDP per Person Employed (EU-15=100), 1995-2001



Source: Based on Van Ark and Piatkowski (2004) and Piatkowski (2004) for Russia.

Figure 2 also shows that, within the CEER group, countries with higher labor productivity levels are characterized by a somewhat larger contribution of ICT capital. This implies that, provided CEE countries have reached a certain degree of industrial development, they have successfully used ICT to increase the growth rates in labor productivity to the same degree as the most ICT-intensive countries in the EU-15. This suggests that ICT investment in CEE countries may have been dependent on "network effects": higher levels of development, particularly as regards to the ICT infrastructure, have stimulated faster growth in ICT use through feed-back effects.[13]

The most important source of convergence between the CEER countries and the EU-15 during the first convergence phase has been the higher contributions of total factor productivity in the former group (column 4 of **Table 1**). These relatively high TFP growth rates are likely to be strongly related to the effects of restructuring which was driven by large scale privatization and liquidation of inefficient state-owned companies, a phenomenon

[13] See for instance, Roller and Waverman (2003) who argue that improvements in telecom infrastructure provide for non-linear network effects.

mostly unique to countries transitioning from a centrally planned to a market economy.[14] But TFP growth in CEER countries may to some extent also have arisen from "productivity effects" derived from the production or use of ICT goods and services, which is the topic of the next two sections.

4. The Contribution of ICT Production

Although ICT capital has been an important source of growth in CEER countries, there are reasons to assume that at least some countries in the region may also have greatly benefited from attracting production of ICT goods and facilities, in particular through foreign direct investment. Van Ark and Piatkowski (2004) provide estimates of the direct contribution of ICT production to labor productivity growth in CEE countries, EU-15 and the U.S. during 1993/95-2001.[15] Perminov and Egorova (2004) provide results, using a similar method, for Russia for the period 1995-2001.

Table 2 shows that ICT production had the largest absolute contribution to labor productivity growth in the U.S., Hungary and the Czech Republic.[16] These two CEE countries also reported higher absolute ICT contributions than the EU-15. Hence, the growth in the ICT producing sector accelerated the convergence between these two countries and the EU-15. This was not the case, however, for Poland, Slovakia and Russia where the contribution of ICT sector to labor productivity growth was substantially lower than in the other two CEE countries, EU-15 and the U.S.

Gaspar (2004), on the basis of data from Eurostat, provides estimates of the share of ICT sector in GDP in Slovenia, Bulgaria and Romania in 2003. It turns out that the size of the ICT sector in Slovenia and Bulgaria is comparable to that of Hungary and the Czech Republic and significantly larger than in Poland and Slovakia. The size of the Romania's ICT sector is roughly equal to that of the latter two countries. However, lack of data on productivity growth

[14] Between 1990 and 2000, the share of the private sector in GDP in CEE countries increased from less than 10% to more than 60% of the total (EBRD 2003).

[15] The study is based on data from the GGDC 60-Industry database (http://www.ggdc.net/dseries/60-Industry.shtml) for Czech Republic, Hungary, Poland and Slovakia. Data for other CEER countries was not available. Labor productivity growth rates for CEER countries are based on a price deflator for the U.S.. The latter excludes changes in prices of semiconductors and computers as these are not manufactured in CEE countries. For more details, see Van Ark and Piatkowski (2004).

[16] It has to be remembered that most of the production in the two CEE countries does not represent ICT-products at the high-tech end, but rather household electronic equipment and and assembly items, for example, television screens, computer monitors, other electronic equipment, etc.

rates in ICT sector does not allow for measuring the contribution of the ICT sector to productivity growth in these countries.

Table 2: Contributions to labor productivity growth (GDP per person employed) of ICT-producing industry in CEER, EU-15 and the US, 1993/1995-2001

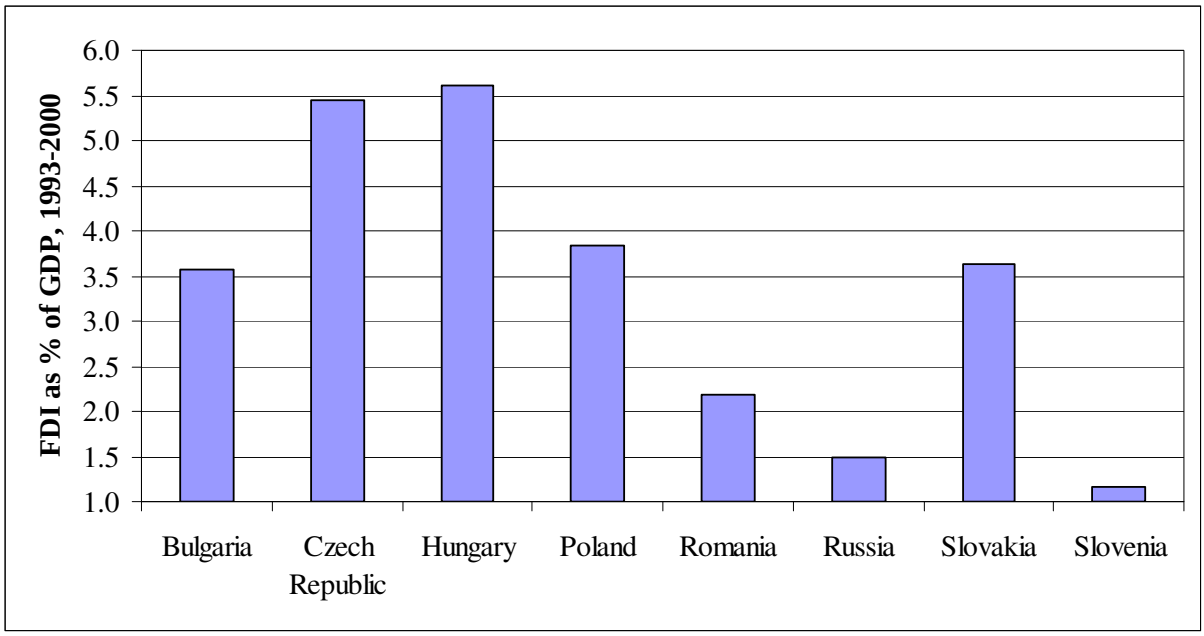
	EU-15	USA	Czech Republic	Hungary	Poland	Slovakia	*Russia**
	1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001	*1996-2000*
Labor productivity (LP) growth	1.34	2.19	2.83	2.41	3.33	2.50	*2.10*
Contribution of ICT Producing Industries to LP growth	0.58	0.98	0.68	0.68	0.21	0.15	*0.08*
As share of LP growth (in %)	43.6	44.5	23.9	28.4	6.3	5.9	*3.8*
Pro memoria: *Share of ICT sector in GDP (in %)*	6.0	7.8	5.0	6.7	4.7	4.5	*n.a.*

Note: *Results for Russia are not fully comparable due to different industry classification, different data sources and difficulties with comparability of output and employment across industries.

Source: based on Van Ark and Piatkowski (2004) and underlying dataset for CEE countries; Perminov and Egorova (2004) for Russia.

The question arises as to what explains the difference between the fast growth of the ICT sector in the Czech Republic and Hungary and much slower growth in other CEE countries. It appears that the rise of the ICT sector in the former two countries has been mostly driven by inflows of FDI as domestic industries were not competitive enough to develop due to technological retardation, lack of access to high-risk financing and low level of innovation.[17] **Figure 3** shows that throughout the 1990's Czech Republic and Hungary were the major recipients of FDI in the CEE region as measured by the share of FDI in GDP.

Figure 3: Gross annual inflows of FDI in CEE countries as a share of GDP, 1993-2000 average



Source: World Development Indicators (2004).

Similarly, **Table 3** shows that FDI inflows into the ICT sector in the Czech Republic and Hungary, as represented by the stock of foreign investment in the machinery, electrical and optical equipment industries, were the highest among the four leading CEE economies.

[17] Until 1990/1991imports of high-technology products to former socialist countries was restricted under the so-called COCOM (Coordinating Committee) restrictions enforced by NATO to prevent diffusion of dual use civilian-military high-tech equipment in the member countries of the Warsaw military pact. Consequently, the domestic ICT sector was effectively cut off from importing modern ICT technologies. In addition, as argued by Perminov and Egorova (2004), a large part of the output of the domestic ICT sector was defense-oriented, particularly in Russia. After transition, most of this production failed to find new customers.

Table 3: FDI stocks in ICT industries in CEE countries as % of total manufacturing FDI stocks, end 2001

	Czech Republic	Hungary	Poland	Slovakia
Machinery and equipment	4.2	5.3	1.2	4.1
Electrical and optical equipment	13.9	19.5	7.7	4.8

Source: based on Havlik and Urban (2003), p. 56, Table 9.

But why were the Czech Republic and Hungary able to attract more FDI than other CEE countries? Campos and Kinoshita (2003) argue that in transition economies FDI inflows are mostly dependent on trade openness, opportunities for agglomeration (clustering), and the quality of institutions. IMF (2001) adds the quality of infrastructure and the privatization policy. **Table 4** shows that between 1993/94-2001 the Czech Republic and Hungary score relatively high on almost all indicators determining inflows of FDI: trade openness, development of infrastructure, rule of law and macroeconomic stability. The value of the Composite Reform Indicator A1 for the first convergence phase puts to two countries in the second and third place, respectively, among the CEER countries. Only Slovenia is a clear outlier, as it has a very low FDI inflow percentage and at the same time comes out very high on the various reform indicators. This is due to the privatization policy, which mostly relied on domestic rather than on foreign investors.

Table 4: Determinants of FDI in CEE countries, 1993/94-2001 average

		Reforms related to FDI in First Convergence ("Restructuring") Phase					
	FDI Inflow as % of GDP	Trade openness	Development of infrastructure	Macroeconomic stability	Rule of law	Composite Reform Indicator A1	Ranking
Hungary	5.61 (1)	92.48 (5)	517.2 (3)	17.17 (4)	0.81 (2)	**2.11**	**3**
Czech Rep.	5.45 (2)	120.40 (2)	587.7 (2)	7.23 (1)	0.65 (3)	**3.31**	**2**
Poland	3.85 (3)	54.67 (8)	339.1 (6)	18.64 (5)	0.59 (4)	**(0.70)**	**5**
Slovakia	3.62 (4)	126.81 (1)	450.8 (4)	8.98 (2)	0.26 (5)	**2.00**	**4**
Bulgaria	3.58 (5)	100.83 (4)	399.4 (5)	161.10 (7)	-0.08 (6)	**(1.67)**	**6**
Romania	2.19 (6)	61.64 (6)	223.2 (8)	89.20 (6)	-0.13 (7)	**(3.35)**	**7**
Russia	1.48 (7)	57.72 (7)	237.1 (7)	177.53 (8)	-0.80 (8)	**(5.78)**	**8**
Slovenia	1.16 (8)	115.57 (3)	773.3 (1)	13.17 (3)	0.88 (1)	**4.08**	**1**

Note: Trade openness: aggregate share of imports and exports in GDP, 1993-2001 average. Development of infrastructure: combined penetration of mainline telephones, mobile phones and PCs per 1000 inhabitants, 1994-2001 average. Macroeconomic stability: 1993-2001 average inflation rate (CPI). Rule of law: World Bank Rule of Law Indicator (Kaufmann et al., 2003), average for years 1996, 1998, 2000 and 2002. The Composite Reform Indicator represents an aggregate standardized value of all four variables. The variables are standardized by subtracting a sample mean from each observation and then the result is divided by a sample standard deviation. This implies a mean of zero and a standard deviation of one across countries in the sample. Hence all results are comparable and can be aggregated. Numbers in brackets indicate the position of each country within the sample.

Source: World Development Indicators (2004) and Kaufmann et al. (2003) for the rule of law.

In other CEER countries, privatization policies also had a large impact on the size and direction of FDI. But Kornai (2001) and EBRD (1995) argue that the Czech Republic and Hungary started their privatization process, based on sales to foreign investors, earlier than other CEE countries. This gave both countries an important head start, as early FDI inflows into the ICT sector tended to entice further foreign investment in the same industry thus creating a positive feed-back mechanism.

While none of the above factors by itself explains the differences in growth of the ICT sector within CEE countries, together these factors clearly show that the overall business environment for FDI-driven growth in the ICT sector was more conducive in the Czech Republic and Hungary than in the remaining CEE countries.[18]

We conclude that the convergence driven by ICT production in the CEE countries seems to be mostly dependent on basic fundamental reforms, which allow for inflows of FDI: open markets, basic rule of law, infrastructural improvements, privatization process and some measure of macroeconomic stability. These factors are consistent with our hypothesis of a "two-phase" convergence.

5. The ICT Use and Convergence from an Industry Perspective

Given the small size of the ICT producing sector, which in all CEE countries does not represent more than 8 percent of GDP (see **Table 2**), the sustained convergence towards the EU-15 income levels will naturally have to rely on productivity growth outside ICT producing industries. Apart from the use of ICT for the restructuring of production processes in manufacturing, ICT has also a great potential for intensive use in the service sector of the economy. Accelerated labor productivity growth in ICT-using industries is driven by a rise in capital intensity and total factor productivity growth.

To adequately distinguish between the effects from ICT use and ICT production, Van Ark and Piatkowski (2004) provide estimates of labor productivity growth rates in ICT-producing, ICT using and non-ICT industries (subdivided into manufacturing and service industries) in four CEE countries, Czech Republic, Hungary, Poland and Slovakia, for the period 1993-2001. In addition, Perminov and Egorova (2004) provide results from a study for Russia for the period 1995-2001. **Table 5** shows that productivity growth rates in ICT-using

[18] One could add other factors that could also have played a role in stimulating growth of the ICT sector: low wages, political stability, size of the domestic market, level of taxation, geographical proximity to Western Europe, initial conditions etc.

manufacturing industries in the four CEE countries are in most cases more than double the productivity growth rates in non-ICT manufacturing. This is a clear indication that ICT use has been an important source of productivity growth in manufacturing in CEE countries.

Productivity growth rates in ICT-using manufacturing industries in CEE countries, and this time including Russia, are also substantially higher than in the EU-15 and the U.S. It provides evidence for the success of the "first phase" restructuring process of the ICT-using manufacturing industries in CEER countries driven by basic fundamental reforms which are comparable to those that applied to ICT production. These are reforms which allowed for inflows of FDI, increase in management skills, labor shedding, and replacement of old equipment with new capital embedding modern technologies, particularly ICT. Thanks to the high productivity growth rates, ICT-using manufacturing industries in the CEE countries contributed between 0.46 and 0.98 percentage point to aggregate labor productivity growth between 1993 and 2001, against close to zero for the EU-15 and the U.S (**Table 6**). Russia took an intermediate position, accounting for 0.2 percentage point of labor productivity growth in ICT-using manufacturing.

In ICT-using services, however, productivity growth rates in the CEE countries and Russia, but also in the EU-15, are much lower than in the U.S. (**Figure 4**). The mixed picture of productivity growth in ICT-using services in the CEE countries is also reflected in the contributions of this industry group to aggregate productivity growth, which ranges from -0.58 percentage points to 0.92 percentage points in CEE countries (**Table 6**). The contribution for Poland and for the Czech Republic is higher than in the EU-15, but lower than in the U.S.[19]

[19] The contribution from the ICT-using service group for Russia is relatively large, because of the large share of some of industries in this group which for Russia cannot really be characterized as intensive ICT-users.

Table 5: Labor productivity growth (GDP per person Employed) of ICT-producing, ICT-using and non-ICT industries, 1993/1995-2001

	EU-15	US	Czech Rep.	Hungary	Poland	Slovakia	*Russia**
	1995-2001	1995-2001	1993-2001	1993-2000	1993-2001	1993-2001	*1995-2001*
Total Economy	1.3	2.2	2.8	2.4	3.3	2.5	*2.8*
ICT Producing Industries	7.2	9.6	13.0	7.8	5.8	8.5	*6.4*
ICT Producing Manufacturing	11.9	23.0	15.4	7.5	8.1	7.1	*16.4*
ICT Producing Services	5.5	1.8	12.9	8.6	4.6	9.2	*2.5*
ICT Using Industries	1.6	4.6	4.4	1.0	4.8	1.8	*5.5*
ICT Using Manufacturing	1.6	0.1	9.2	7.1	12.0	7.1	*6.4*
ICT Using Services	1.5	5.4	2.3	-0.6	2.3	-1.1	*3.4*
Non-ICT Industries	0.6	-0.2	1.3	2.3	2.4	2.4	*1.1*
Non-ICT Manufacturing	1.3	0.2	5.3	2.6	4.6	3.4	*8.4*
Non-ICT Services	0.2	-0.2	-1.5	2.1	1.9	4.1	*-4.9*
Non-ICT Other	1.9	0.7	2.3	2.6	1.3	-1.8	*-0.5*

Note: * Results for Russia, based on Perminov and Egorova (2004), are not fully comparable with other countries. For industry classification into main industry groups, see Van Ark and Piatkowski, 2004, Table A.4. Real estate has been excluded from both GDP and Total persons engaged for all countries; For the CEE countries instead of using US ICT deflators, the US ICT deflators exclude prices of computers and semi-conductors.

Source: Van Ark and Piatkowski (2004) for all countries except for Russia, which is based on Perminov and Egorova (2004).

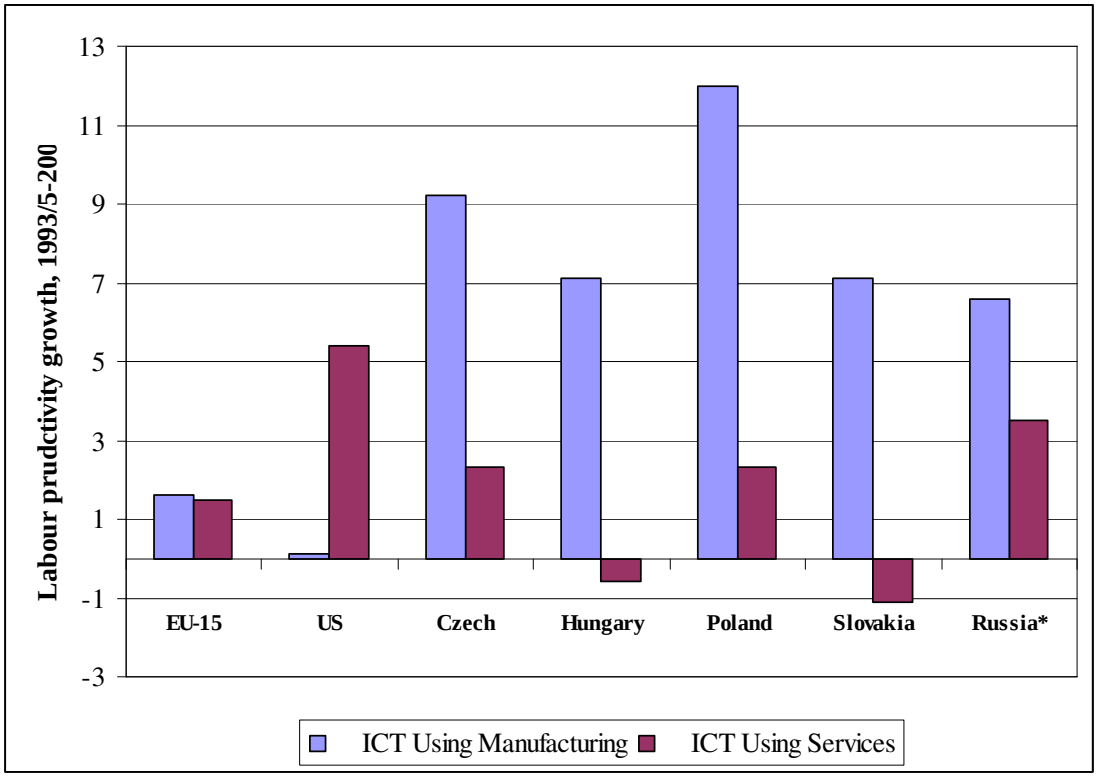
Table 6: Contributions to labor productivity growth of ICT-producing, ICT-using and non-ICT industries, 1995-2001

	EU-15	US	Czech Rep.	Hungary	Poland	Slovakia	*Russia**
	1995-2001	1995-2001	1993-2001	1993-2000	1993-2001	1993-2001	*1996-2000*
Total Economy	1.34	2.19	2.83	2.41	3.33	2.5	2.80
ICT Producing Industries	0.58	0.98	0.68	0.68	0.21	0.15	0.06
ICT Producing Manufacturing	0.2	0.73	0.15	0.27	0.06	0.12	0.01
ICT Producing Services	0.38	0.25	0.53	0.42	0.15	0.03	0.05
ICT Using Industries	0.46	1.17	1.55	0.54	1.57	0.4	2.40
ICT Using Manufacturing	-0.01	-0.12	0.67	0.46	0.65	0.98	0.06
ICT Using Services	0.47	1.29	0.89	0.07	0.92	-0.58	2.34
Non-ICT Industries	0.29	0.06	0.6	1.19	1.56	1.96	0.34
Non-ICT Manufacturing	0.01	-0.18	0.94	0.31	0.66	1.84	1.40
Non-ICT Services	0.30	0.10	-0.01	0.80	0.75	1.54	-1.06
Non-ICT Other	-0.01	0.14	-0.33	0.08	0.15	-1.43	-0.1

Note: as in Table 5.

Source: as in Table 5.

Figure 4: Labor productivity growth rates in ICT using manufacturing and ICT-using services in CEER, EU-15 and the US, 1993/95-2001 average.



Note: Data for Russia, based on Perminov and Egorova (2004), is not fully comparable with other countries. 1993-2001 average for CEE countries, 1995-2001 for Russia, EU-15 and the U.S.

Source: Van Ark and Piatkowski (2004) for all countries except for Russia, which is based on Perminov and Egorova (2004).

The differences in the productivity growth rates in the ICT using services in favor of the U.S. seem to suggest that only that country has succeeded in moving to the "second phase" of the productive use of ICT in the service sector of the economy.[20] This is due to the much more conducive business environment in the U.S., which stems primarily from competitive products markets, flexible labor markets, organizational innovations, large investments in R&D, and availability of high-risk financing (OECD 2003, 2004, McKinsey 2001).

[20] See, for example, Bosworth and Triplett (2004).

Table 7: Indicators of business environment for ICT use in CEER countries, EU-15 and the US, 1993/94-2001 average

		Reforms related to ICT use in Services in Second Convergence Phase						
	%-point contribution of ICT - use in services	Product market regulation	Employment protection	R&D investments	Development of financial markets	Quality of human capital	Composite Reform Indicator A2	Ranking
Bulgaria	n.a.	n.a.	n.a.	0.59	15.2	3.3	**(3.1)**	**10**
Czech Republic	0.89	2.9	1.7	1.19	64.4	4.6	**0.7**	**4**
Hungary	0.07	1.6	1.4	0.75	26.5	4.6	**(0.92)**	**7**
Poland	0.92	3.3	1.9	0.70	19.2	5.2	**(0.42)**	**5**
Romania	n.a.	n.a.	n.a.	0.53	9.4	3.5	**(3.08)**	**9**
Russia	n.a.	n.a.	n.a.	0.94	10.9	3.8	**(2.05)**	**8**
Slovakia	-0.58	n.a.	n.a.	0.81	32.9	4.6	**(0.67)**	**6**
Slovenia	n.a.	n.a.	n.a.	1.46	33.1	5.8	**1.83**	**3**
EU-15*	0.47	1.5	2.4	1.91	87.4	5.1	**2.99**	**2**
USA	1.29	1.0	0.2	2.62	129.6	4.8	**4.74**	**1**

Note: unweighted average for the EU-15, except for data on R&D investments and quality of human capital. Product market flexibility and employment protection legislation for year 1998; the lower the number, the higher product market flexibility and lower employment protection.. R&D investments (% of GDP): average 1995-2001. Development of financial markets: Domestic credit to private sector (% of GDP), 1995-2001 average. Quality of human capital: Public spending on education (% of GDP), 1995-2001. The Composite Reform Indicator A2 is based on the last three variables: R&D investments, development of financial markets and quality of human capital. For the procedure for constructing the indicator, refer to Table 4.

Source: Nicoletti et al. (2000) for product market flexibility and employment protection. Eurostat (2003) for R&D investments and public spending on education. World Development Indicators (2004) for the remaining indicators.

Table 7 shows that the CEE countries, Russia as well as the EU-15 lag behind the U.S. in terms of product market and labor market flexibility, development of the financial markets, quality of human capital and spending on innovation. The Composite Reform Indicator A2 for the second convergence phase ranks the U.S. in the distant first position, followed by the EU-15, Slovenia, Czech Republic and Poland. Russia, Romania and Bulgaria are at the bottom of the table.[21]

A conducive environment for productive use of ICT in services is much harder to achieve in CEER countries than in the U.S. (or even the EU-15). It requires fundamental and often painful reforms in product and labor markets and in the financial sector. These structural reforms, required for the second phase of convergence, are especially needed for CEER countries as the productivity effects from the "restructuring" phase have been mostly exhausted, in particular in the five most developed CEE countries.

In addition to the reform measures discussed above, the quality of management practices within firms may also have played an important role in explaining the differences in productivity performance between the CEER, EU-15 and the U.S. (see, for example, McKinsey 2001). The preliminary results of a recent enterprise survey in the U.S., UK, Germany and France suggest that productivity of ICT investments is strongly depended on the quality of management (Dorgan and Dowdy 2004). As shown in Table 8, productivity growth stemming from IT investment can be substantial only when it is supported by high quality of management practices which allows for business re-organization necessary to reap full benefits of ICT use.[22]

[21] The choice of variables for each of the determinants, as in Van Ark and Piatkowski (2004), was dependent on the availability of data covering the whole sample of countries.

[22] Interestingly, improvements in management practices has higher impact on productivity than investment in IT. This however should be interpreted with caution given the small underlying dataset as well as a lack of information on the underlying sources of the improvement in management practices (ICT could also play a role in it).

Table 8: Increase in firm-level TFP in France, Germany, UK and USA driven by the quality of management and IT investment, 2001-03 average

		Intensity of IT deployment	
		25% quartile and below	75% quartile and above
Management Practice Score	25% quartile and below	**0%**	**2%**
	75% quartile and above	**8%**	**20%**

Source: London School of Economics and McKinsey survey and analysis of 100 companies in France, Germany, UK and the US published in Dorgan and Dowdy (2004).

The above analysis suggests that ICT use has contributed to faster productivity growth in CEE countries at the industry-level, particularly in the ICT-using manufacturing industries, which have exploited a large catch-up potential through ICT-aided restructuring. Productivity growth rates in ICT-using services in CEE countries as well as in the EU-15 were lower than in the U.S. This is linked to a more conducive business environment in the U.S., which stimulates business re-organization, labor force re-allocation and investment in human skills. These facts provide support to our hypothesis of a "two-phase" convergence pattern. Implementation of far-reaching structural reforms and investment in human capital is prerequisite for the CEE countries and Russia to benefit from the large remaining potential for catch-up and convergence in the service and the non-ICT using sector.

6. Conclusions

This paper has investigated how the productivity performance of the CEE countries vis-à-vis the EU-15 and the US has evolved during the 1990s. We showed that five leading CEE countries (the Czech Republic, Hungary, Poland, Slovakia and Slovenia) and – to a lesser extent - Bulgaria have exploited the productivity potential of ICT to accelerate its convergence with the EU-15, partly through ICT investment and productivity growth in ICT using manufacturing, and in some cases (Czech Republic and Hungary) through productivity growth in ICT production. However, in the case of Romania and Russia, ICT led to a divergence rather than convergence. The divergence between the economic impact of ICT in Romania and Russia vis-à-vis the other six CEE countries provides substance to a hypothesis that there is a close link between diffusion of ICT and advancement of fundamental reforms.

We have also showed that the ICT-led convergence process in the CEER countries can be divided into two phases: in the first "restructuring" phase, convergence is driven by growth in ICT production and ICT-aided restructuring in manufacturing industries. At the end of the first phase, however, productivity growth slows down as the restructuring process in manufacturing nears completion. Hence, in the second, "expansionary" phase, the convergence needs to mainly rely on an intensive use of ICT in non-ICT producing sector of the economy, particularly in services.

The completion of the first, restructuring phase is mostly dependant on some basic fundamental reforms: open markets, which allow for inflows of FDI, basic rule of law, some fundamental labor and product market deregulation, infrastructural improvements, and some measure of macroeconomic stability. A successful transition to the "expansionary" phase, however, requires ICT to be complemented with other reform measures: deregulation of product markets, more flexible labor markets, business re-organization based on improved management practices, higher spending on innovation and finally larger investment in human capital and ICT skills. These are in practice much harder to achieve.

At present there are insufficient observations to carry out a comprehensive statistical analysis of the relation between reforms during these two convergence phase and the performance in terms of ICT investment and productivity from ICT production and use. But on the basis of the available evidence, it appears that most CEER countries have more or less realized the first convergence phase (although less so in Bulgaria, Romania and Russia). We argue that the convergence process may slow as the productive implementation of ICT in services is more complicated and requires larger changes in the economic environments of CEER countries.

Further income and productivity convergence of the CEER countries with the EU-15 will now be dependent on faster growth in the service and non-ICT using sector manufacturing, which together already represent more than two-thirds of GDP in these countries. In spite of the potential for technological leapfrogging, as evidenced by the manufacturing sector, the service sector in the CEE and Russia countries has reported much lower labor productivity growth rates than in the U.S during 1995-2001. The latter country seems to be among the few advanced countries which thanks to a better economic environment have so far moved successfully into the "second phase" of ICT-led productivity growth. Further growth in CEE countries and Russia (as well as in many EU-15 countries) will therefore depend on continued progress in the creation of modern institutions, implementation of market-oriented policy reforms aimed at strengthening competition,

increased innovation, improvements in the quality of the human capital and an enhancement of the comprehensiveness and effectiveness of regulations.

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