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The Impact of ICT on Growth in Transition Economies[1]

Summary

The paper analyzes the multi-channel contribution of Information and Communication Technologies (ICT) to output and labour productivity growth in eight transition economies of Central and Eastern Europe (CEE), i.e. Bulgaria, Czech Republic, Hungary, Poland, Romania, Russia, Slovakia and Slovenia between 1995-2001. The impact of ICT on growth in the new five EU member countries (Czech Republic, Hungary, Poland, Slovakia and Slovenia) was higher than the average for the former EU-15. Hence, ICT - through both the capital deepening and TFP growth in ICT-producing sector - contributed to convergence of the level of income between those countries and the EU-15. This was however not the case for Bulgaria, Romania, and Russia, where ICT contribution to growth was lower than in the EU-15. ICT thus led to income deconvergence.

Future growth prospects of the CEE countries, including Russia, will largely depend on further ICT investments and an ability to ensure their productive use on a macro, industry and micro level. The paper speculates that ICT capital will have a significant contribution to long-term growth in Poland, taken as a proxy for other CEE countries, on the level of 15% of the projected average annual GDP growth of 4% until 2025. This projection does not however take into account the potential for emergence of new applications of ICT, which could stimulate further increases in aggregate productivity. Neither does it measure the possible contribution from TFP growth in ICT sector and from the spillover effects of ICT production and use.

The paper argues that the potential of ICT will not however be realized without changes in business models and an increase in the quality of human capital and ICT skills. On the macrolevel, as indicated by the *New Economy Indicator*, ICT will not benefit CEE countries without them making consistent progress in economic, institutional and regulatory environment.

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1. Introduction

During the 1990's Information and Communication Technologies (ICT) have contributed to an acceleration in GDP and labour productivity growth rates in a number of developed countries, in particular in the US. This has been evidenced by numerous research results on the impact of ICT on macro, industry and micro-level.[2] In spite of the collapse of the "internet bubble" and dashed hopes as to the emergence of the so-called "new economy", the technological progress spurred by ICT seems not to have been arrested as evidenced by continued high labour productivity growth rates in the US, which during 2000-02 amounted on average to 3.4% versus "only" 2.5% in the 1995-2001 period (Economist 2003). Similar trends have also been witnessed by a number of other developed countries, including Ireland, Netherlands, Australia, Denmark, and Great Britain (OECD 2004, 2003, and van Ark and Piatkowski 2004).

There is however hardly any evidence for the impact of ICT on developing and emerging economies, including the post-communist countries transitioning from a centrally planned to a market economy. Among the few publications, IMF (2001) indicates the positive contribution of ICT production to growth in late 1990's in selected countries of South-East Asia. Lee and Khatri (2003) document contributions of ICT capital to growth in the South-East Asian countries.[3] Piatkowski (2003a, 2004b) provides first estimates, based on growth accounting methodology, of ICT capital contribution to growth and labour productivity in Bulgaria, Czech Republic, Hungary, Poland, Slovakia, Slovenia, Romania and Russia.

The aim of this paper is to extend the previous research results of the same author to estimate the overall, multi-channel contribution of ICT to growth and labour productivity in the four CEE countries of Czech Republic, Hungary, Poland and Slovakia, the new EU members as of May 1, 2004, during 1995-2001. Their performance will be juxtaposed against results on ICT capital contribution to growth in Bulgaria, Romania, Russia, and Slovenia, EU-15 and the US in the same period.

In Section 2 the paper briefly describes the methodology. Section 3 analyzes the role of each of the ICT channels in the catching-up process of the CEE countries with the EU-15. Section 4 relates the aggregate contribution of ICT to output and labour productivity growth to economic, institutional and regulatory determinants of diffusion and productive use of ICT. In Section 5 the author - in order to get a feel for the potential of ICT for accelerating catching-up in Poland and in the remaining CEE countries – speculates on the contribution of ICT to output growth in Poland during 2002-25. Section 6 concludes and presents policy recommendations.

2. Accounting for Overall Impact of ICT on Output Growth and Labour Productivity

The methodology of measuring the contribution of ICT to growth and productivity is based on 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). Since ICT products and services are both outputs from the ICT industries and inputs into ICT-using industries, ICT can impact economic growth through four major channels:

[2] Macro research on USA: Jorgenson (2001), Jorgenson and Stiroh (2000), Oliner and Sichel (2002), Stiroh (2002a); on the EU-15 countries: Colecchia and Schreyer (2001), van Ark *et. al*. (2002), Daveri (2002), Jalava and Pohjola (2002). On the industry level in the US and the EU: Stiroh (2002b), Timmer *et. al.* (2003) and OECD (2003). On a microlevel in the US and the EU: Brynjolfsson i Hitt (1996, 2000) and OECD (2004, 2003).

[3] Zhen-Wei and Pitt (2003) provide a useful literature review.

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

To measure the overall impact of ICT on growth, it is best to express the aggregate production function in the following form:

$$Y_t = Y(Y_t^{ICT}, Y_t^0) = A_t F(C_t, K_t, L_t) \qquad (1)$$

where, at any given time t, aggregate value added Y is assumed to consist of ICT goods and services ICT – $Y^{ICT}{}_{t,}$ as well as of other production $Y^0{}_t$. These outputs are produced from aggregate inputs consisting of ICT capital $C_{t,}$, other (i.e. non-ICT) physical capital $K_{t,}$, and labor L_t. TFP (total factor productivity) is here represented in the Hicks neutral or output augmenting form by parameter A.

Assuming that constant returns to scale prevail in production and that all production factors are paid their marginal products, equation (1) can be expressed in the following form:

$$\hat{Y} = w_{ICT}\hat{Y}^{ICT} + w_0\hat{Y}^0 = v_{ICT}\hat{C}_t + v_0\hat{K}_0 + v_L\hat{L} + \hat{A} \qquad (2)$$

where symbol ^ indicates the rate of change and the time index t has been suppressed for the simplicity of exposition. The weights w_{ICT} and w_0 denote the nominal output shares of ICT and non-ICT production, respectively. The weights sum to one similarly as the weights $v_{ICT,}$ $v_{0,}$ and v_L, which represent the nominal shares of ICT capital, non-ICT capital, and labor, respectively.

Denoting the total employment by *H(t)* and labor productivity by *Y(t)/H(t)*, the equation (2) can then be re-arranged to measure the contribution of ICT investment to growth in labour productivity

$$\hat{Y} - \hat{H} = v_{ICT}(\hat{C}_t - \hat{H}) + v_0(\hat{K}_0 - \hat{H}) + \hat{A} \qquad (3)$$

As shown in the above equation, there are three sources of growth in labor productivity: ICT capital deepening, i.e. increase in ICT capital services per employed person, non-ICT capital deepening, and exogenous growth of TFP, which is derived from increase in productivity in ICT-producing, ICT-using and non-ICT sector.

3. Have ICT Contributed to faster Catching-up of the CEE Countries?

The contribution of ICT to the catching-up of CEE countries with the EU-15, or – in other words – to the convergence process between the two groups of countries, can be analyzed from the viewpoint of the four channels, through which ICT can impact output and labour productivity growth. The following four subsections look separately at each of the channels.

3.1 Contribution of ICT Production

The direct contribution of ICT production – as show in the left hand side of equation (2) – can be estimated through multiplication of the nominal share of ICT production in GDP (w_{ICT}) by a real growth rate of the value of ICT production ($\hat{Y}^{ICT}$):

$$\hat{Y} = w_{ICT}\hat{Y}^{ICT} + w_0\hat{Y}^0 \qquad (4)$$

where weights w_{ICT} and w_0 denote nominal shares in GDP of ICT and non-ICT production, respectively.

Table 1 and Figure 1 show an average contribution of ICT production to output growth in the CEE countries between 1995-2001 in comparison to the EU-15 and the US.[4] ICT production in absolute terms had the largest contribution to GDP growth in Hungary, USA, and Czech Republic. The contribution of ICT sector to GDP growth in Poland and Slovakia was much lower. In relative terms, the contribution of ICT production to growth was higher in Hungary and Czech Republic than in the US and the EU. Thus ICT production helped the two CEE countries to converge on the EU-15. This was not the case for Poland and Slovakia, which reported lower relative contributions to growth. It seems that the size of FDI inflows to the ICT sector has been the main driver of the difference in the value of ICT production among the CEE countries.[5]

Table 1: The contribution of ICT-producing sector, ICT-using sector and non-ICT sector to GDP growth in CEE countries, EU-15 and USA, 1995-2001 average

	UE-15	USA	Czech Republic	Hungary	Poland	Slovakia
ICT producing sector	0,51	1,01	0,75	0,99	0,28	0,37
Share in GDP growth	*19,4%*	*27,1%*	*36,6%*	*43,2%*	*6,8%*	*12,1%*
ICT using sector	0,93	1,83	1,55	0,20	1,56	1,31
Non-ICT sector	1,20	0,89	-0,25	0,89	2,37	1,36
GDP growth	2,64	3,73	2,06	2,30	4,22	3,04
Contribution of ICT producing sector: US ICT deflator	0,69	1,01	0,92	1,38	0,56	0,47
Share in GDP growth	*26,1%*	*27,1%*	*44,6%*	*59,9%*	*13,3%*	*15,5%*
Contribution of ICT producing sector: ICT national deflators	0,53	1,01	0,74	1,27	0,40	0,36
Share in GDP growth	*20,0%*	*27,1%*	*36,1%*	*54,9%*	*9,6%*	*11,7%*

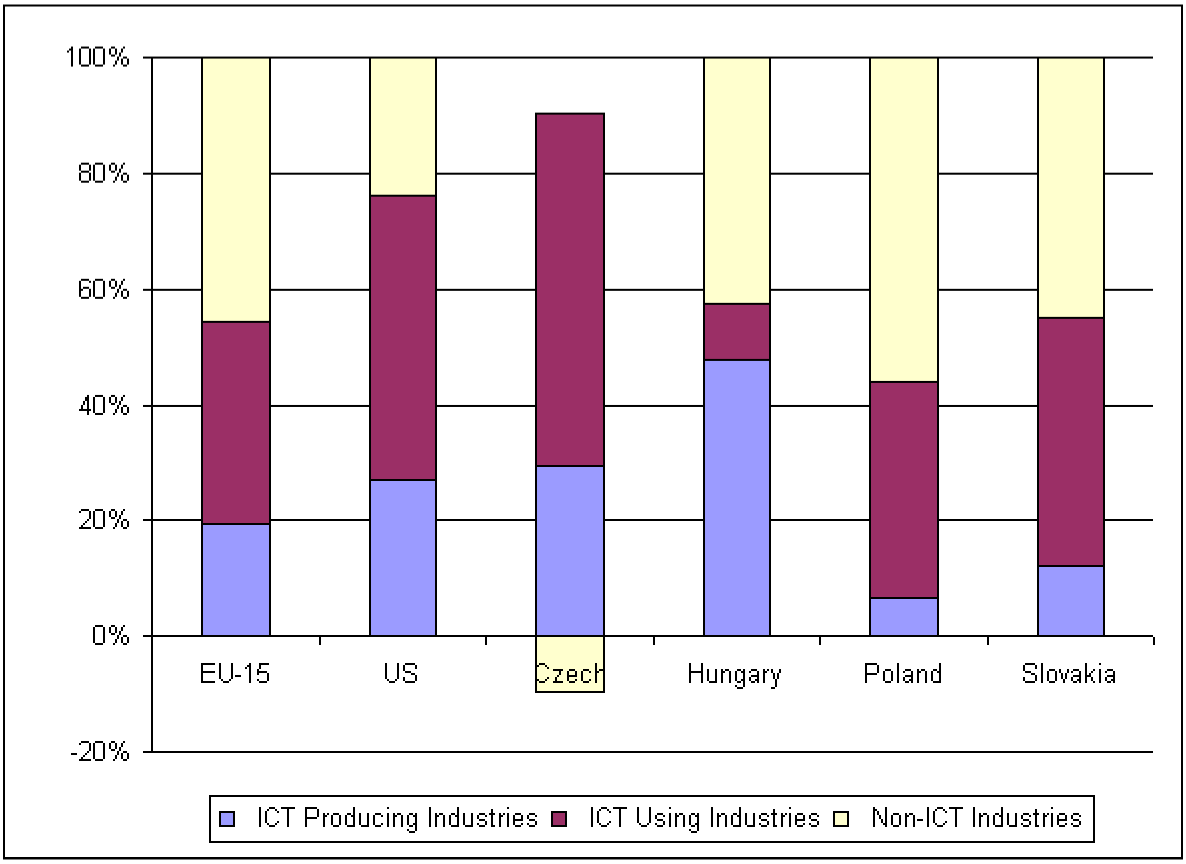
[4] Data on value added in fixed and current prices and on ICT deflators are based on the "60 Industry Database of the Groningen Growth and Development Centre" available at http://www.ggdc.net/dseries/. ICT producing sector is defined on the basis of the OECD classification OECD (2001b). Definitions of ICT-using and non-ICT sectors are based on van Ark, Inklaar and McGuckin (2002).

[5] Although, as illustrated by the recent withdrawal of IBM from ICT manufacturing in Hungary and transfer of its one-billion-dollar-plus-in-revenue manufacturing plant to South-East Asia (Gaspar et al. 2004), ICT production in CEE countries seem to rest on a shaky ground and is subject to fierce cost competition from other parts of the world, in particular China and South-East Asia.

Note: GDP growth rates based on the GGDC database[6]. Real estate has been excluded from both GDP and Total persons engaged for all countries. Based on US ICT deflators excluding semiconductors and computers.

Source: based on dataset from Van Ark and Piatkowski (2004) and Groningen Growth and Development Centre (GGDC), 60-Industry Database, http://www.ggdc.net

Figure 1: The contribution of ICT-producing sector, ICT-using sector and non-ICT sector to GDP growth in CEE countries, EU-15 and USA, 1995-2001 average (based on US ICT deflator excluding semiconductors and computers).



Note*:* as in Table 1
Source: as in Table 1

Most EU-15 and all CEE countries do not report separate quality-adjusted deflators for ICT production, which would adequately reflect rapid decreases in prices of ICT products and services and continuous increase in their quality.[7] Failure to take account of the changes in quality of ICT products would lead to a substantial underestimation of their real contribution to growth. Hence, in light of the lack of national hedonic ICT deflators, this paper relies on hedonic ICT production deflators for the US ICT industry corrected for the general inflation level in each country through the so-called "price harmonization method" developed by

[6] GDP growth rates in the GGDC database do not usually conform to official statistics as in order to ensure cross-country consistency the GGDC dataset uses chain-weighted indices for all aggregated real output series rather than fixed-weight (Laspeyres) indices used by the national statistical offices. The latter due to changes in the structure of the economy may result in a significant substitution bias. More details in van Ark and Piatkowski (2004).

[7] Only France, Denmark, Sweden, Kanada and USA publish ICT hedonic deflators. For detailed discussion on the methodology of hedonic prices please refer to OECD (2000) and Mulligen (2002).

Schreyer (2000) and then utilized by inter alia Van Ark and Piatkowski (2004). However, since – as opposed to the US ICT sector – the ICT production in CEE countries mostly comprises of household electronics rather than semiconductors and computers, changes in prices of the latter were excluded from the deflator to better reflect the real structure of ICT production in CEE countries.

Table 1 also presents results based on the harmonized US ICT deflator and national non-hedonic ICT deflators. Based on these deflators, the contribution of ICT production to growth is higher for all CEE countries. Hence, these results will represent the upper bound limit for the contribution of ICT production to growth in CEE countries.

A slightly different picture of the convergence process transpires from a comparison of ICT production contribution to labour productivity growth (Table 2 and Figure 2). While again the absolute contributions of ICT production are highest in Hungary, the US, and Czech Republic, the relative contributions in the CEE countries, with the exception of Hungary, are much lower than in the EU and the US.[8] It is mostly due to high labour productivity growth rates in the CEE countries which resulted from deep structural reforms, transfers of technology, higher capacity utilization, improvement in managerial and business skills, increase in human capital and higher macroeconomic stability. If it were possible to disentangle the contribution to labour productivity growth of the one-off positive productivity effects of structural reforms (i.e. privatization and liquidation of inefficient state-owned firms, emergence of new, more productive firms) and cyclical effects of an economic recovery which followed the 1990-93 transitional recession (Kolodko 2000), the role of ICT production in labour productivity growth in the four CEE countries would be much higher. For Poland and Slovakia, however, this effect would not be significant enough to make up for the difference in relative ICT production contribution to labour productivity growth. One could therefore argue that in Poland and Slovakia, as opposed to Hungary and Czech Republic, the ICT-production contributed to divergence rather than convergence with the income levels of the EU and the US.

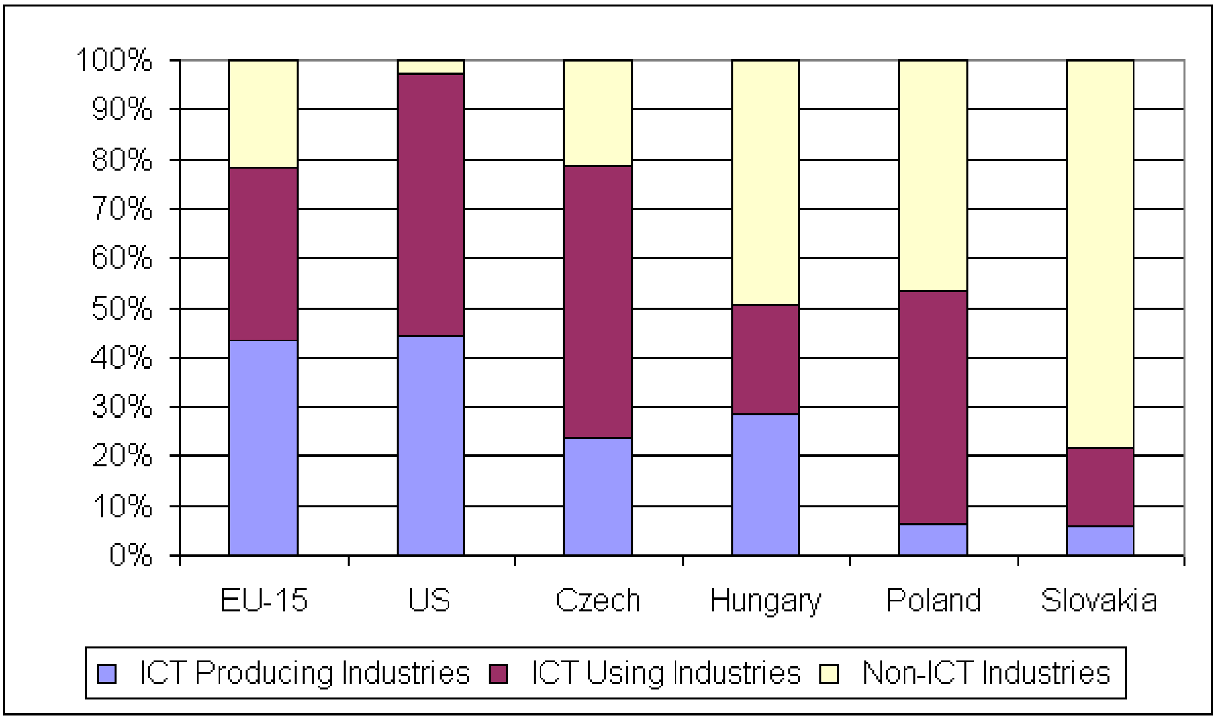
[8] It is worth mentioning that the level and growth rates in in labour productivity in the ICT producing and the ICT using sector in the CEE countries during 1993-2001 was significantly higher than in the non-ICT sector (van Ark and Piatkowski 2004). This evidence points to the important contribution of ICT to labour productivity on the industry level in the CEE countries.

Table 2: Contributions to labour productivity growth (GDP per person employed) of ICT-producing, ICT-using and non-ICT industries in CEE, EU-15 and the US, 1993/1995-2001

	UE-15	USA	Czech Republic	Hungary	Poland	Slovakia
	1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001
GDP growth	1,34	2,19	2,83	2,41	3,33	2,50
ICT Producing Industries	0,58	0,98	0,68	0,68	0,21	0,15
As share of GDP growth (in %)	43,6%	44,5%	23,9%	28,4%	6,3%	5,9%
ICT Using Industries	0,46	1,17	1,55	0,54	1,57	0,40
Non-ICT Industries	0,29	0,06	0,60	1,19	1,56	1,96
ICT Producing Manufacturing						
Using US ICT deflators	0,07	-	0,33	0,90	0,11	0,19
Using national ICT deflators	0,13	-	0,16	0,56	0,19	(0,93)

Note: Real estate has been excluded from both GDP and Total persons engaged for all countries. EU-15 and US for 1995-2001; Czech Republic, Hungary, Poland and Slovakia for 1993-2001.
Source: based on van Ark and Piatkowski (2004), Table 7 and underlying dataset.

Figure 2: Contributions to labour productivity growth of ICT-producing, ICT-using and non-ICT industries in CEE countries, EU-15 and the US (based on US ICT deflator excluding semiconductors and computers)



Note: as in Table 2
Source: as in Table 2

3.2 The Contribution of TFP Growth in ICT Production

Jorgenson, Ho and Stiroh (2002) provide methodology for measuring TFP growth at the industry level. The methodology is based on the industry production function:

$$Y_j = f(K_j, L_j, X_j, T) \qquad (5)$$

where *Y* is industry gross output, *K* is capital input, *L* is labour input, and *X* is intermediate input, and *T* is an indicator of efficiency, all for industry *j*. P_{Yj}, P_{Kj} , P_{Lj}, and P_{Hj} denote the prices for outputs and three inputs, respectively. All variables are indexed by time, yet the subscript *t* is eliminated for clarity of notation. Under the usual assumptions of constant returns to scale and competitive markets, a translog index of TFP growth can be defined as:

$$v_{T,j} = \Delta \ln Y_j - \bar{v}_{K,j}\, \Delta \ln K_j - \bar{v}_{L,j}\, \Delta \ln L_j - \bar{v}_{X,j}\, \Delta X_j \qquad (6)$$

where $\bar{v}$ is the two-period average share of the input in the value of nominal output.

Having calculated the industry-level TFP growth rates, the contribution of each industry's TFP growth rates to aggregate TFP growth in the whole economy can be estimated on the basis of Domar model through weighing the TFP growth rate in a particular industry with the so-called Domar weights, i.e. a ratio of gross output of a particular industry to aggregate GDP (Domar 1961). Domar weights can be measured as gross output of a particular industry adjusted - on the basis of input-output tables - for intra-industry deliveries (Timmer *et al.* 2003).

There is a relative wealth of evidence for the substantial role of TFP growth in ICT-producing sector in enhancing the aggregate TFP growth rate, particularly in the US (Jorgenson 2001, Oliner and Sichel 2002 and Jorgenson, Ho and Stiroh 2002). Timmer et al (2003) provide first estimates for TFP growth in ICT producing sector in the EU in comparison to the US. Since on average the size of ICT industries in the EU, as measured by the share in GDP, is much smaller than in the US, the contribution of ICT industries to aggregate TFP growth in the former was lower than in the latter.

Alas, due to insufficient data on industry-level capital service input measures and deflators for both input and output, Timmer et al. (2003) estimates for the EU ICT producing sector TFP contribution to aggregate TFP growth are based on TFP growth rates in the US ICT industries.[9] It is a very rough assumption, but Timmer et al. (2003) argue that given the highly competitive nature of the global ICT market, there is no overarching rationale for TFP growth rates in ICT sector in the EU to be different than in the US. In addition, this approach allows comparison of ICT sector TFP impact on aggregate TFP due to different output shares of ICT industries in each country.

An alternative method of TFP growth measurement is based on changes in industry level value added. In this approach, productivity growth is simply calculated as the difference between total output and total input growth:

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[9] Timmer et al. (ibid.) estimate the contributions of three industries: office, accounting and computing equipment, communication equipment and electronic components (ISIC rev 3 industry numbers 30, 322 and 321 respectively). Due to lack of data, the computer services industry, including software, is excluded. US TFP growth rates for IT production are based on Jorgenson, Ho and Stiroh (2002, Table 18), while TFP growth rates in communication industry are based on Timmer et al. (ibid.) estimates based on Corrado (2003) and Aizcorbe, Flamm and Kurshid (2002).

$$\ln\left(\frac{TFP_{i,t}}{TFP_{i.t-1}}\right) = \ln\left(\frac{va_{i,t}}{va_{i,t-1}}\right) + \alpha_{i,t}\ln(l_{i,t}) + (1-\alpha_{i,t})\ln(k_{i,t}) - \alpha_{i,t-1}\ln(l_{i,t-1}) - (1-\alpha_{i,t-1})\ln(k_{i,t-1}) \quad (7)$$

where $va_{i,t}$ denotes value added, $l_{i,t}$ and $k_{,t\,t}$ represent labour and capital, respectively, while α stands for the labor compensation share in total income.

In comparison to the methodology based on Domar weights, this approach however fails to appropriately identify the role of rapidly declining prices of intermediate inputs such as semiconductors, which are widely used in ICT production (Jorgenson 2001 remarks that semiconductors represent almost half of a cost of a standard computer). Hence, in the context of ICT industry, the first approach based on gross output and Domar weights seems to be more appropriate.

Since data from existing input-output tables for the CEE countries is not sufficient to calculate the Domar weights[10], the only way to get any estimate of the contribution of TFP growth in ICT producing industry to aggregate TFP growth is to make an assumption that the ratio between ICT sector value added and Domar weights for the EU-15 is also the same for the four CEE countries (Czech Republic, Hungary, Poland and Slovakia) and that – like in Timmer et al. (2003) - the TFP growth rates in ICT sector in CEE countries are the same as in the US ICT sector.[11] Since, however, none of the CEE countries produces semiconductors and microprocessors, which have recorded the highest TFP growth rates, and because most of the ICT production in CEE countries comprises of household electronics, it seems reasonable to assume that the TFP growth rate in CEE countries in “electronic components” (ISIC 321, which includes mostly semiconductors and microprocessors) will be equal to the TFP growth rate for “telecommunications equipment” (ISIC 322). The comparability of results between CEE and EU-15 is one of the main benefits of this approach. The obvious shortcoming is the simplifying assumption underlying the calculations. Hence, the estimated results give only a very rough measure of the ICT sector contribution to aggregate TFP growth. However, along with the continued progress in availability of data, more precise calculations should be possible.

Table 3 and Figure 3 show estimates of the contribution of TFP growth in ICT producing sector to aggregate TFP growth in CEE countries, EU-15 and the US. It transpires that in absolute terms ICT sector in Hungary and the US had the largest contribution to overall TFP growth at the level of 0.44 of a percentage point. The contributions in other three CEE countries were much smaller, particularly in Poland and Slovakia (less than 0.1 of a percentage point). This mostly reflects the much smaller size of the ICT sector in these two countries as measured by the share of ICT sector value added (defined as above as ISIC 30, 321 and 322) in total GDP: 0.49% in the Czech Republic, 0.26% in Poland and 0,29% in Slovakia. Likewise, in relative terms, ICT sector contribution to TFP growth was the lowest in Poland and Slovakia (4% and 3%, respectively) while highest in the Czech Republic and Hungary, where it reached 20% and 19% of the total TFP growth, respectively. Quite interestingly, the relative contribution of ICT sector in the EU-15 amounted to 59% of total TFP growth. This result should however be interpreted as an evidence that non-ICT sectors of

[10] The I/O tables for the CEE countries are based on the product rather than industry classification. The former classification does not allow proper accounting for the intra-industry deliveries and hence the exact measurement of the Domar weights is not possible.

[11] The assumption about the equal ratio of value added to Domar weights implies that intra-industry deliveries in the total output of the ICT industry are the same for the CEE countries as for the EU-15 average.

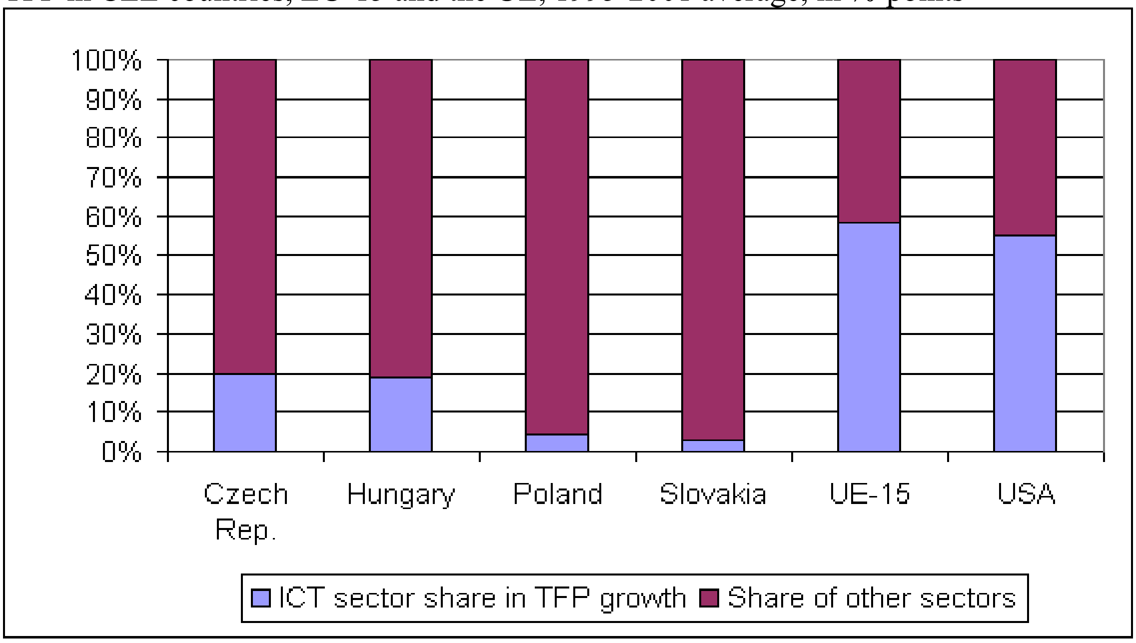
the EU-15 economies reported very low or even negative TFP growth rates rather than that the ICT sector was the driver of productivity growth in these countries.

Table 3: The contribution of TFP growth in ICT sector to aggregate TFP in CEE countries, EU-15 and the UE, 1995-2001 average

Share in total value added (in %)	**UE-15**	**USA**	**Czech Rep.**	**Hungary**	**Poland**	**Slovakia**
ICT production (total)	0,68	1,48	0,49	1,16	0,26	0,29
Computers (30)	0,23	0,41	0,08	0,56	0,09	0,07
Electronic components (321)	0,17	0,65	0,24	0,33	0,03	0,13
Communications equipment (322)	0,28	0,41	0,17	0,26	0,15	0,09
Domar weights (in %)						
ICT production (total)	2,07	3,0	1,3	3,5	0,8	0,8
Computers (30)	0,8	0,9	0,29	1,99	0,30	0,25
Electronic components (321)	0,4	1,3	0,56	0,78	0,06	0,30
Communications equipment (322)	0,8	0,8	0,49	0,74	0,42	0,26
TFP growth (in %)						
Computers (30)	16,8	16,8	16,8	16,8	16,8	16,8
Electronic components (321)	18	18	7,2	7,2	7,2	7,2
Communications equipment (322)	7,2	7,2	7,2	7,2	7,2	7,2
Contribution to aggregate TFP growth (in % points)						
ICT production (total)	**0,26**	**0,44**	**0,12**	**0,44**	**0,09**	**0,08**
Computers (30)	0,13	0,15	0,05	0,33	0,05	0,04
Electronic components (321)	0,07	0,23	0,04	0,06	0,00	0,02
Communications equipment (322)	0,06	0,06	0,04	0,05	0,03	0,02
Aggregate TFP growth	0,31	1,05	0,62	2,38	2,05	2,75
Share of ICT in aggregate TFP growth	59%	55%	20%	19%	4%	3%

Notes: ICT sector defined as a sum of "Computers" (30), "Electronic Components" (321) and "Communications Equipment" (322). TFP growth for „Electronic components" (321) in CEE countries was assumed to equal TFP growth in „Telecommunications equipment" (322).
Source: Timmer *et al.* (2003) for industry-level TFP growth rates. Van Ark and Piatkowski (2004) for aggregate TFP growth rates. GGDC database for shares of ICT sectors in total value added, 1995-2001 average.

Figure 3: The contribution of TFP growth in ICT sector and non-ICT sectors to aggregate TFP in CEE countries, EU-15 and the UE, 1995-2001 average, in %-points



Notes: as in Table 3.

Source: as in Table 3.

The above results can be juxtaposed against estimates of ICT sector contribution to aggregate TFP growth based on the alternative value added methodology. Here however the data for the CEE countries is quite scarce, particularly on the value of industry-level fixed capital stocks. The data on the industry-level gross fixed capital formation (GFCF), which could be used to construct a measure of capital stock on the basis of the perpetual inventory method, is also not sufficient. It is however possible to calculate TFP growth rates for the ICT sector in Poland on the basis of data published by the Polish Central Statistical Office in various editions of the "Yearbooks of Industry Statistics".

Table 4 shows the 1995-2001 average annual TFP growth in the Polish ICT sector, calculated according to equation (7). It turns out that the ICT industries recorded TFP growth rates significantly higher than the average for total manufacturing. Similar results have also been reported by Kolasa and Żółkiewski (2003). Based on data on the share of value added in total GDP (Table 3 for industries 30 and 32 [321 and 322 taken together]) and TFP growth rates (Table 4), the contribution of ICT sector TFP growth to aggregate TFP growth in Poland between 1995-2001 would amount to 0.05 of a percentage point, that is slightly less than the 0.09 contribution based on the gross output methodology.

Table 4: Annual TFP growth and real changes in value added, gross capital stock and labour force in ICT sector in Poland, 1995-2001 average, in %

	Value added	Capital stock	Labour force	TFP growth
Total manufacturing	7,83	4,37	- 1,99	6,82
Office machinery and computers (30)	29,74	7,63	5,58	20,18
Electrical machinery and apparatus n.e.c. (31)	10,83	5,49	- 0,37	8,55
Radio, TV and communication equipment (32)	15,24	0,04	- 6,61	17,87
Medical, precision and optical instruments (33)	11,82	2,99	0,46	11,87

Source: own estimates based on various editions of the „Yearbooks of Industry Statistics" published by Poland's Central Statistical Office.

Very high TFP growth rates in the ICT sector presented in Table 4 raise however some doubts as to their viability, particularly as regards quite low growth rates in the value of gross capital stock. It is quite unlikely that such high TFP growth rates were only due to organizational changes and higher managerial efficiency related to inflows of FDI (Thomson, Philips, LG etc), without any sizable increase in capital investments. It is also worth mentioning, that the data from Central Statistical Office – as opposed to US data – does not use the hedonic deflator to deflate output of the ICT sector. If it were possible to use hedonic deflator, TFP growth rates would even be higher. This would be hard to explain. Hence, future research should focus on either elucidating the exact methodology underlying the official data or on constructing one's own measures of the value of fixed capital stock on the basis of data on gross fixed capital investments on the industry level.

Nonetheless, in the context of this paper, both methodologies provide evidence for high TFP growth rates in ICT sector in the CEE countries. It implies that an increase in the size of the sector would have strongly positive implications for growth in aggregate TFP. Hence, the ICT sector could considerably contribute to faster labour productivity and GDP growth.

3.3 The Contribution of ICT Capital

As on the right hand-side of the equation (2) the contribution of ICT investment to output growth can be defined as a sum of contributions from ICT capital ($\hat{C}_t$), non-ICT capital ($\hat{K}_0$) and labor ($\hat{L}$), where weights v_{ICT}, v_0, and v_L represent the nominal shares of ICT capital, non-ICT capital, and labor, respectively, and sum to one. Total factor productivity (TFP) is represented in the Hicks neutral or output-augmenting form by parameter A. Symbol ^ indicates the rate of change.

$$\hat{Y} = v_{ICT}\hat{C}_t + v_0\hat{K}_0 + v_L\hat{L} + \hat{A} \qquad (8)$$

The contribution of ICT capital to labour productivity can be in turn measured based on equation (3). Yet, ICT investment directly impacts output and labour productivity growth not only through the increase in capital stock available to the employed in an economy: it also adds to growth through the increase in the quality of capital as - due to high depreciation and rapid decrease in prices of ICT - ICT capital has higher marginal rates of return than non-ICT capital. Hence, ICT investment enhances the quality of growth as any increase in the share of ICT capital in the overall capital stock results in higher growth of output (Jorgenson 2001).[12] Vu (2004, p. 11) argues that “ICT is superior to the conventional capital in fostering growth. For a given increases in capital stock (measured in $) and labor, a 10% increase in the ratio between ICT and non-ICT forms in capital stocks adds about 0.4 to 0.6 percentage points to GDP growth”. From this point of view, ICT investments are much more productive than investments in other assets (real estate, means of transport etc.).

Tables 5 and 6 show the size of ICT capital contribution to GDP and labour productivity growth in CEE countries, EU-15 and in the US during 1995-2001. In this period the ICT capital contribution in CEE countries, in spite of much lower levels of GDP and labour productivity per capita, was in absolute terms only slightly lower than the EU average. However, ICT capital contribution to growth in Czech Republic, Hungary, Poland and was higher than in the EU-15. Russia and Romania reported the lowest contributions. This is due to low value of ICT capital stock in both countries and lower growth rates in ICT investment than in the other CEE countries. As argued later, slower diffusion of ICT in Romania and Russia seems to be related to low quality of economic, institutional and regulatory infrastructure.

[12] The increase in the quality of capital can be metaphorically explained when thinking about the difference in filling up a car tank with either low or high octane gasoline. The latter, here representing ICT capital, burns uch faster and more effectively than the low octane gasoline. Hence, by increasing the share of high-octane gasoline in the total stock of gas in a car tank, the capacity and power of the engine increases, i.e. GDP growth accelerates.

Table 5: The contribution of ICT capital to GDP growth in CEE countries, UE-15 and the US, 1995-2001 average, in % points

	GDP growth	Non-ICT capital	ICT capital	Labour force	TFP	Share of ICT capital in GDP growth
CEE-8	**2,67**	**0,47**	**0,48**	**-0,27**	**1,98**	**18,0%**
Bulgaria	0,51	-0,89	0,45	-0,60	1,55	88,4%
Czech Republic	2,27	1,20	0,73	-0,28	0,62	32,2%
Hungary	3,64	0,37	0,71	0,18	2,38	19,4%
Poland	4,81	1,98	0,55	0,23	2,05	11,5%
Romania	0,79	0,08	0,22	-1,35	1,84	28,3%
Russia	1,12	-0,97	0,09	-0,17	2,17	8,3%
Slovakia	4,10	1,15	0,55	-0,35	2,75	13,5%
Slovenia	4,10	0,87	0,54	0,20	2,49	13,1%
USA	**3,52**	**0,75**	**0,82**	**0,90**	**0,82**	**23,2%**
EU-15	**2,42**	**0,81**	**0,46**	**0,84**	**0,46**	**18,8%**

Note: Unweighted average for the eight CEE countries, including Russia.
Source: Timmer *et al.* (2003) for the EU and the US. Own estimates for CEE countries based on extended results from Piatkowski (2003b), which cover additional year 2001.

Table 6: The contribution of ICT capital to labour productivity growth in CEE countries, UE-15 and the US, 1995-2001 average, in % points

	Labour productivity growth	Non-ICT capital	ICT capital	TFP	ICT capital share in total labour productivity growth
CEE-8	**3,27**	**0,78**	**0,50**	**1,98**	**16%**
Bulgaria	1,91	-0,13	**0,49**	1,55	26%
Czech Republic	2,80	1,43	**0,75**	0,62	27%
Hungary	3,25	0,17	**0,71**	2,38	22%
Poland	4,45	1,82	0,58	2,05	13%
Romania	3,55	1,45	**0,26**	1,84	7%
Russia	1,66	-0,64	**0,13**	2,17	8%
Slovakia	4,76	1,44	**0,57**	2,75	12%
Slovenia	3,75	0,73	**0,54**	2,49	14%
USA	**2,21**	**0,42**	**0,74**	**1,05**	**34%**
EU-15	**1,13**	**0,41**	**0,41**	**0,31**	**36%**

Note: Unweighted average for the eight CEE countries, including Russia. Labour productivity defined as GDP growth per person employed.
Source: Van Ark and Piatkowski (2004). Results for Russia based on extended results from Piatkowski (2003b).

The high contribution of ICT capital to GDP and labour productivity growth in CEE countries resulted mostly from rapid real growth rates in ICT investment, which between 1995 and 2001 were increasing at a rate between 25% and 36% per year, with the exception of Russia, which recorded only 18% average growth rate (extended results based on Piatkowski 2003b). The same growth rates for the EU and the US were much lower at 18.5% an 19.3%, respectively (van Ark and Piatkowski 2004). Fast growth in ICT investments had a considerable impact on output growth in CEE countries in spite of low share of ICT capital compensation in total factor input compensation: during 1995-2001 it ranged from 1.78% in Poland to 2.82% in the Czech Republic (extended results based on Piatkowski 2003b) versus the EU-15 and the US average of 3.0% and 5.4%, respectively (Van Ark *et al*. 2002).

Fast growth in ICT investments in CEE countries was stimulated by:

a) Rapidly declining prices of ICT, which encouraged firms to substitute ICT investment for non-ICT investments

b) Large pent-up demand for ICT stemming from low level of development of ICT infrastructure and ICT penetration, which was a legacy of technological backwardness and low ICT investment intensity from before 1989[13]

c) Significant opportunities for utilization of ICT in economic restructuring,

d) Cultural impact of globalization and the „new economy" hype, which stimulated changes change in consumption and investment patterns towards increase in outlays on ICT.

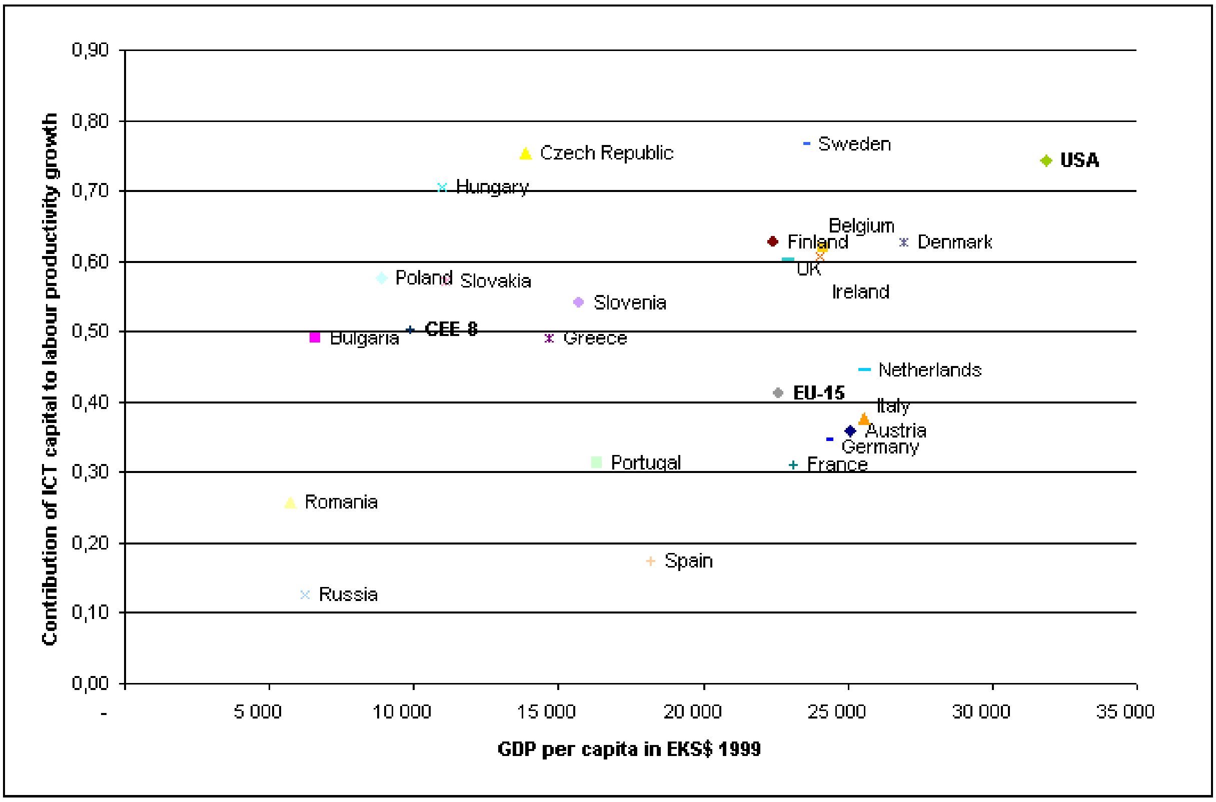
High absolute contribution of ICT capital to output and labour productivity growth in the five leading CEE countries (Czech Republic, Hungary, Poland, Slovakia and Slovenia) provides evidence that ICT capital contributed to the convergence process with the EU countries.

Relative ICT capital contribution in CEE countries is however much lower than in the EU and the US. As already explained earlier, if it were possible to disentangle the one-off positive productivity effects, which raised GDP and productivity growth rates during 1995-2001, the relative ICT capital contribution to growth in CEE countries would be much higher. Hence, the convergence or catching-up hypothesis would still be valid.

Figure 4 shows the relationship between ICT capital contribution to labour productivity and GDP per person employed in CEE, EU and the US. It turns out that there is a relatively strong correlation between both values for the CEE countries, but much weaker one for the EU and the US. This may suggest that for the CEE countries, where the economic restructuring is still in full swing, investments in ICT can have a considerable contribution to acceleration in labour productivity, particularly in the manufacturing sector.

[13] It is worth remembering that until 1990/1991 any imports of ICT products from NATO countries to the CEE countries, members of the Warsaw military pact, were restricted under the so-called COCOM (Coordinating Committee) agreement.

Figure 4: Contribution of ICT capital to labour productivity growth versus GDP per person employed in CEE, EU-15 and the US, 1999 $EKS, average 1995-2001



Source: data for all countries except for Russia based on van Ark and Piatkowski (2004) and GGDC database. Russia based on extended results of Piatkowski (2003b).

In turn, as argued by van Ark and Piatkowski (2004), the lack of correlation for the EU-15 and the US between the level of income and economic effects of ICT investments suggests that the most developed countries are not in a position to increase productivity growth rates in the manufacturing sector thanks to ICT as most of these industries are already at the global technological frontier. Thus, any impact of ICT on labour productivity would have to rely on an increase in productivity in the service sector. This however requires deep changes in the organizational structure of firms, in managerial methods, innovation processes, and in quality of human capital.[14] In this context, EU countries are quite different. Hence, it can be argued that the convergence process in its first phase mainly relies on the increase in productivity in the manufacturing sector. In the second phase, however, all increase in aggregate productivity will be dependent on the ability of the service sector to productively use ICT (van Ark and Piatkowski 2004).

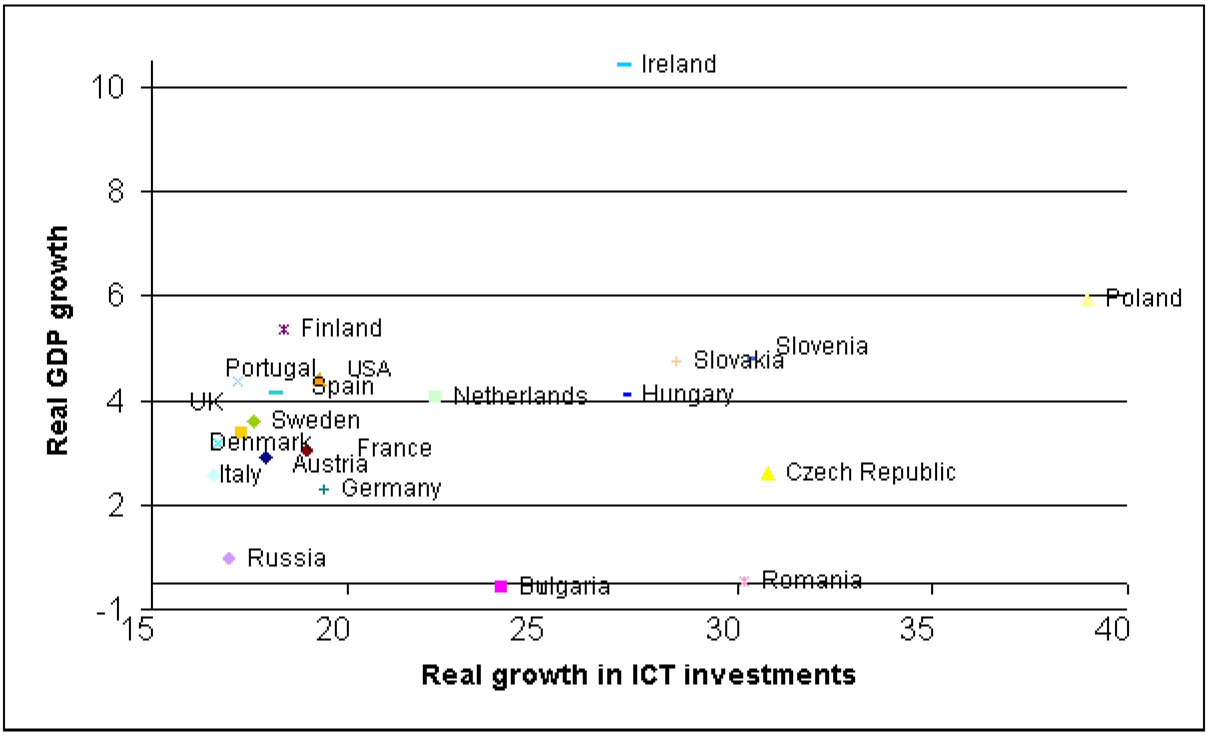
Aside from the growth accounting, the role of ICT capital in stimulating GDP growth can be estimated on the basis of econometric regression analysis on a large sample of countries. This kind of analysis allows for testing of causality between ICT investments and GDP growth. Vu (2004) in his regression analysis for 50 countries finds that a 10% increase in the real value of ICT capital contributes additional 0.6 percentage points to GDP growth. This

[14] Brynjolfsson and Hitt (1996, 2000) show that those US firms, which proved to use ICT most productively, have made substantial changes in management of operations and invested in enhancing the quality of ICT skills of employees. OECD (2004) reaches similar conclusions on the basis of a number of firm-level studies in the OECD countries.

result provides further evidence that ICT capital can play an important role in acceleration of growth and consequently in stimulating the convergence process.

A small number of countries in this paper's sample and relatively short time series do not allow for meaningful statistical testing. Nonetheless, it is possible to measure the strength of correlation between average real increase in ICT investments and GDP growth during 1995-2001 (Figure 5). It transpires that the correlation at the level of 0.25 is not statistically significant. This may suggest that if Vu's (2004) results are viable the positive ICT capital contribution to growth in CEE countries, EU and the US must have been offset by negative impact of other factors or the lack of statistical relationship is due to low value of the accumulated ICT capital stock. Further research is needed to elucidate the relation between ICT capital and growth.

Figure 5: Relationship between real growth in ICT investments and GDP growth in CEE, EU-15 and US, 1995-2001 average



Source: Timmer *et al.* (2003) for the EU and the US. Own estimates based on Piatkowski (2003b) for the CEE countries. Correlation coefficient: 0.25

3.4 Contribution of Spillover Effects of ICT Production and Use

ICT can add to growth also through the so-called spillover effects of ICT production and use. Spillover effects can be defined as acceleration in TFP growth on either macro, industry or micro level due to indirect productivity-stimulating effects of ICT production and/or use. The end of the decade of the 1990's was fraught with speculations about the "extraordinary" characteristics of ICT, utilization of which was believed to indirectly increase TFP growth There were also efforts to link the increase in TFP growth in the US, Australia, Sweden, Canada and Denmark with rapidly growing ICT investments (OECD 2001, Pilat and Woelfl 2003).

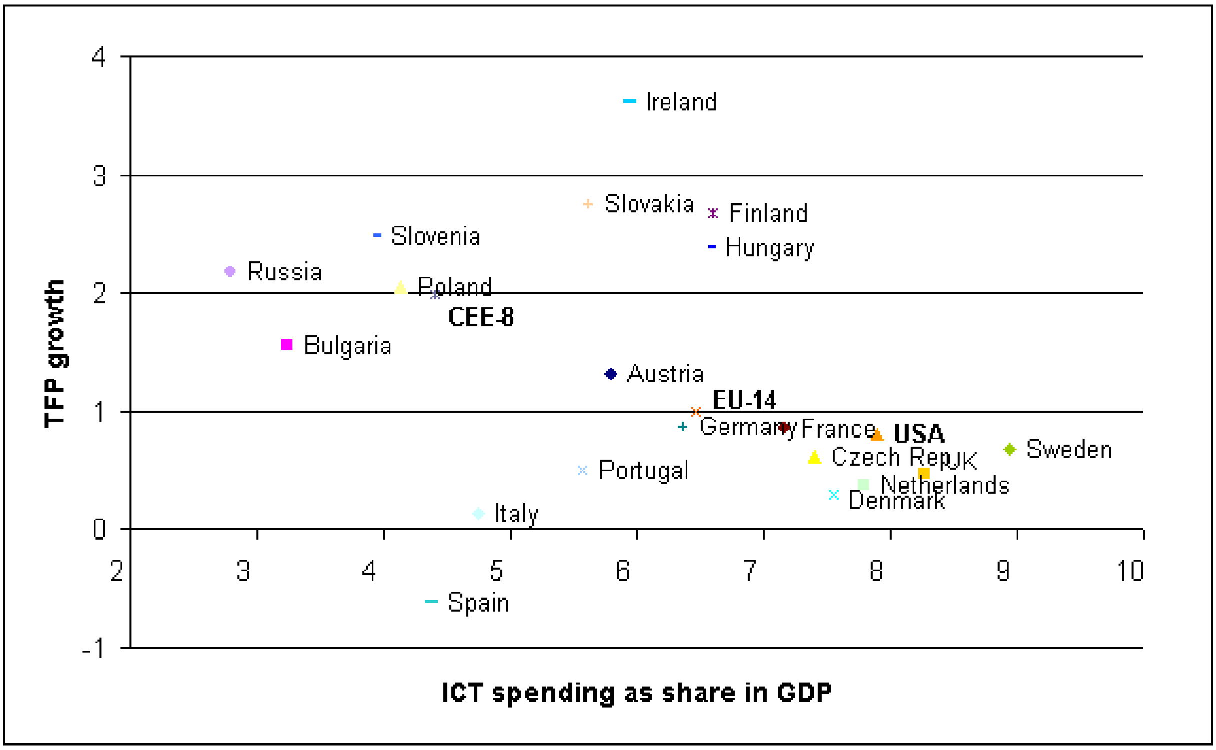
Moreover, Pilat and Lee (2001) argued that the increase in TFP growth in the ICT-using service sector in the second half of the 1990's might have been related to the spillover effects of the ICT use. Similar arguments were put forth by Oliner and Sichel (2000), Council of Economic Advisors (2001) and – on the firm level – Brynjolfsson and Kemerer (1996) and Gandal et al. (1999).

However, the neoclassical economics does not allow for existence of spillover effects. It assumes that TFP growth is exogenous and hence it can not be related with any of the production factors. This assumption can be verified as long as it would be possible to prove that the use or production of ICT led to an increase in TFP growth. If there is no increase, then either ICT has no impact on TFP, so the spillover effects do not exist, or the positive contribution of ICT was more than offset by negative impact of other factors.

However, if there is an increase in TFP growth rate on any level, then it may suggest that there may exist some spillover effects related to ICT. Regression analysis is one of the best ways of testing for the existence of spillover effects of ICT. Until today, however, due to insufficiently long data series on ICT investments on macro or industry-level, there are only a few studies, which endeavored to estimate these effects. On the macro level, Vu (2004) in his regression analysis of fifty countries for the years 1990-2000 did not find any evidence for spillover effects of ICT use. He showed that there were no statistically significant relationship between ICT investments and TFP growth. Gordon (2000), Schreyer (2000) and IMF (2001) arrived at similar conclusions. No other reliable and conclusive evidence for the existence of the spillover effects has been since presented. Even the proponents of the ICT spillovers admit that there is not enough data to evidence their existence (OECD 2003, 2004, Pilat and Woelfl 2003).

Figure 6, based on data from Timmer et al. (2003) and Piatkowski (2003b) that there is a negative correlation between average TFP growth between 1995-2001 and ICT spending measured as share of GDP (based on WITSA 2002) in CEE countries, EU and the US. It then seems that either spillover effects indeed do not exist, or that the value of ICT capital stock is still too small to bear on TFP.

Figure 6: Relationship between ICT spending intensity (as % of GDP) and TFP growth in CEE, EU-15 and the US, 1995-2001 average



Source: WITSA (2002) for ICT spending. Timmer *et al.* (2003) for the EU and the US, extended results of Piatkowski (2003b) for CEE countries. Correlation coefficient: -0.33

On the industry level, Stiroh (2002b) in his econometric study for 60 US industries for the years 1973-99 does not find any evidence for spillover effects of ICT use in terms of faster TFP growth. It turns out that the whole increase in labour productivity can be explained by changes in traditional sources of growth, i.e. increase in value of available capital.[15] No other

[15] Stiroh (2002b) and OECD (2004) present a useful literature review on spillover effects.

studies have found any evidence for industry level spillover effects, although OECD (2004) finds that in the US and Australia sectors that intensively invested in ICT, like wholesale and retail trade, have reported an increase in the TFP growth rates. In Italy, Milana and Zeli (2004) found that TFP growth is positively affected by the increased intensity of ICT use on the industry level. This might suggest the existence of spillover effects of ICT. The evidence is however not conclusive as all the above studies have failed to prove the causality.

Nevertheless, in spite of the lack of quantitative evidence, it is quite possible that spillover effects do exist, yet traditional economic methods do not succeed in measuring them. Perhaps at this stage of its development, the science of economics can not yet cope with that kind of a challenge. It can be argued that spillover effects of ICT can stimulate faster productivity growth in the following ways, which so far has escaped measurement:

a) First of all, ICT – thanks to the emergence of global communication networks (Internet), which allow for faster production, diffusion, and sharing of knowledge – contribute to faster pace of innovation, which in turn leads to an increase in productivity growth rates.[16] In addition, ICT accelerate diffusion of existing knowledge through stimulating imitation, adoption and diffusion of business models, ideas and through improving access to information;

b) Secondly, ICT tend to stimulate changes in business models and increased investments in human capital at the firm level. These positively contribute to increase in productivity[17];

c) Thirdly, ICT – similarly to earlier technological revolutions based on general-purpose technologies (electricity, combustion engine) – may in future find yet unknown applications, which could enhance overall productivity growth.[18] Investments in ICT thus seem to come with an embedded option, which can be realized in future through utilization of ICT for new purposes going beyond the original applications.[19] In this sense, ICT investments are entirely different from investment in other types of assets (real estate, machinery, means of transport etc.), since their potential for new applications is dramatically smaller. From this point of view, investments in ICT are much superior to investments in alternative assets.

In spite of lacking economic evidence for spillover effects, ICT seem to represent significant potential for faster growth and hence accelerated catching-up. In line with progress in availability of data and emergence of new methods of economic testing, more exact estimation of spillover effects may be possible.

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[16] Global R&D networks provide a useful example for knowledge sharing made possible by Internet. Twenty years ago this kind of collaboration would be considered almost fanciful.

[17] It is not possible to introduce, for instance, "just-in-time" procurement based on ICT systems without changes in firm's organization and structure and additional training for its employees. Introduction of ICT thus stimulates changes, which are most often positive for the overall productivity of not only the procurement department, but also the whole firm (ICT systems accelerate the speed of information sharing, facilitate access to information, drives cost-cutting initiatives etc.).

[18] The history of steam engine is a fitting example. The original purpose of steam engines was nothing but to perpetuate pumps, which drained water from underground coal shafts. Only much later the potential of steam engines was fully realized in transport, manufacturing and almost every other aspects of economic and social life. ICT seem to have the same extraordinary potential, which is still far from being fully discovered.

[19] Up until 1990's computers were used in firms mostly to perform various back-office operations. Since then, however, thanks to the Internet, computers could be used for entirely new applications: electronic supply chains, customer relationship management, e-commerce etc.

As for the CEE countries, given current relatively low level of ICT penetration (Internet, computer, telephone, IT systems, software packages etc.), any spillover effects, even if existing, are not likely to be significant (Piatkowski 2004). Nonetheless, their potential will be growing in tandem with an increase in ICT penetration and use.

4. Total Contribution of ICT to Growth and its Determinants

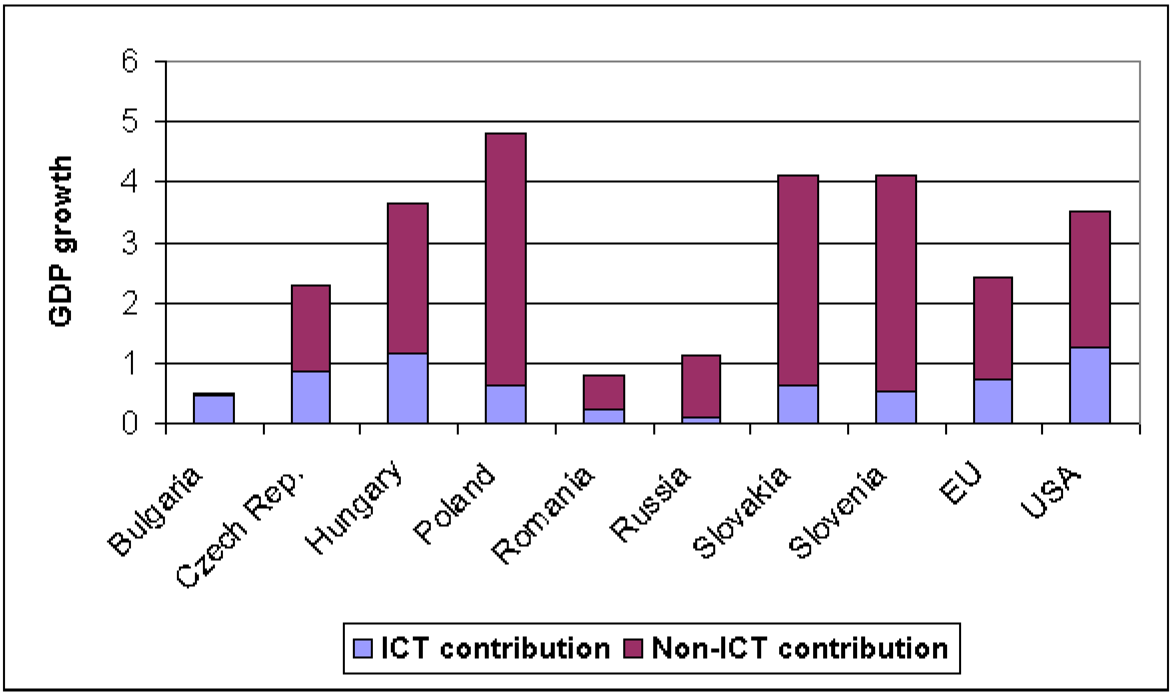
Table 7 and 8 and Figure 7 and 8 show first available estimates of total impact of ICT on output growth and labour productivity in CEE countries, EU and the US during 1995-2001. ICT had a large role in stimulating growth in CEE countries, yet its impact was still smaller than the impact of other non-ICT capital, labour force and TFP. It is however worth noticing that the contribution of ICT to growth in Czech Republic, Hungary, Poland, Slovakia and Slovenia was higher than the EU-15 average. This suggests that in these countries ICT have contributed to an acceleration in the convergence process and consequently to the catching-up with the EU countries. However, in the case of Bulgaria, Romania and Russia, the contribution of ICT to growth was much lower than both in the other CEE countries and the EU-15 average. Hence, in these countries ICT led to a divergence in growth and to a slow-down in catching-up with the more developed countries.

Table 7: Total contribution of ICT to GDP growth in CEE countries, EU-15 and the US, 1995-2001 average (in % points)

	GDP growth	Non-ICT capital	ICT capital	Labour force	TFP	Contribution of ICT sector to TFP	Total ICT contribution	Share in GDP growth
Bulgaria	0,51	-0,89	0,45	-0,60	1,55	-	0,45	88%
Czech Republic	2,27	1,20	0,73	-0,28	0,62	0,13	0,86	38%
Hungary	3,64	0,37	0,71	0,18	2,38	0,58	1,29	35%
Poland	4,81	1,98	0,55	0,23	2,05	0,14	0,70	14%
Romania	0,79	0,08	0,22	-1,35	1,84	-	0,22	28%
Russia	1,12	-0,97	0,09	-0,17	2,17	-	0,09	8%
Slovakia	4,10	1,15	0,55	-0,35	2,75	0,09	0,64	16%
Slovenia	4,10	0,87	0,54	0,20	2,49	-	0,54	13%
CEE-8	2,67	0,47	0,47	-0,27	1,98	0,24	0,60	22%
EU-15	2,42	0,81	0,46	0,84	0,46	0,27	0,73	30%
USA	3,52	0,75	0,82	0,9	0,82	0,44	1,26	36%

Source: own estimates for the CEE countries. Timmer et al. (2003) for the EU-15 and the US.

Figure 7: Total contribution of ICT to GDP growth in CEE countries, EU-15 and the US, 1995-2001 average (in % points)



Note: Results for Bulgaria, Romania, Russia and Slovenia do not take into account the contribution of TFP growth in ICT sector to aggregate TFP. Yet, given a small size of this sector in all countries in question, any contribution would not significant. „Non-ICT contribution": contribution from non-ICT capital, TFP growth in non-ICT sector and changes in labour force.
Source: own estimates for CEE countries. Timmer *et al.* (2003) for the EU and the US.

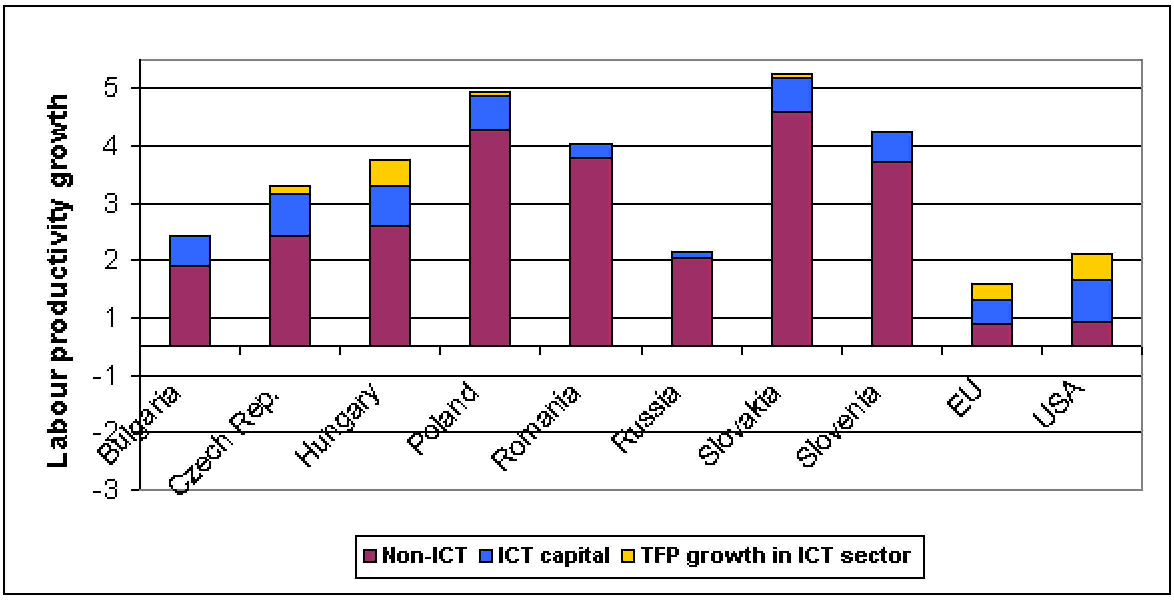
Similar conclusions could be drawn from a comparison of the total ICT contribution to labour productivity growth. Among the leading five CEE countries, in three of them the contribution of ICT to growth in labour productivity was higher than the EU average (in Slovakia and Slovenia the ICT contribution was slightly lower). Yet, Bulgaria, Romania and Russia distinctly lag behind (Table 8 and Figure 8)

Table 8: Total contribution of ICT to labour productivity (LP) growth in CEE countries, EU-15 and the US, 1995-2001 average (in % points)

	LP growth	Non-ICT capital	ICT capital	TFP growth	Contributi on of ICT sector to TFP	Total ICT contribution	Share of ICT in LP growth
Bulgaria	1,91	-0,13	0,49	1,55	0,00	0,49	26%
Czech Republic	2,80	1,43	0,75	0,62	0,13	0,88	32%
Hungary	3,25	0,17	0,71	2,38	0,58	1,29	40%
Poland	4,45	1,82	0,58	2,05	0,14	0,72	16%
Romania	3,55	1,45	0,26	1,84	0,00	0,26	7%
Russia	1,66	-0,64	0,13	2,17	0,00	0,13	8%
Slovakia	4,76	1,44	0,57	2,75	0,09	0,66	14%
Slovenia	3,75	0,73	0,54	2,49	0,00	0,54	14%
CEE-8	3,27	0,78	0,50	1,98	0,12	0,62	19%
EU-15	1,13	0,41	0,41	0,31	0,27	0,68	60%
USA	2,21	0,42	0,74	1,05	0,44	1,18	53%

Source: as in Table 7.

Figure 8: Total contribution of ICT to labour productivity growth in CEE countries, EU-15 and the US, 1995-2001 average (in % points)



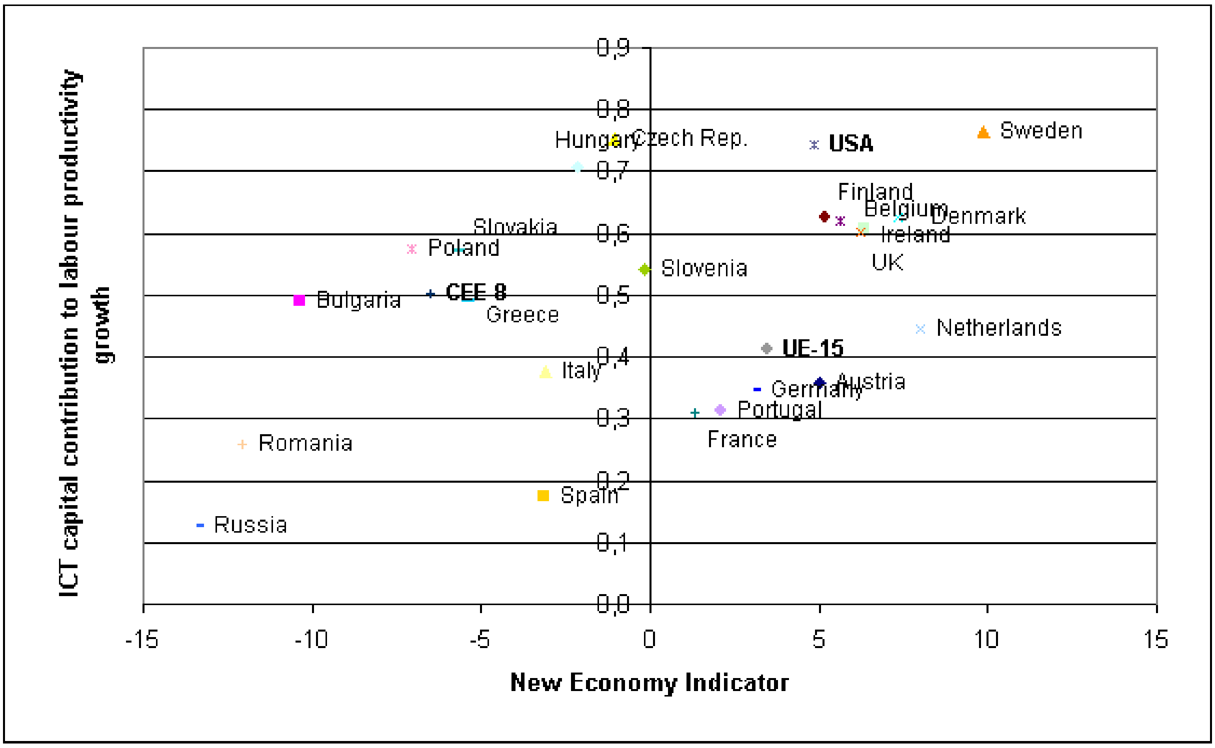
Note: as in Figure 7. „Non-ICT" comprises contribution of non-ICT capital and increase n TFP in non-ICT producing sector.
Source: as in Figure 7.

What factors led to such a divergence in the impact of ICT on output and labour productivity growth in CEE countries? The impact of ICT is likely to be dependent on the quality and level of development of economic, institutional and regulatory framework of an economy. This framework seems to largely determine the speed of ICT diffusion and the extent of its productive use. The quality of the economic, institutional and regulatory framework can be assessed on a basis of the "New Economy Indicator" (NEI) developed by Piatkowski (2002). The "NEI" is aimed at measuring the level of preparedness of countries to benefit from ICT to accelerate output and productivity growth.

Table 10 in the Appendix shows an updated „New Economy Indicator" based on van Ark and Piatkowski (2004). It compares the level of development of the economic, institutional and regulatory framework in the CEE countries, EU-15 and the US. The "NEI" ranking confirms that in the five leading CEE countries, where ICT has had the largest contribution to growth, the level of development and quality of economic and institutional infrastructure was considerably higher than in the remaining three CEE countries (Bulgaria, Romania and Russia). A relatively strong correlation (0.46) between the value of the "NEI" and the average contribution of ICT capital to labour productivity growth between 1995-2001 provides evidence that the economic, institutional and regulatory factors have a large bearing on the use of ICT (Figure 9). It then can be argued that a continuous improvement in the quality of institutions and regulations, increase in trade openness and macroeconomic stability, enhanced labour and product market competition as well as the size of outlays on human capital and R&D are prerequisites to absorption and productive use of ICT in order to shorten the distance in level of development relative to the EU countries. Kolodko (2003) provides similar arguments.

The importance of institutions, regulations and macroeconomic stability for diffusion of ICT is also confirmed by a fact that the NEI seems to have a relatively strong predictive power: the correlation between the value of NEI in 1995 and the average ICT capital contribution to labour productivity during 1995-2001 amounts to 0.55.

Figure 9: Relationship between ICT capital contribution to labour productivity growth and the value of the „New Economy Indicator", 1995-2001 average



Source: based on van Ark and Piatkowski (2004).

Other studies on the determinants of productive use of ICT call attention to the same variables as in the NEI: quality of human capital, quality of law enforcement, trade openness, level of competition, direct costs of ICT products, size of foreign direct investments and the level of liberalization of the telecom markets (Pohjola 2003, Clarke 2003, OECD 2003, 2004)

5. What is the Potential of ICT for Long-term Growth in CEE Countries?

Assuming that the overall business environment in CEE countries will steadily improve, and on the basis on the growth accounting model based on Piatkowski (2003b), one can venture to speculate about the contribution of ICT to growth in CEE countries until 2025 taking Poland as a proxy for the five leading CEE countries (Czech Republic, Hungary, Slovakia and Slovenia). For the purposes of the exercise, which is aimed at projecting the potential impact of ICT rather than future GDP growth trends, the following assumptions will be taken (all assumptions for Poland only):

1. Employment will grow by 0.5% annually until 2025. This would translate – *ceteris paribus* – into the unemployment level of 7% at the end of the period.
2. Depreciation rate for non-ICT capital: 7.5% annually; for IT hardware, software and communications equipment: 29.5%, 31.5% and 11.5%, respectively.
3. Labor compensation share in total income to amount to 65% throughout the period
4. TFP growth: 1.5% annually (versus 2,05% on average during 1995-2001).

5. ICT hedonic price deflator: prices of IT hardware, software and communications equipment until 2025 will decrease at an average hedonic rate equal to the 1990-2001 average rate for the US, that is, respectively, 20.7%, 1.3% and 3.2% annually.[20]
6. Non-ICT deflator: 3% annual growth.
7. Increase in real investments in ICT (before deflation with hedonic price index): 5, 10% and 15% annually.
8. Increase in real non-ICT investments: 5% annually.

Table 9 shows the projected average contribution of ICT capital to output growth in Poland during 2002-25. Depending on the assumed rate of growth in real ICT investments (before price adjustment for changes in quality), the ICT capital would contribute between 0.35 to 0.85 of a percentage point to GDP growth in the period. In the base scenario, assuming a 10% rate of growth in ICT investments, ICT capital would contribute 0.6 of a percentage point or 15% of the projected GDP growth

Table 9: Projected ICT capital contribution to GDP growth in Poland for the years 2002-2025, average rate of growth

Real rate of growth in ICT investments*	GDP growth	Total capital	Non-ICT capital	**ICT capital**	Labour force	TFP	Share of ICT in GDP growth
5%	3,76	1,94	1,59	**0,35**	0,32	1,50	9,3%
10%	4,01	2,19	1,59	**0,60**	0,32	1,50	15,0%
15%	4,26	2,43	1,59	**0,85**	0,32	1,50	20,0%

Note: * before adjustment for hedonic price changes of ICT investments.
Source: own estimates

The projection does not take into account the contribution of TFP growth in ICT producing sector to aggregate TFP and potential spillover effects of ICT production and use.[21] If contribution of the former was taken into account, the total contribution of ICT to growth would most likely surpass 20% of the projected growth rates. This would also most likely be the case for the four other leading CEE countries: Czech Republic, Hungary, Slovakia and Slovenia. In the case of the three lagging countries – Bulgaria, Romania and Russia – the contribution of ICT capital to growth, based on the historical trends, is likely to be smaller than for the other CEE countries. Yet, more precise projections are hardly possible since future rates of growth in ICT and non-ICT capital until 2025 will be dependant on a large number of factors, including the quality of economic policy, which is impossible to predict ex ante.

[20] During 1995-2001 hedonic prices of ICT (IT hardware, software and communications equipment) were declining at an average annual rate of 25.4%, 1.0% and 4.4%, respectively (Jorgenson et al. 2002). However, a more conservative pace of price decline was assumed, which was to equal the 1990-2001 average, which comprised two periods of both faster and slower price declines.

[21] However, since projections on the future of ICT industry in CEE countries are burdened with large risk, any assumptions as to the size and TFP growth rate in the ICT sector until 2025 would not be more than a pure speculation. Nonetheless, it could be argued that ICT sector – in line with the increasing penetration of ICT – should be growing faster in the CEE countries than the rest of the economy.

The projected average GDP growth rate of approx. 4% per annum (Orłowski 2002 projects the same GDP growth rate for Poland until 2025) will be mostly dependent on the rate of growth in TFP. So far, high TFP growth rates in Poland and in other CEE countries were mostly driven by easy-to-utilize post-transition growth reserves stemming from deep structural reforms (privatization, liquidation of unproductive state-owned enterprises, inflows of FDI), elimination of wastage in the use of resources as well as shortages in the offer products and services, large pent-up demand for consumer products, revolution in the managerial and business skills and a largely completed process of institution building. The positive impact on productivity is particularly visible in labour productivity statistics for the manufacturing sector: for instance in Poland between 1993 and 2001 labour productivity growth in ICT using industries amounted to 11.3% annually (van Ark and Piatkowski 2004). Such a high rate of productivity growth was mostly due to reductions in the labour force and relatively easy to achieve replacement of old machinery with new, state-of-the art equipment.

However, these reserves of productivity growth are by now mostly exhausted. In the next twenty years TFP growth will then have to rely on further restructuring of the manufacturing sector and – above all – of the service sector, which generates more than 60% of GDP in all the leading CEE countries. In both sectors, the restructuring is doomed to fail without an ability to productively use ICT. Hence, long term growth in TFP (and hence in GDP) will have to result from increase in ICT investments and an ability to benefit from ICT through changes in firms' business and organizational models and increase in the quality and level of ICT skills of the labour force.

It seems that firms investing in ICT need time to learn to use ICT productively. The US experienced a boom in labour productivity only in the latter part of the 1990's, some twenty years after the beginning of a wave of large investments in ICT. Until the late 1990's the Solow's (1987) famous "productivity paradox" still seemed to be valid. Adoption of electricity, another revolutionary general purpose technology, exhibited a similar pattern (David 1990): it was only in the 1920's – forty years after the discovery of electricity – that more than half of American companies learned to use electricity in production processes. Still more time was needed to fully benefit from the new technology. When it was finally achieved, similarly as was the case in the late 1990's with ICT, the long awaited acceleration in productivity arrived.

It seems very likely that, in line with the growth in ICT penetration, a similar sequence of events could unfold in the case of the five leading CEE economies. This time, however, thanks to much higher level of openness and development of the Internet, which immensely facilitates the exchange and sharing of knowledge, the learning process of ICT use in the CEE countries may be shorter than it was the case with the early adopters in the developed countries. Taking into account that enterprises in the CEE countries started their ICT investments in earnest at around 1995, it may be projected that within the following fifteen years, that is around 2010, ICT investments should finally start to strongly feed into the productivity statistics.

Such a positive scenario is by no means given. The economic potential of ICT will be dependent on continued large investments in ICT and – even more importantly – on the ability to incorporate ICT into the business models. Investments in ICT also bring an opportunity for increase in productivity thanks to emergence of new, more productive uses ICT, which would allow shortening of production cycles, increase in effectiveness of supply and distribution channels and quality and choice of products and services. Investments in ICT are also likely to contribute to productivity growth through spillover effects of ICT use, which

– although still elusive in terms of their quantitative impact – are likely to be increasingly tangible.

6. Conclusions and Recommendations for Economic Policy

ICT had a large contribution to GDP and labour productivity growth in CEE countries. During 1995-2001 ICT – through increase in the value of ICT capital and TFP growth in ICT producing sector – brought on average 0.87 of a percentage point of output growth in the four CEE countries (Czech Republic, Hungary, Poland and Slovakia), the only countries for which sufficient data was available. The aggregate contribution of ICT in these countries was higher than the EU-15 average of 0.73 of a percentage point. This suggests that ICT has contributed to a convergence process between these CEE countries and the EU-15.

ICT capital alone contributed on average 0.61 of a percentage point to output growth in the five leading CEE countries - Czech Republic, Hungary, Poland, Slovakia and Slovenia – substantially higher than the EU-15 average of 0.46. The large contributions of ICT capital seem to be higher than what one might expect on the basis of the level of GDP or productivity per capita. There are however substantial differences among the CEE countries: the contribution of ICT capital to output growth in Bulgaria, Romania, and Russia was much lower than in the leading CEE countries and also lower than in the EU average. Similar pattern emerges from the comparison of the contribution of ICT capital to labour productivity growth. Hence, in the case of the three lagging CEE countries, ICT seems to have led to a divergence rather than convergence with the income levels in the EU-15.

Since the easy-to-utilize post-transition growth reserves have been by now mostly exhausted, it seems that the future growth in the CEE economies will have to be largely dependent on an ability to productively use ICT. According to the projection developed in this study, in Poland the ICT capital is likely to contribute 0.6 of a percentage point of an average GDP growth of 4% until 2025. This projection however does not take into account opportunities for finding new, more productive application for ICT, which could further lift the contribution of ICT to growth and productivity.

ICT are also likely to stimulate productivity growth through the so-called spillover effects. Thanks to ICT, which dramatically accelerate the pace of innovation and diffusion of knowledge, firms, industries and whole economies will stand a chance to accelerate productivity growth through imitation and absorption of concepts, models and ideas developed in other, more advanced countries.

However, ICT will not be productively utilized without changes in the structure, organization and business models of firms and without improvement in ICT skills of the labour force. On the macro level, as indicated by the "New Economy Indicator", ICT is not likely to rapidly diffuse without consistent progress in economic, institutional, and regulatory infrastructure.

In order to fully benefit from ICT, economic policies should focus on creating friendly business environment, opening borders to trade, increasing inflows of foreign capital and spending on human capital, improving effectiveness of law enforcement, enhancing macroeconomic stability and – above all – promoting vigorous competition in the labour and product markets.

As for more specific recommendations, development of public e-services could have considerable contribution to stimulation of the use of ICT among firms and individuals. Similarly, universal use of online public procurement platforms would not only bring savings to the public administration, decrease bureaucracy and the scope for corruption, but would also galvanize interest of firms in using more advanced ICT applications (like, for instance, e-commerce) also in the private sector. Public e-procurement could then have sizable spillover effects.

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Appendix Table 10: The New Economy Indicator: values for the CEE countries, EU-15 and the US, 1995-2001 average

Country	**Rank**	**Value 1995-2001**	Regulations and law enforcement	Infrastructure	Trade openness	Financial system	R&D spending	Human Capital	Labor marker flexibility	Product market flexibility	Openness to foreign investment	Macroeconomic stability
Sweden	1	9.882	0.818	1.724	-0.067	0.541	2.273	1.884	0.334	0.641	1.257	0.476
Netherlands	2	8.001	1.035	0.765	0.975	1.197	0.513	-0.195	1.099	0.641	1.600	0.370
Denmark	3	7.331	0.914	1.439	-0.278	-0.217	0.614	2.453	0.898	0.641	0.462	0.404
Ireland	5	6.210	0.977	0.710	-0.716	1.395	0.393	-0.403	0.634	1.539	1.283	0.397
UK	4	6.343	0.830	0.300	2.102	0.554	-0.262	-0.213	0.245	1.240	1.228	0.318
Belgium	6	5.624	0.254	0.257	1.843	0.253	0.467	0.810	0.161	0.142	1.006	0.430
Finland	9	4.857	0.754	1.260	-1.615	1.510	1.201	-0.239	1.098	1.040	-0.540	0.387
Austria	8	5.021	1.108	0.439	0.163	0.840	0.283	0.643	1.095	0.641	-0.625	0.433
USA	7	5.162	1.109	1.268	-0.355	-0.271	1.544	1.048	-0.687	0.342	0.744	0.420
Germany	10	3.105	0.720	0.526	-0.708	1.166	0.928	-0.416	0.120	0.641	-0.319	0.446
Portugal	11	2.076	0.215	-0.187	-0.347	0.854	-0.860	0.422	0.902	0.342	0.390	0.345
France	12	1.340	0.160	0.410	-0.929	0.439	0.784	0.659	-0.509	-0.057	-0.083	0.466
Slovenia	13	-0.180	-0.406	-0.243	0.925	-0.865	-0.054	0.540	0.445	0.442	-0.930	-0.034
Czech Rep.	14	-1.060	-0.482	-0.714	1.148	-0.043	-0.309	-0.485	0.711	-0.856	-0.218	0.187
Hungary	15	-2.163	-0.202	-0.880	0.483	-1.029	-0.792	-0.331	0.295	0.442	0.085	-0.233
Italy	17	-3.141	0.244	-0.282	-0.797	0.477	-0.647	-0.499	-2.182	0.442	-0.255	0.358
Spain	16	-3.102	-0.273	0.199	-0.890	-0.072	-0.468	-0.298	-0.488	-0.257	-0.942	0.386
Greece	18	-5.399	-0.382	-0.117	-0.936	-0.527	-0.946	-1.409	-0.240	-0.157	-0.975	0.290
Slovakia	19	-5.670	-1.051	-1.060	1.306	-0.857	-0.717	-0.531	-1.323	-0.856	-0.593	0.012
Poland	20	-7.042	-0.674	-1.352	-0.707	-1.212	-0.828	0.107	-0.616	-1.255	-0.405	-0.099
Bulgaria	21	-10.372	-1.355	-1.197	0.611	-1.284	-0.319	-1.427	-1.470	-1.913	-0.500	-1.517
Romania	22	-12.063	-1.670	-1.653	-0.504	-1.438	-1.025	-1.388	0.482	-1.913	-0.763	-2.191
Russia	23	- 13,375	- 2,643	- 1,610	- 0,711	- 1,411	- 0,574	- 0,974	- 0,582	- 1,913	- 0,907	- 2,049

Source: based on Van Ark and Piatkowski (2004). Russia based on own estimates.