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The Potential of ICT for the Development and Economic Restructuring of the New EU Member States and Candidate Countries

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The Potential of ICT for the Development and Economic Restructuring of the New EU Member States and Candidate Countries[1]

Summary

The purpose of this paper is to analyze the potential of ICT in the Central and Eastern European (CEE) countries for faster convergence with the EU-15 income level. The paper investigates this question from both macro and industry perspectives. First, it argues that, between 1995 and 2001, ICT contributed to accelerated growth in all five new EU member states (a case of technological leapfrogging) and thus contributed to their faster convergence with the EU-15. However, in two of the EU candidate countries - Romania and, to a lesser extent, Bulgaria - the income gap widened, mainly due to the lower quality economic and institutional environment. Second, the paper shows that ICT use had an important role in stimulating productivity growth at industry level in the CEE countries. Third, it argues that ICT offers significant potential for faster productivity growth in today's non-ICT using industries. If these industries were able to achieve the same rate of productivity growth as the ICT-using industries, then they would make a significant contribution to faster growth in the CEE countries. Realizing this potential, however, will crucially depend on far-reaching structural reforms, business re-organization and investment in human capital. Finally, the paper develops a methodology, on the basis of which it speculates that some industries in CEE countries stand to benefit more from ICT use than others.

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1. Introduction

The recent accession to the European Union of the eight Central and Eastern Europe (CEE) economies marked the end of their transition from a centrally planned to a market economy[2]. This historical event begs the question of what role is played by information and communication technology (ICT) in the convergence process of CEE countries with the EU-15 and the U.S. and the potential it may have for accelerating growth in the future.[3] Given that the most straightforward transition growth reserves (i.e. those resulting from largely completed privatization, advanced stage of the institution building, macroeconomic stability, elimination of most loss-making state-owned enterprises, etc.) in CEE countries (although less so in Bulgaria and Romania) have already been exhausted, the pace of further convergence with the EU-15 and the US will now partly rely on the productive use of ICT.

Hence, the purpose of this paper is to analyze the potential of ICT in the CEE countries for faster growth towards convergence with the EU-15 income level. The paper investigates this question from both macro and industry perspectives. First, it argues that, between 1995 and 2001, ICT did, indeed, contribute to accelerated growth in all five new EU member states (a case of technological leapfrogging) and thus contributed to their faster convergence with the EU-15. However, in two of the EU candidate countries - Romania and, to a lesser extent, Bulgaria - the income gap widened, mainly due to the lower quality economic and institutional environment. Second, the paper shows that ICT use had an important role in stimulating productivity growth at industry level in the CEE countries. Third, it argues that ICT offers significant potential for faster productivity growth in today's non-ICT using industries. If these industries were able to achieve the same rate of productivity growth as the ICT-using industries, then they would make a significant contribution to faster growth in the CEE countries. Realizing this potential, however, will crucially depend on far-reaching structural reforms, business re-organization and investment in human capital. Finally, the paper develops a methodology, on the basis of which it speculates that some industries in CEE countries stand to benefit more from ICT use than others.

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[2] For the history of the post-communist transition see, for instance, Kolodko (2000).

[3] The eight new EU member states are the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. The European Candidate Countries are Bulgaria, Romania, Turkey and Croatia.

The paper proceeds as follows. In Section II, the paper analyzes the role of each of the three channels through which ICT contributed to the process of the CEE countries catching up with the EU-15. It then relates it to the quality of economic and institutional environment as the determinant of the diffusion and productive use of ICT. In Section III, an industry perspective is adopted to show the divergence in labour productivity growth rates between ICT-using and non-ICT using industries in CEE countries, the EU-15 and the US. Section IV discusses the potential contribution of a more intensive use of ICT in the non-ICT using sector for the aggregate productivity growth in CEE economies. Section V develops a methodology for assessing which of the non-ICT using industries could benefit more than others from the use of ICT. It then goes on to provide an assessment of their potential contribution to faster convergence with the EU-15. Section VI presents conclusions and policy recommendations.

2. The Contribution of ICT to Convergence and its Determinants

Based on the above growth accounting methodology described briefly in the Appendix 1, Piatkowski (2004) shows the contribution of ICT investment to growth in GDP and labour productivity in CEE countries, EU-15 and the US. during 1995-2001.

Table 1 shows that the contribution of ICT capital to GDP growth in CEE countries, with the exception of Romania and Bulgaria, in absolute terms was higher than in the EU-15 (column 3), despite lower levels of GDP per capita in the former. Thus, in the case of the five leading CEE countries, ICT capital contributed to convergence with the EU-15 (although not with the US). Yet, in the case of Romania and Bulgaria, ICT capital led to the widening of the income gap with the EU-15 and the US.

Table 1: The contribution of ICT capital to GDP growth in CEE countries, EU-15 and the US, 1995-2001 average, in % points

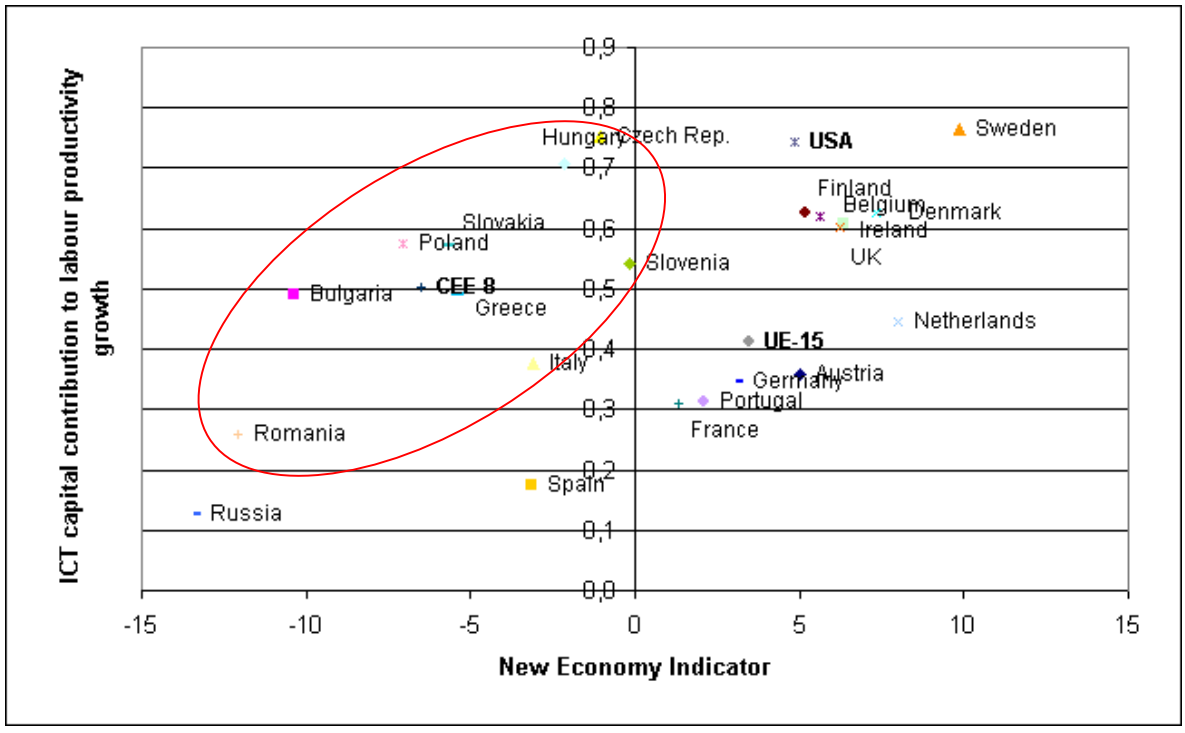
	GDP growth	Non-ICT capital	ICT capital	Labour force	TFP growth	Share of ICT capital in GDP growth
Bulgaria	0.51	-0.89	0.45	-0.60	1.55	88.4%
Czech Republic	2.27	1.20	0.73	-0.28	0.62	32.2%
Hungary	3.64	0.37	0.71	0.18	2.38	19.4%
Poland	4.81	1.98	0.55	0.23	2.05	11.5%
Romania	0.79	0.08	0.22	-1.35	1.84	28.3%
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%
CEE	**2.89**	**0.68**	**0.54**	**(0.28)**	**1.95**	**29.5%**
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 CEE countries.

Source: Timmer *et al.* (2003) for the EU-15 and the US. Piatkowski (2004) for CEE countries.

In this context, a question arises as to what explains the differences in the intensity of ICT investment and in its impact on GDP and productivity growth within CEE countries relative to the EU-15 and the US. Piatkowski (2002, 2004) and Van Ark and Piatkowski (2004) argue that this divergence seems to be primarily driven by the differences in the overall quality of the economic and institutional environment, labour and product market flexibility, development of infrastructure, spending on innovation, quality of human capital, development of financial markets and macroeconomic stability. **Figure 1** shows that in all of these dimensions, which are combined in the *New Economy Indicator*, Romania and Bulgaria lag behind the other five CEE countries and the EU-15.[4]

Figure 1: Relationship between the 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). Higher value of the 'New Economy Indicator' implies higher quality of economic environment.

[4] The *New Economy Indicator* combines ten variables. The sample mean of values of all variables is subtracted from each number and then the result is divided by 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. Higher score implies higher quality of economic environment. For a complete methodology of the *New Economy Indicator*, please refer to Piatkowski (2002) and Van Ark and Piatkowski (2004).

As to the role of the ICT producing sector in the convergence process, **Table 2** shows that in Hungary and the Czech Republic the impact of ICT production on GDP growth was higher than in the EU-15, thereby contributing to an accelerated convergence. This was not the case for Poland and Slovakia, which reported lower contributions to growth. As argued by Van Ark and Piatkowski (2005), the divergence in the size of ICT production among CEE countries was mainly driven by the differences in the value of FDI. This in turn depended on trade openness, basic rule of law, development of infrastructure, macroeconomic stability and privatization policies.

Table 2: The contribution of the ICT-producing sector, ICT-using sector and non-ICT using sector to GDP growth in CEE countries, the EU-15 and the US, 1995-2001 average

	EU-15	USA	Czech Republic	Hungary	Poland	Slovakia
ICT producing sector	0.51	1.01	0.75	0.99	0.28	0.37
ICT using sector	0.93	1.83	1.55	0.20	1.56	1.31
Non-ICT using sector	1.20	0.89	-0.25	0.89	2.37	1.36
Share of ICT producing sector in GDP growth (in %)	*19.4*	*27.1*	*36.6*	*43.2*	*6.8*	*12.1*
Share of ICT producing sector in GDP (in %)	*6.0*	*7.8*	*5.0*	*6.7*	*4.7*	*4.5*

Note: Real estate has been excluded from GDP for all countries. Based on the US ICT deflators excluding semiconductors and computers.

Source: Piatkowski (2004)

There is no data on the contribution of the ICT producing sector to labour productivity growth in other CEE countries.[5] However, Gaspar (2004), on the basis of data from Eurostat, provides estimates of the share of the 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

[5] Although Perminov and Egorova (2005) provide estimates of the contribution of the ICT production to labour productivity growth in Russia between 1995 and 2001.

of the Romania's ICT sector is roughly equal to that of the latter two countries. Alas, lack of data on productivity growth rates in the ICT sector does not allow for measuring its contribution to productivity growth in these countries and thus its role in convergence.

Table 3 sums up the total contribution of ICT from investment, use and production to growth in CEE countries, the EU-15 and the US. It turns out that during 1995-2001 in five CEE countries – the Czech Republic, Hungary, Poland, Slovakia and Slovenia – ICT contribution to GDP growth was higher or comparable to that of the EU-15. Bulgaria and Romania though lagged behind.[6] These results suggest that the five leading CEE countries, which have completed the transition process as confirmed by their recent accession to the EU, took advantage of ICT to accelerate their catching-up with the EU-15. Unfortunately, this was not the case of Bulgaria and Romania where due to a slower pace of reforms ICT played a much smaller role in growth. Thus, in these countries ICT contributed to the increase in the income divide with the EU.

[6] Please note that due to the lack of data, Table 3 does not include the contribution of the ICT producing sector for Bulgaria, Romania, and Slovenia. However, the earlier mentioned data from Gaspar (2004) on the size of ICT sector in CEE countries suggests that only in the case of Slovenia and Bulgaria the contribution of ICT production could be significant. Yet, given the low contribution of ICT investment to growth in Bulgaria, ICT sector contribution is not likely to be large enough to compensate for the difference in the ICT contribution to growth with the EU-15.

Table 3: Total contribution of ICT to GDP growth in CEE countries, the EU-15 and the US, 1995-2001 average (in % points)

	GDP growth	Non-ICT capital	ICT capital	Labour force	TFP growth	Contribution of ICT sector to TFP	Total ICT contribution	Share of ICT 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%
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	**2.89**	**0.68**	**0.54**	**-0.28-**	**1.95**	**0.24**	**0.67**	**33%**
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%**

Note: Unweighted average for CEE countries.

Source: Piatkowski (2004) for CEE countries. Timmer et al. (2003) for the EU-15 and the US

3. 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 the productivity growth in the non-ICT producing sectors, particularly in services. The accelerated labour productivity growth will be driven by a rise in capital intensity and technical change. ICT can have a large role in both.

Van Ark and Piatkowski (2004) provide estimates of labour productivity growth rates in ICT-producing, ICT using and non-ICT using industries in four CEE countries (the Czech Republic, Hungary, Poland and Slovakia) for the period 1993-2001. **Table 4** shows that productivity growth rates in ICT-using manufacturing in four CEE countries are in most cases more than double the productivity growth rates in the non-ICT using manufacturing (**Table 5** in Appendix 2 provides detailed data for labour productivity growth rates for each industry). This suggests that ICT use has been an important source of productivity growth and convergence.[7]

[7] Although it has to be remembered that these results do not prove the existence of causality between ICT and productivity growth. It may be that either ICT use contributes to faster productivity growth or that industries with high productivity growth rates happen to use ICT intensively. Given the evidence, the first proposition sounds more probable.

Table 4: Labour productivity growth of ICT-producing, ICT-using and non-ICT using industries, 1993/1995-2001

	EU-15	US	Czech Republic	Hungary	Poland	Slovakia
	1995-2001	1995-2001	1993-2001	1993-2000	1993-2001	1993-2001
Total Economy	1.34	2.19	2.83	2.41	3.33	2.5
ICT Producing Industries	0.58	0.98	0.68	0.68	0.21	0.15
ICT Producing Manufacturing	0.2	0.73	0.15	0.27	0.06	0.12
ICT Producing Services	0.38	0.25	0.53	0.42	0.15	0.03
ICT Using Industries	0.46	1.17	1.55	0.54	1.57	0.4
ICT Using Manufacturing	-0.01	-0.12	0.67	0.46	0.65	0.98
ICT Using Services	0.47	1.29	0.89	0.07	0.92	-0.58
Non-ICT Using Industries	0.29	0.06	0.6	1.19	1.56	1.96
Non-ICT Using Manufacturing	0.01	-0.18	0.94	0.31	0.66	1.84
Non-ICT Using Services	0.3	0.1	-0.01	0.8	0.75	1.54
Non-ICT Using Other	-0.01	0.14	-0.33	0.08	0.15	-1.43

Note: Real estate has been excluded from both GDP and total persons engaged for all countries; For CEE countries the US ICT deflators exclude prices of computers and semi-conductors. Productivity growth defined as GDP per person employed.

Source: Van Ark and Piatkowski (2004).

Productivity growth rates in the ICT-using manufacturing in CEE countries are also substantially higher than in the EU-15 and the US. This provides evidence for the success of the restructuring process of ICT-using manufacturing industries in CEE countries driven by basic fundamental reforms allowing for inflows of FDI, increase in management skills, labour 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 CEE countries contributed between 0.46 and 0.98 percentage point to the aggregate labour productivity growth between 1993 and 2001, against close to zero for the EU-15 and the US (**Table 6**).

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

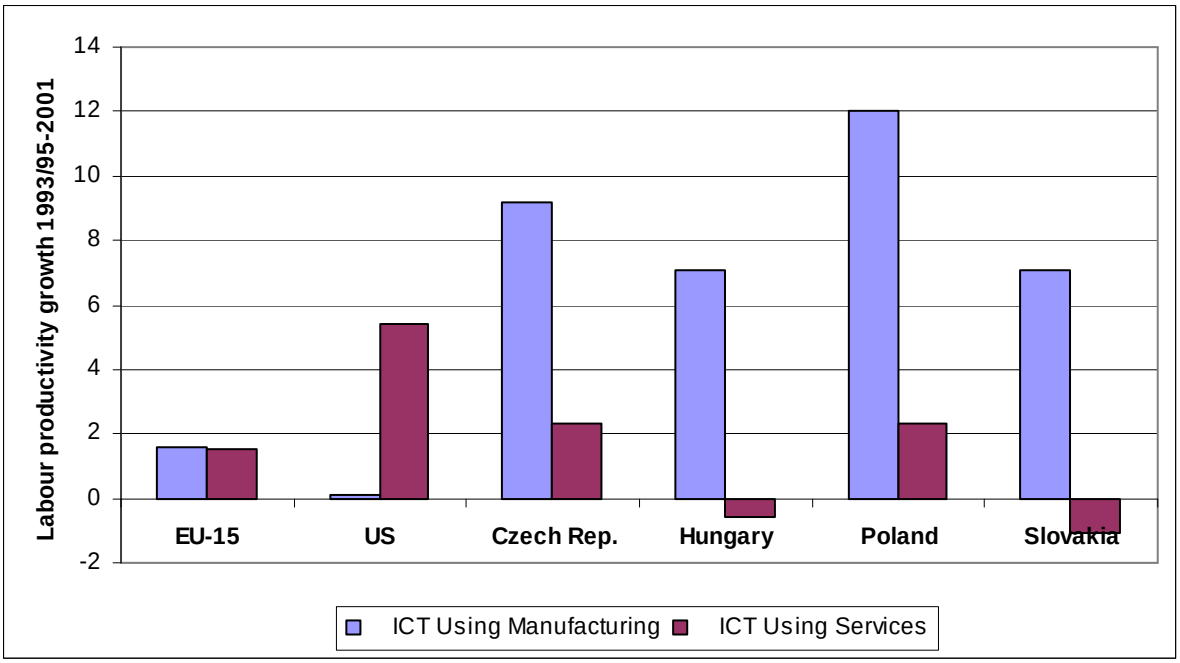
	EU-15	US	Czech	Hungary	Poland	Slovakia
	1995-2001	1995-2001	1993-2001	1993-2000	1993-2001	1993-2001
Total Economy	1.34	2.19	2.83	2.41	3.33	2.5
ICT Producing Industries	0.58	0.98	0.68	0.68	0.21	0.15
ICT Producing Manufacturing	0.2	0.73	0.15	0.27	0.06	0.12
ICT Producing Services	0.38	0.25	0.53	0.42	0.15	0.03
ICT Using Industries	0.46	1.17	1.55	0.54	1.57	0.4
ICT Using Manufacturing	-0.01	-0.12	0.67	0.46	0.65	0.98
ICT Using Services	0.47	1.29	0.89	0.07	0.92	-0.58
Non-ICT Using Industries	0.29	0.06	0.6	1.19	1.56	1.96
Non-ICT Using Manufacturing	0.01	-0.18	0.94	0.31	0.66	1.84
Non-ICT Using Services	0.3	0.1	-0.01	0.8	0.75	1.54
Non-ICT Using Other	-0.01	0.14	-0.33	0.08	0.15	-1.43

Note: as in Table 4.

Source: as in Table 4.

In ICT-using services, however, productivity growth rates in both CEE countries and in the EU-15 were much lower than in the US (**Figure 2**).

Figure 2: Labour productivity growth rates in ICT-using manufacturing and ICT-using services in CEE, the EU-15 and the US, 1993-2001 average.



Note: 1995-2001 average for the EU-15 and the US.

Source: Van Ark and Piatkowski (2004). Perminov and Egorova (2005) for Russia.

The differences in the productivity growth rates in the ICT using services in favour of the US provide ground for a hypothesis of a "two-phase" convergence. In the first phase, as argued by Van Ark and Piatkowski (2004), productivity growth is driven by the restructuring the in ICT-using manufacturing based on a relatively simple replacement of old machinery with new equipment as well as growth in FDI-driven ICT production. Quite importantly, the former does not require any major changes to the enterprise organization or large investments in human skills. In the second phase, however, productivity growth is driven by the ICT use in the service and non-using ICT sector. This requires a conducive business environment, business re-organization and investment in human and ICT skills. It seems that so far only the US succeeded in moving to the "second phase" of the productive use of ICT as evidenced by much higher productivity growth rates in ICT-using services. Piatkowski and Van Ark (2005) argue that this is due to a

much more conducive business environment in the US than in CEE countries and in the EU-15 as well as a higher quality of management practices.

One can conclude that given that the simple transition growth reserves in CEE countries, although less so in Bulgaria and Romania, have already been exhausted (as evidenced by the rapid productivity growth in the ICT-using manufacturing industry which has exploited the large catch-up potential through ICT-aided restructuring) sustained convergence with the EU-15 will now have to rely on productivity growth in the non-ICT using sector. Productive use of ICT in these industries, however, requires far-reaching structural reforms stimulating business re-organization, labour force re-allocation, and increase in ICT and management skills. Otherwise, the ICT-led convergence may slow down as the restructuring process in ICT-using manufacturing nears completion and further investments in ICT yield diminishing returns.

4. The Potential of ICT Use in Non-ICT Using Industries

Since ICT-using sectors in CEE countries reported higher productivity growth rates than non-ICT using sectors during 1993-2001, higher ICT investment intensity in the latter sector, coupled with organizational innovations in enterprises and appropriate human skills, could contribute to faster productivity growth and thus accelerated catching-up with the EU-15.

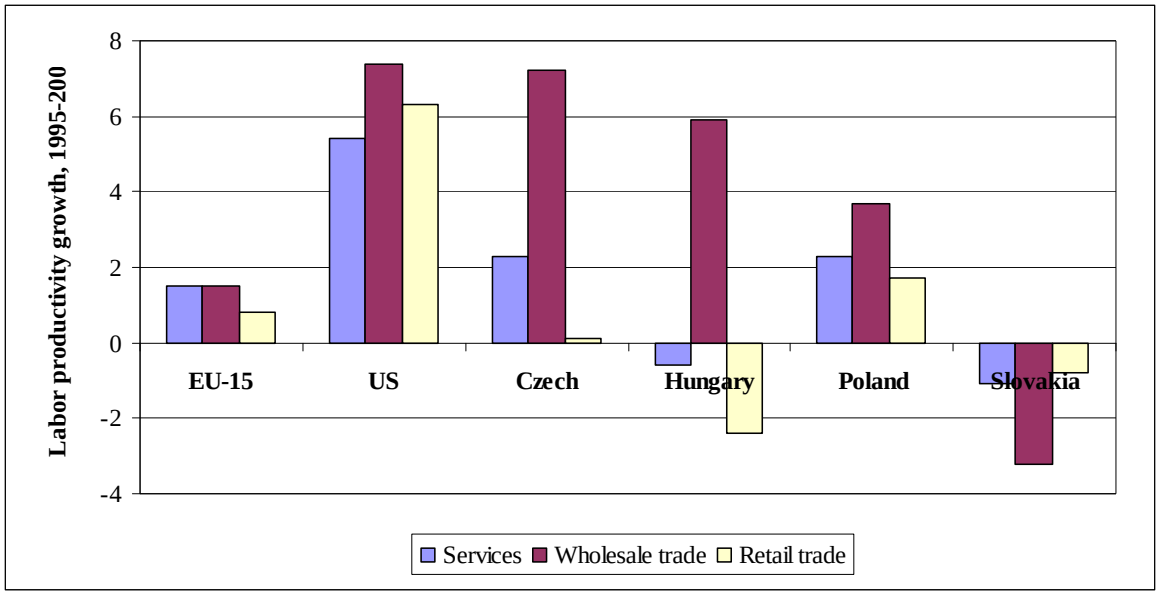
But what would be the size of the potential contribution of a more intensive ICT use to faster productivity growth? In order to answer this question, one needs to zoom in on the service sector in CEE countries to examine the size of the additional contribution to the aggregate productivity growth if the service sector was able to achieve the same rate of productivity growth as in ICT-using services in the US.

Table 5 in Appendix 2 shows that the largest difference in productivity growth in the service sector in CEE countries and the US concerns the wholesale and retail trade. Between 1993/5 and 2001 the average productivity growth in these two sub-sectors in the US was considerably higher than in CEE countries (**Figure 3**).[8] This was the case in spite of the large productivity gap

[8] It is worth noting though, that the measurement of productivity growth in the service sector is widely-known to be plagued by a number of measurement problems. See, for instance, Triplett and Bosworth (2004).

between these sub-sectors in CEE countries and in the US, which – similarly to the manufacturing sector – should have driven much higher productivity growth.[9]

Figure 3: Labour productivity growth in total services and in wholesale and retail trade in CEE countries, EU-15 and the US, 1993-2001



Note: GDP per person employed. 1995-2001 for the EU-15 and the US

Source: based on Van Ark and Piatkowski (2004)

Given the large share of wholesale and retail trade in GDP of CEE countries, productivity growth on par with the US would result in a substantial additional contribution to the aggregate labour productivity growth ranging from 0.32 of a percentage point in the Czech Republic to 1.21 in Slovakia (**Table 7**). Faster productivity growth in the non-ICT using sector would also boost the aggregate labour productivity in the EU-15 by 0.60 of a percentage point. As argued in Section 3, such a sizeable productivity increase, however, can not be achieved without improvements in business organization, human skills and in the overall business climate.

[9] Although the high productivity growth in the US wholesale and retail trade seem to have been at least partly driven by factors unique to the U.S., including economies of scale, lack of zoning rules and the "Walmart effect". See, for instance, McKinsey (2001).

Table 7: Additional contribution to aggregate labour productivity (LP) growth from ICT-led acceleration in productivity growth in the wholesale and retail trade in CEE countries and in the EU-15, in percentage points, 1993-2001 annual average

	EU-15	USA	Czech Rep.	Hungary	Poland	Slovakia
Wholesale trade – share in total valued added	0.05	0.06	0.06	0.04	0.11	0.08
Retail trade – share in total valued added	0.05	0.07	0.05	0.06	0.07	0.06
Additional contribution to aggregate LP growth from wholesale trade	0.32	-	0.01	0.07	0.40	0.82
As a share of total LP growth	23.8%	0.0%	0.4%	2.7%	12.1%	32.6%
Additional contribution to aggregate LP growth from retail trade	0.28	-	0.30	0.48	0.34	0.39
As a share of total LP growth	20.9%	0.0%	10.7%	19.9%	10.1%	15.6%
Aggregate labour productivity growth	1.3	2.2	2.8	2.4	3.3	2.5
Total additional contribution to LP growth	**0.60**	**-**	**0.32**	**0.54**	**0.74**	**1.21**
As a share of LP growth	**44.7%**	**0.0%**	**11.2%**	**22.6%**	**22.2%**	**48.3%**

Note: Aggregate productivity growth for EU-15 and US for 1995-2001 only.

Source: Aggregate productivity growth rates based on Van Ark and Piatkowski (2004) and author's own estimates.

The potential for ICT-driven productivity growth and convergence can also be assessed on the basis of experts' assessments. Rivlin and Litan (2001) provide estimates of ICT-related savings due to the use of the Internet in the US between 2000 and 2005 in eight sub-sectors of the economy representing 70 percent of GDP. They find that the manufacturing, health and transport industry show the largest promise for ICT-related savings and related increase in productivity (**Table 8**). The benefits of ICT use in education and retail trade, however, proved to be too hard to quantify.

Table 8: Estimates of the potential savings due to the use of Internet in the US during 2000-05, by sub-sectors

Industry	Estimated savings until 2005 (in billion $)	As share of GDP in 2003
Education	Hard to estimate	-
Financial services	19	0,2%
Public administration	At least 12	0,1%
Health	41	0,4%
Manufacturing	50-100	0,5% - 1,0%
Retail trade	Hard to estimate	-
Transport	3-79	0%-0,7%
Total	125-251	1,2%-2,4%

Source: based on Litan and Rivlin (2001, p. 39)

Litan and Rivlin (ibid.) analysis also underscores the potential for ICT-led productivity growth also in the public sector. This potential seems to be particularly large for CEE countries, where the overall quality and efficiency of the public sector is low relative to the EU-15 and to the US in particular. An enhanced use of ICT in the public sector would contribute to an increase in its productivity, improve revenue collection and generate large savings in operating costs. These benefits could go a long way towards "saving the welfare state" in both CEE countries and in the EU-15 that is now being undermined by the erosion of the tax base due to the combined effect of

globalization and spread of ICT networks.[10] More intensive use of ICT in the public sector would also boost productivity of the private sector through reduction of red tape, better quality of public services, easier access to information and higher transparency.

5. Divergence in the Potential of ICT Use

The discussion on the sources of faster growth and convergence of CEE countries with the EU-15 begs a question of which industries in the non-ICT using sector are likely to benefit the most from ICT use and hence drive the productivity convergence. While I have shown that more rapid productivity growth in the wholesale and retail sector would substantially add to productivity of CEE economies, the achievement of higher productivity growth in these two sub-sectors may be more difficult than in other non-ICT using sub-sectors of the economy. Should it be possible to pinpoint the latter, such a selection of industries could provide some ground for both additional private investment as well as a public policy focused on promoting ICT use in the most promising industries from the point of view of their potential for ICT-led faster productivity growth. A better understanding of the ICT-related growth potential of specific industries could be particularly pertinent to CEE countries which need to decide on how to spend EU structural funds earmarked for the absorption of ICT and the development of the information society.[11] The section below develops a methodology for selecting these industries. It also provides estimates of the potential contribution of a higher productivity growth in these selected industries to convergence with the EU-15.

Before, however, I analyze the productivity potential of specific non-ICT using industries, it is important to discuss the determinants of ICT diffusion on the industry level. In essence, why is it that some industries invest in ICT more intensively than others?

[10] See Tanzi (2001) for the discussion of the implications of globalization and ICT for revenue collection in developed countries.

[11] For instance, EU funds for ICT and the information society development available to Poland between 2004 and 2006 amount to around one billion euro. How to most productively spend this money is then truly a 'billion euro question'.

There is a very limited number of studies examining the determinants of ICT diffusion at the industry-level, particularly in CEE countries. OECD (2003, 2004) underscores the importance of competition, stemming from flexible product markets and the ease of market entry and exit, trade openness, labour market flexibility and the quality of human capital. Muller and Salsas (2004) examine, on the basis of data from the "e-Business Survey 2003", Internet usage in enterprises in 25 EU Member States.[12] They find that the access to the Internet as well as the use of e-mail is strongly and positively correlated with the share of trade in total revenue and the company size. Taking Internet usage as a proxy for intensity of ICT investment, this suggests that ICT intensity is dependent on the level of trade openness and degree of consolidation of the industry (the higher, the better for ICT investment). Clarke (2003) finds that access to the Internet in CEE countries is positively correlated with the share of foreign ownership. The absorption of ICT on the industry-level is also likely to be driven by the inherent nature of industries in question. The 'weightless' industries like the financial sector, mass media, and entertainment seem to be naturally better suited to absorb ICT than more 'material' sectors (agriculture, mining, manufacturing).

The significance of each of the above factors for ICT investment intensity can not be assessed due to a lack of data on ICT investment at the industry-level in CEE countries. Likewise, it is not possible to provide a classification of ICT-using and non-ICT using industries in CEE countries as well as in the EU-15. Instead, one can rely on an ICT industrial taxonomy available from Van Ark and Piatkowski (2004), which divides industries in the EU-25 into industries that use ICT more intensively ("ICT using") and less intensively ("non-ICT using") on the basis of the intensity of ICT investment in the US industry.[13] The ICT-producing group is in turn distinguished on the basis of the OECD classification.

As pointed out by Van Ark and Piatkowski (2004), the main issue here is whether the US classification of industries can be applied to the EU-25. This mostly concerns the new EU member states from Central and Eastern Europe, which are at a much different stage in industrial

[12] The "e-Business Survey" was carried out by e-Business W@tch in November 2003 for the European Commission Enterprise Directorate General. The survey covered Business services, Chemicals, Crafts & Trade, Electronics, Health services, ICT services, Retail, Textile, Tourism, and Transport. For more information, please refer to http://www.ebusiness-watch.org.

[13] As measured by the share of ICT capital in total capital services. See van Ark, Inklaar and McGuckin (2003) for a detailed description of this methodology.

development than the US economy.[14] Here the main assumption is that the industry-level distribution of the ICT use in the US presents a set of technological opportunities that is likely to be also taken up by industries in CEE countries. For instance, the utility of the ICT use in agriculture in the US and in CEE countries is likely to be similarly low.

The validity of the ICT taxonomy can be confronted with the industry-level data for Slovenia on the ICT investment during 1996-2001 available from the Slovenian Statistical Office.[15] Based on the data, the Slovenian industries can be divided into "ICT-using" and "non-ICT using" depending on the value of ICT investments as a share in total investment (gross fixed capital formation). Industries with higher share than the median for all industries can be classified as ICT-using, while those below the median as non-ICT using.

Table 9 shows the classification of Slovenian industries in terms of the intensity of ICT investments. It turns out that the resulting classification is largely similar to the ICT taxonomy presented by Van Ark and Piatkowski (2004) and used in this paper.

[14] As regards the EU-15, on the basis of the available evidence for some EU countries, Van Ark, Inklaar and McGuckin (2003) show that the rankings of ICT intensity across industries in the EU-15 are reasonably similar to that of he US. However, a few industries, like transport, storage and textile products, are classified as ICT-using in the US but not in the EU. In contrast, chemical industry is classified as non-ICT using in the US, but ICT-using in the EU-15.

[15] Data for 1996-2000 is available only for investment in IT hardware and software. Starting in 2001, the data also includes investment in telecommunication equipment.

Table 9: Classification of industries on the basis of intensity of ICT investments in Slovenia, 1996-2001 average

	Share of ICT investment in total GFCF, 1996-2001 average
ICT-using	
Financial intermediation	30.6%
Real estate, rental, professional services	18.0%
Education	16.7%
Transport and communications	11.8%
Other services	10.8%
Fishing	9.6%
Wholesale and retail trade, repair	9.3%
Health	8.4%
Non-ICT using	
Public administration	7.8%
Manufacturing	6.7%
Construction	6.1%
Agriculture	5.5%
Hotels and restaurants	3.6%
Utilities (gas, electricity, water)	3.3%
Mining	2.2%
Average for the whole economy	9.1%
Median	**8,4%**

Source: Based on Stare et al. (2004).

The ICT taxonomy can now be used to analyze the potential of ICT for industry-level productivity growth. This can be done through building a matrix of industries combining two taxonomies: the ICT taxonomy based on the ICT use and the taxonomy developed by Peneder (1999, 2003), which divides manufacturing industries according to their physical and human capital intensity (for instance, industries can be labour intensive and low-skill). The argument here is that industries of the same nature as regards physical and human capital intensity should

exhibit the same patterns in ICT use and consequently in the productivity growth rates. If this is not the case, then it can be argued that non-ICT using industries could accelerate their productivity growth to the same level as in ICT-using industries of the same nature through increased spending on ICT. As shown in Section 3, given that ICT-using industries have higher productivity growth rates, the additional contribution of ICT to the productivity growth in an economy would be equal to the difference between the productivity growth in ICT-using and non-ICT using industries.

This matrix approach can also provide indications as to which non-ICT using industries stand to benefit the most from the ICT use to increase their productivity growth. The number of industries of the same nature represented in the ICT-using category suggests the size of the potential for productive use of ICT, i.e. the larger the number of industries in the ICT using category, the higher the economic potential for ICT use in these industries relative to other industries. Should such a group of industries be found, then non-ICT using industries of the same physical and human capital intensity would have the largest potential to increase productivity thanks to a more intensive ICT use.

Peneder (1999, 2003) taxonomies are built on the basis of a technique of statistical clustering, based on which industries are classified according to their similarity in terms of typical patterns of factor input combinations.[16] The taxonomy based on the physical capital intensity divides the manufacturing sector into mainstream manufacturing, labour-intensive, capital-intensive and marketing driven industries. This classification is based on the following variables:

1. labour intensity (average ratio of gross wages and salaries to value added from 1990 to 1995)
2. capital intensity (average ratio of total investments to valued added from 1990 to 1994)
3. advertising sales ratio (average ratio of advertising outlays on total sales from 1993 to 1995)
4. R&D sales ratio (average ratio of expenditures on R&D to total sales 1993-95)

[16] To quote from Peneder (2002), p. 113): „the technique of statistical clustering produces a classification scheme of individual observations, depending on their relative similarity or nearness to an array of variables. The basic idea is one of dividing a specific data profile into segments by creating maximum homogeneity within and maximum distance between groups of observations".

The remaining industries, which are distinguished by their lack of reliance of any of the four factor inputs, are classified as "manufacturing mainstream".[17]

The taxonomy on the human capital intensity in turn is based on the input of the quality of labour skills based on two different types and levels of skills. Manufacturing industries are divided into four groups: "white-collar high-skill", "white collar low skill", "blue collar high skill" and „blue-collar low-skill".

Table 10 and **Table 11** present the matrix built on the ICT taxonomy combined with, respectively, the taxonomy on the physical and human capital intensity. **Table 10** shows that labour-intensive and mainstream manufacturing industries are on the whole most likely to use ICT intensively as they have the largest representation in the ICT-using category. Hence, the potential for the productive use of ICT in these industries can be considered as the largest among all industries. Consequently, the mainstream and labour intensive non-ICT using industries should stand to benefit the most from a more intensive use of ICT.

Similarly, **Table 11** based on the taxonomy on human capital input shows that medium-skill white collar and medium-skill blue collar industries are the most likely to use ICT intensively. Hence, the non-ICT using industries of the same human capital input are likely to be able to use ICT more productively than other industries.

[17] The data refers exclusively to the US manufacturing industries. The underlying assumption is that industries in CEE countries have largely similar dispersion of human capital intensity.

Table 10: Industrial matrix based on ICT and capital intensity taxonomy.

	ICT-producing	ICT-using	Non-ICT using
Mainstream manufacturing	Manufacture of office machinery and computers (30)	Machinery and equipment (29) Other transport equipment (351, 353, 352+359)	**Rubber and plastic products (25)** **Other non-metallic mineral products (26)** **Motor vehicles, trailers and semi-trailers (34)**
Labour-intensive		Wearing apparel and furriery (18) Electrical machinery and apparatus (31-313) Furniture; other manufacturing (36-37)	**Leather and manufacture of leather products (19)** **Wood and wood straw and wicker products (20)** **Metal products (except machinery and equipment) (27)**
Capital-intensive			Textiles (17) Coke, refined petroleum products and derivatives (23) Pulp and paper (21) Chemicals and chemical products (24) Basic metals (27)
Marketing driven		Publishing and printing (22)	Food products and beverages (15-16) Tobacco products (16)
Technology driven	manufacture of radio, TV and communications equipment (32)	Medical precision and optical instruments, watches and clocks (33-331)	

Note: in brackets ISIC Rev 3 industry codes.

Source: Van Ark and Piatkowski (2004) for the ICT taxonomy, Peneder (1999) for the capital intensity taxonomy.

Table 11: Industrial matrix based on ICT and educational intensity taxonomy.

	ICT-producing	ICT-using	Non-ICT using
Low skill		Wearing apparel and furriery (18)	Rubber and plastic products (25) Other non-metallic mineral products (26) Leather and manufacture of leather products (19) Textiles (17) Basic metals (27) Food products and beverages (15-16) Tobacco products (16)
Medium-skill blue collar		Other transport equipment (351, 353, 352+359) Furniture; other manufacturing (36-37)	**Motor vehicles, trailers and semi-trailers (34)** **Wood and wood straw and wicker products (20)** **Metal products (except machinery and equipment) (28)**
Medium skill white collar	manufacture of radio, TV and communications equipment (32)	Medical precision and optical instruments, watches and clocks (33-331), Publishing and printing (22) Electrical machinery and apparatus (31-313)	**Coke, refined petroleum products and derivatives (23)** **Pulp and paper (21)** **Chemicals and chemical products (24)**
High skill	manufacture of office machinery and computers (30)	Machinery and equipment (29)	

Note: in brackets ISIC Rev 3 industry codes

Source: Van Ark and Piatkowski (2004) for the ICT taxonomy, Peneder (2002) for the taxonomy based on human capital intensity.

Table 12 illustrates the differences in productivity growth rates in mainstream manufacturing and labour intensive ICT-using and non-ICT using industries. Productivity growth rates in the former, except for the US and Slovakia's mainstream manufacturing, were much higher than in the non-ICT using sector. Similarly, **Table 13** based on the human capital taxonomy shows that the productivity growth in medium skill blue and white collar ICT using industries was higher than in the non-ICT using sector. These results provide a strong indication of the important role of ICT in stimulating productivity growth at the industry level.

Table 12: Differences in labour productivity (LP) growth rates in CEE countries, the EU-15 and the US for mainstream manufacturing and labour intensive ICT-using and non-ICT using industries

	EU-15	US	Czech Rep.	Hungary	Poland	Slovakia
	1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001
Average LP growth for ICT-using and mainstream manufacturing*	1.1	0.2	19.7	18.3	16.9	(0.9)
Average LP growth for non-ICT using and mainstream manufacturing	0.9	1.5	7.1	8.9	9.3	5.8
Difference	**0.18**	**(1.33)**	**12.60**	**9.40**	**7.52**	**(6.70)**
Average LP growth for ICT-using and labour intensive	2.13	1.23	9.63	5.33	7.20	11.63
Average LP growth for non-ICT using and labour intensive	1.20	0.50	4.93	2.67	5.63	6.50
Difference	**0.93**	**0.73**	**4.70**	**2.67**	**1.57**	**5.13**

Note: GDP per person employed. Averages are unweighted. * calculated as an average of separately growth rates in machinery and equipment and average growth rates in other transport equipment. For Slovakia without "Ships (351)".

Source: author's calculations based on Van Ark, Piatkowski (2004) and data from Table 5 and Table 9.

Table 13: Differences in labour productivity (LP) growth rates in CEE countries, the EU-15 and the US for medium skill blue and white collar ICT-using and non-ICT using industries

	EU	US	Czech Rep.	Hungary	Poland	Slovakia
	1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001
Average LP growth for ICT-using and medium-skilled blue collar	1.2	2.8	24.1	14.2	13.9	9.2
Average LP growth for non-ICT using and medium-skilled blue collar	1.0	0.1	7.1	7.7	3.2	6.1
Difference	**0.27**	**2.65**	**17.00**	**6.48**	**10.62**	**3.07**
Average LP growth for ICT-using and medium skill white collar	2.20	(0.17)	9.23	5.93	10.10	16.90
Average LP growth for non-ICT using and medium-skilled white collar	1.63	1.00	(2.00)	(0.30)	3.07	9.50
Difference	**0.57**	**(1.17)**	**11.23**	**6.23**	**7.03**	**7.40**

Note: as in Table 12

Source: as in Table 12

The differences in productivity growth rates between the ICT-using and non-ICT using industries also show that there is a large potential for faster productivity growth in non-ICT using industries. This begs a question of the impact on the economy-wide productivity growth rates if the above selected non-ICT using industries were able to increase their ICT investments and subsequently catch-up with the productivity growth rates of the ICT-using industries.

In order to estimate this potential, the difference in labour productivity growth rates between the ICT using and non-ICT using industries needs to be multiplied by the share of the non-ICT using industries in the aggregate value added. **Table 14** shows that a more intensive ICT investment in non-ICT using mainstream and labour intensive manufacturing could have substantially added to the aggregate labour productivity between 1993-2001 in the Czech Republic and – to a lesser extent – in Hungary and Poland. In all three countries ICT-led restructuring in the non-ICT using sector could thus considerably accelerate convergence with the EU-15. For the EU-15, the US and Slovakia, however, the difference in productivity growth rates would not be significant.[18]

[18] Needless to say, these results are indicative only. The negative result for the US can be explained by the fact that non-ICT using industries in the US have already achieved productivity levels similar to ICT-using industries and hence there was no space for productivity catch-up. In the case of Slovakia, the negative result is due to low productivity growth rates in the ICT-using mainstream manufacturing sector, which suggests that ICT investment in this sector may have not been used productively.

Table 14: Additional contribution to the aggregate labour productivity (LP) growth from ICT-led acceleration in productivity growth in the labour intensive industries and mainstream manufacturing in CEE countries, the EU-15 and the US, in percentage points, 1993-2001 annual average

	EU-15	USA	Czech Rep.	Hungary	Poland	Slovakia
Total share in value added of non-ICT using mainstream manufacturing	3.7	2.7	4.6	3.7	3.2	3.5
Total share in value added of non-ICT using labour intensive	1.7	1.3	3.4	1.5	2.3	3.2
Additional contribution to aggregate LP growth due to the increase in productivity in mainstream manufacturing	0.01	(0.04)	0.58	0.35	0.24	(0.24)
As share of total LP growth	0.5%	-1.6%	20.6%	14.4%	7.2%	-9.4%
Additional contribution to aggregate LP growth due to the increase in productivity in labour intensive industries	0.02	0.01	0.16	0.04	0.04	0.17
As share of total LP growth	1.2%	0.4%	5.7%	1.7%	1.1%	6.6%
Aggregate Labour Productivity Growth	1.34	2.19	2.83	2.41	3.33	2.50
Total contribution to LP growth	**0.03**	**-0.03**	**0.74**	**0.39**	**0.28**	**-0.07**
As a share of LP	**1.7%**	**-1.2%**	**26.4%**	**16.0%**	**8.3%**	**-2.8%**

Note: Aggregate productivity growth for EU-15 and US for 1995-2001 only.

Source: Aggregate productivity growth rates based on Van Ark and Piatkowski (2004) and author's own estimates.

The contribution to a faster productivity growth and accelerated convergence would be even higher for medium-skill blue and white collar industries. As shown in **Table 15**, higher ICT investment in non-ICT using manufacturing could increase the aggregate labour productivity growth in CEE countries by additional 16% to 42% per year. This would have a significant contribution to faster convergence with the EU-15.

Table 15: Additional contribution to labour productivity growth from enhanced ICT investment intensity in manufacturing non-ICT using sector, in percentage points, 1993-2001 annual average

	EU-15	USA	Czech Rep.	Hungary	Poland	Slovakia
Total share in value added of non-ICT using medium-skilled blue collar	4.1%	3.4%	5.3%	3.8%	3.1%	3.7%
Total share in value added of non-ICT using medium-skilled white collar	3.2%	3.4%	2.7%	4.6%	2.9%	4.7%
Additional contribution to aggregate LP growth due to increase in productivity in non-ICT using medium-skilled blue collar	0.01	0.09	0.89	0.24	0.33	0.11
As share of total LP growth	0.8%	4.1%	31.6%	10.1%	9.9%	4.5%
Additional contribution to aggregate LP growth due to increase in productivity in non-ICT using medium-skilled white collar	0.02	(0.04)	0.31	0.29	0.20	0.35
As share of total LP growth	1.4%	-1.8%	10.9%	11.9%	6.1%	13.9%
Aggregate Labour Productivity Growth	1.34	2.19	2.83	2.41	3.33	2.50
Total contribution to LP growth	**0.03**	**0.05**	**1.20**	**0.53**	**0.53**	**0.46**
As a share of LP growth	**2.2%**	**2.3%**	**42.5%**	**21.9%**	**16.0%**	**18.5%**

Note: Aggregate productivity growth for the EU-15 and the US for 1995-2001 only.

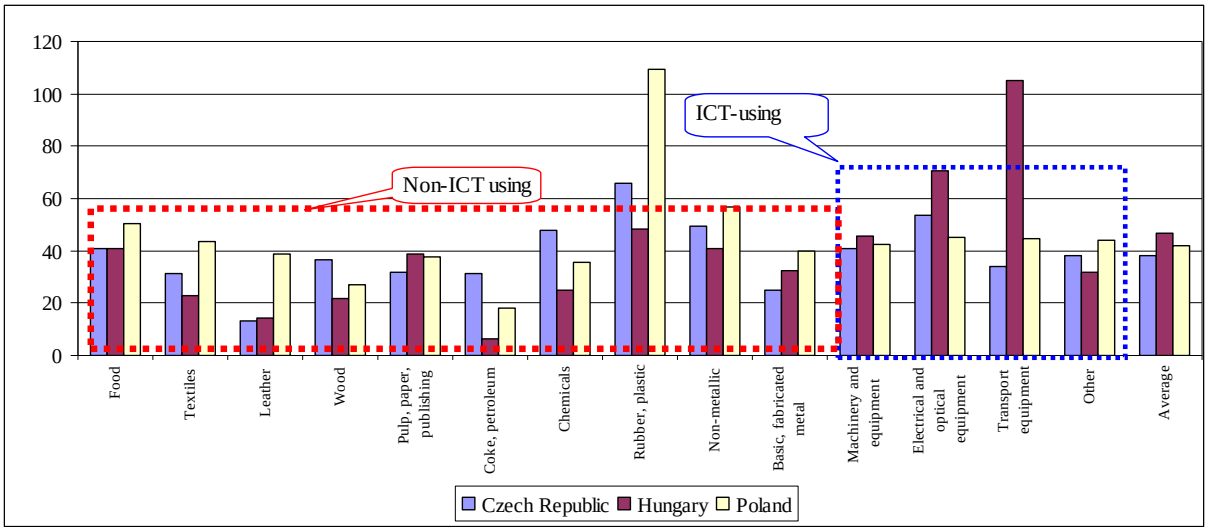
Source: Aggregate productivity growth rates based on Van Ark and Piatkowski (2004) and author's own estimates.

The above projections assume, however, that the more intensive ICT investment in non-ICT using industries will automatically translate into higher productivity growth. This is obviously not the case since, as argued by Brynjolffson and Hitt (2000), ICT investment in order to be productive needs to be complemented with adequate ICT skills and re-organization of business processes around new ICT solutions. Dorgan and Dowdy (2004) emphasize a similar point by showing that the productive use of ICT is closely linked to the quality of management practices. In turn, Hempell (2002) on the basis of a study of the German service sector argues that innovation experience is prerequisite to the productive use of ICT. A history of innovation is also much more important for the use of ICT than for other forms of capital. This argument is particularly pertinent to enterprises in CEE countries, which under the centrally planned economy did not have to innovate to survive. Hence, managers of CEE companies with no previous innovation experience are much less likely than their western counterparts to innovate around new ICT applications. As a result, *ceteris paribus*, the productivity of ICT investments in CEE companies could be lower than in the EU-15. The other point is that managers of CEE companies would also be less likely to invest in ICT in the first place. When faced with a choice of making an investment in either ICT or in other forms of capital (machinery, real estate, transport equipment etc.), they would most likely choose the latter, already familiar investments rather than high-risk ICT, which they have not ever done before.

Assuming, however, that non-ICT using industries in CEE countries would be able to use ICT productively, the question is whether the projections on the considerable potential for higher productivity growth in non-ICT industries are realistic. One way of checking it is to show that there is enough of a gap in productivity levels between CEE countries and the EU-15 so that ICT-led productivity catching-up is possible. **Figure 4** shows that labour productivity levels in non-ICT using industries in CEE countries are indeed much lower than in the EU-15, as proxied – due to lack of other data – by Austria.[19] This evidences the existence of a substantial room for productivity improvements in the non-ICT using sector.

[19] According to Eurostat's New Cronos Database, in 2003 the level of productivity in Austria amounted to 96.9% of the EU-15 average as measured by labour productivity per person employed.

Figure 4: Labour productivity levels in manufacturing industry in CEE countries in 2002, Austria=100



Source: based on Havlik and Urban (2003)

A similar picture transpires from **Table 16** showing productivity levels in CEE industries in comparison to the average productivity levels in the whole manufacturing sector in the same countries. Non-ICT using industries of leather, textiles, wood and wood products exhibit the lowest productivity levels relative to the average. Hence, there is ample scope for ICT-driven productivity growth.

Table 16: Labour productivity levels in manufacturing industries in CEE countries, as % of total manufacturing productivity level, 2001

	Czech Republic	Hungary	Poland	Slovakia
Manufacturing total, productivity relative to the EU-15 average (EU-15=100)*	40.6	47.9	36.2	36.5
Food products, beverages	132.4	88.2	118.4	105.5
Textiles	48	25.5	36.9	24.9
Leather and leather products	30.3	20.4	44	30.6
Wood and wood products	106.3	40.9	78	52.9
Pulp and paper, publishing and printing	116	96.2	128.1	135.2
Chemicals	166.3	130	157.9	128.8
Rubber	104.2	84.6	105.9	111
Non-metallic mineral products	90.2	68.4	87.4	72.4
Basic metals	88.2	76.7	98.7	106.3
Machinery and equipment	75.5	57.7	67.2	63.6
Electrical and optical equipment	80.1	163.3	113.5	69.4
Manufacture of transport equipment	159.4	279.5	135.3	295.6
Other manufacturing	71.6	37.1	69.4	76.6
Coke, petroleum products	1103.4	244.6	614.3	598.7

Note: * based on PPP prices for gross fixed capital formation 1999. Productivity level versus total manufacturing sector's average.

Source: based on Havlik and Urban (2003).

6. Conclusions

Between 1995 and 2001, ICT contributed to an accelerated convergence of all five new EU member states from Central and Eastern Europe with the EU-15. Romania and Bulgaria, however, lagged behind as ICT contribution to growth was lower than in the EU-15. This was due to a lower quality economic and institutional environment than in other CEE countries. The divergence between the economic impact of ICT indicates a close link between diffusion of ICT and advancement of economic reforms.

Since the ICT-producing sector in CEE countries, with the possible exception of Hungary and the Czech Republic, is too small to be a main driver of growth and because the simple transition growth reserves have been already exhausted in most CEE countries, sustained productivity growth and convergence with the EU-15 will now have to rely on the productive use of ICT in the non-ICT producing sector, particularly in services. This paper provides evidence that ICT use had an important role in stimulating productivity growth at industry level in the CEE countries, as between 1993 and 2001, ICT-using industries reported higher productivity growth rates than non-ICT using ones.

If non-ICT using industries were able to increase the intensity of ICT investment and thus achieve the same rate of productivity growth as the ICT-using industries, it would provide a considerable boost to the convergence process. Realizing this potential, however, would require further structural reforms aimed at deregulating product markets, more flexible labour 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 much harder to achieve.

It seems that within the non-ICT using sector, mainstream manufacturing, labour intensive industries and medium-skilled white and blue collar manufacturing would benefit more from the ICT use than other industries. More intensive use of ICT in these industries could significantly contribute to faster economic growth in CEE countries and accelerate the speed with which they catch up with the EU-15. It also provides an indication to the private and public sector that returns on ICT investment in certain industries could potentially be higher than elsewhere. The public sector could contribute to the realization of this potential by stimulating a conducive business environment and promoting ICT use by making public productivity level rankings and growth rates, thus raising awareness of the existing productivity gaps. The public sector should

also accelerate the development of public e-services and establish a mandatory use of e-procurement by the whole public sector and all private enterprises willing to participate in public tenders. Finally, EU funding on ICT-related programmes should be based on a detailed cost-benefit analysis in order to ensure the highest returns on investment.

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Appendix 1

METHODOLOGICAL NOTE: ACCOUNTING FOR THE 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:

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 labour 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 labour, respectively.

Denoting the total employment by *H(t)* and labour 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 labour 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 using sector.

Appendix 2.

Table 5: Labour Productivity and employment growth by industry in CEE countries, the EU-15 and the US, 1993-2001

		GDP per person employed						Persons Employed					
ISIC		EU	US	Czech Rep.	Hungary	Poland[1]	Slovakia	EU	US	Czech Rep.	Hungary	Poland[1]	Slovakia
Rev3		1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001	1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001
	Total Economy	**1.3**	**2.2**	**2.8**	**2.4**	**3.3**	**2.5**	**1.3**	**1.6**	**-0.5**	**0.2**	**0.5**	**-0.3**
	ICT Producing Industries	**7.2**	**9.6**	**13.0**	**7.8**	**5.8**	**8.5**	**3.2**	**3.8**	**0.3**	**3.1**	**0.0**	**0.0**
	Manufacturing	**11.9**	**23.0**	**15.4**	**7.5**	**8.1**	**7.1**	**0.6**	**0.2**	**1.7**	**5.8**	**-1.4**	**1.3**
30	Computers	44.5	47.1	32.2	11.3	16.9	17.3	-0.7	-4.1	10.6	18.6	2.7	0.7
313	Fiber optics	0.1	3.1	-2.3	-7.7	-5.6	12.1	0.4	-1.0	6.1	7.8	3.7	11.4
321	Semiconductors	56.6	51.3	26.4	15.5	3.2	-8.0	2.7	2.3	5.0	10.0	-9.0	4.8
322	Communication eq.	0.5	-2.0	34.4	16.5	13.0	2.7	0.8	1.2	-2.0	0.6	0.3	-2.1
323	Radio and TV eq.	-7.2	-9.1	47.1	18.6	19.6	-1.4	-1.7	-4.0	-10.4	9.4	-6.3	-3.7
331	Instruments	-7.8	-6.8	8.1	0.5	4.4	3.9	1.0	0.2	1.3	-4.9	-0.1	-0.1
	Services	**5.5**	**1.8**	**12.9**	**8.6**	**4.6**	**9.2**	**4.3**	**5.7**	**-0.5**	**1.3**	**1.5**	**0.0**
64	Telecommunications	8.5	6.6	16.0	7.3	4.2	9.3	1.0	1.4	-1.6	-0.1	0.5	-0.1
72	Computer services	1.4	-3.9	4.2	13.2	3.9	10.1	9.5	11.1	1.9	6.9	6.9	0.6

	ICT Using Industries[a]	**1.6**	**4.6**	**4.4**	**1.0**	**4.8**	**1.8**	**1.4**	**0.8**	**0.9**	**1.3**	**0.0**	**0.0**
	Manufacturing	**1.6**	**0.1**	**9.2**	**7.1**	**12.0**	**7.1**	**-0.4**	**-1.4**	**-0.9**	**1.5**	**-1.6**	**-2.6**
18	Apparel	3.4	5.3	5.1	2.6	5.2	2.6	-4.1	-9.7	-1.8	-0.4	-2.3	1.8
22	Printing & Publishing	1.6	-0.7	1.8	3.6	12.0	25.3	-0.4	-1.0	1.8	2.4	5.7	-2.2
29	Machinery	0.9	-2.8	6.3	10.8	15.4	-2.1	0.3	-0.4	-2.6	-3.1	-4.9	-6.7
31-313	Electrical machinery	1.8	-3.9	8.7	10.9	7.0	14.2	0.1	-1.5	3.1	10.0	0.1	4.1
33-331	Watches & instruments	3.2	4.1	17.2	3.3	11.3	11.2	-0.4	-2.0	0.7	-1.3	-6.8	-3.2
351	Ships	1.6	2.6	33.1	45.9	15.0	n.a.	-0.3	0.4	-10.6	-2.7	-1.6	n.a.
353	Aircraft	-0.2	2.6	33.1	10.8	17.9	2.0	2.5	-1.3	-0.4	-8.2	-8.0	-14.2
352+359	Railroad and other	2.4	4.4	33.1	20.9	22.0	-1.4	-0.9	4.3	-8.0	3.1	-5.5	5.6
36-37	Misc. manufacturing	1.2	2.3	15.1	2.5	9.4	18.1	0.0	0.0	-0.6	2.4	1.7	-3.2
		GDP per person employed						**Persons Employed**					
ISIC		EU-15	US	Czech Rep.	Hungary	Poland	Slovakia	EU-15	US	Czech Rep.	Hungary	Poland[1]	Slovakia
Rev3		1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001	1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001
	Services	**1.5**	**5.4**	**2.3**	**-0.6**	**2.3**	**-1.1**	**1.9**	**1.2**	**2.0**	**1.2**	**2.4**	**2.9**
51	Wholesale trade	1.5	7.4	7.2	5.9	3.7	-3.2	1.7	0.6	1.4	-3.2	1.9	5.5
52	Retail trade	0.8	6.3	0.1	-2.4	1.7	-0.8	1.3	0.9	0.5	2.2	1.0	1.6
65	Banks	3.9	4.2	3.9	-5.9	18.7	-4.6	0.1	1.6	3.5	1.4	1.3	1.1

66	Insurance	-0.5	0.5	7.2	12.6	14.0	26.5	0.7	0.9	6.0	-0.5	3.1	23.2
67	Securities trade	0.0	10.3	11.7	11.9	9.8	8.7	3.3	3.4	13.0	4.8	24.5	27.9
71	Renting of machinery	1.6	5.9	-14.5	-1.3	3.4	-3.6	5.3	2.8	13.5	-0.8	4.1	3.9
73	R&D	-1.5	2.4	-0.7	-1.9	-3.0	10.1	2.0	1.5	-3.7	1.0	-2.2	-3.9
741-743	Professional services	0.3	0.6	-4.5	0.1	-7.1	-0.5	4.5	2.2	4.8	1.4	12.5	2.7
	Non-ICT Industries	**0.6**	**-0.2**	**1.3**	**2.3**	**2.4**	**2.4**	**1.2**	**1.8**	**-1.1**	**-0.4**	**0.0**	**0.0**
	Manufacturing	**1.3**	**0.2**	**5.3**	**2.6**	**4.6**	**3.4**	**0.1**	**-0.8**	**-0.7**	**-1.1**	**-1.5**	**-1.8**
15-16	Food & beverages	0.3	-5.9	11.1	-0.7	3.9	0.1	0.2	0.1	-0.8	-2.2	-0.4	-1.2
17	Textiles	1.9	1.9	4.4	10.3	9.0	8.9	-2.1	-5.5	-3.1	-6.2	-8.6	-3.6
19	Leather	0.9	-0.3	7.6	0.7	10.4	15.4	-2.6	-8.6	-7.2	-1.6	-7.4	-6.7
20	Wood	1.8	-1.0	6.8	1.3	0.1	15.5	-0.3	-0.1	-0.3	2.3	1.8	-3.1
21	Paper	2.6	0.8	0.6	8.7	3.9	11.3	-0.4	-1.6	-4.2	0.9	1.2	-2.7
23	Petroleum & coal	-1.1	0.8	-4.8	-10.8	11.9	11.0	-0.7	-2.2	-15.9	-4.1	-2.9	-3.3
24	Chemicals	3.4	1.4	-1.8	1.2	-6.6	6.2	-0.5	-0.3	-0.4	-6.4	-2.9	-6.4
25	Rubber & plastics	1.2	3.7	6.8	5.0	6.7	3.2	1.0	-0.5	4.5	5.7	4.1	0.5
26	Stone, clay & glass	1.2	-0.3	7.4	6.1	16.8	7.3	0.3	0.8	0.6	0.3	-1.5	-1.5
27	Basic metals	0.9	2.8	0.4	6.0	6.4	-11.4	-1.2	-1.5	-4.2	-3.3	-9.9	-0.1
28	Fabricated metals	0.8	0.1	7.4	6.1	5.1	-4.0	0.6	0.2	0.5	4.0	3.2	3.2
34	Motor vehicles	0.3	1.2	7.1	15.7	4.5	6.9	2.1	-0.4	3.4	3.3	-2.1	1.0

		GDP per person employed						Persons Employed					
ISIC		EU-15	US	Czech Rep.	Hungary	Poland[1]	Slovakia	EU-15	US	Czech Rep.	Hungary	Poland[1]	Slovakia
Rev3		1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001	1995-2001	1995-2001	1993-2001	1993-2001	1993-2001	1993-2001
	Services	**0.2**	**-0.2**	**-1.5**	**2.1**	**1.9**	**4.1**	**2.0**	**2.1**	**1.0**	**0.6**	**1.5**	**0.9**
50	Repairs	0.4	-7.3	-2.4	0.5	4.1	-1.6	1.9	7.1	7.1	9.4	3.1	5.9
55	Hotels & restaurants	-1.1	-0.7	1.5	-1.1	5.5	5.5	2.6	2.2	2.9	3.3	3.5	0.4
60	Inland transport	2.0	0.3	-2.1	1.6	5.6	2.7	0.6	2.1	-1.2	-1.4	-1.1	-0.9
61	Water transport	2.3	1.0	-11.0	-7.9	15.7	1.4	-0.3	1.8	-7.8	-0.2	-13.1	-1.4
62	Air transport	3.2	1.1	5.9	1.9	1.0	2.6	4.3	3.1	-2.0	-0.7	1.6	-1.4
63	Supporting activities	0.9	3.0	-5.0	-1.5	4.6	4.2	3.5	1.8	3.9	0.5	-2.0	0.7
70	Real estate												
74.9	Other business services	-1.4	1.4	-2.2	-2.2	-7.1	5.1	6.2	4.7	2.0	9.6	12.5	3.6
75	Government	0.6	0.5	-3.7	2.8	-2.4	7.3	0.0	0.9	2.6	1.3	6.3	2.3
80	Education	-0.2	-1.7	-1.7	4.0	1.2	0.5	1.3	2.1	-1.0	-1.3	1.3	-1.1
85	Health	0.6	0.1	-1.3	3.6	1.4	4.4	1.7	1.9	1.1	-0.3	-0.9	1.6
90-93	Personal & social serv.	0.1	-0.2	-2.1	-0.4	1.9	5.7	2.5	1.2	1.3	-0.7	0.1	1.9
95	Private households	0.0	-0.9	n.a.	n.a.	n.a.	n.a.	2.4	-2.2	n.a.	n.a.	n.a.	23.5

	Other non-ICT industries	**1.9**	**0.7**	**2.3**	**2.6**	**1.3**	**-1.8**	**-0.6**	**2.1**	**-5.2**	**-1.9**	**0.0**	**-2.7**
01	Agriculture	3.2	8.7	7.9	4.5	-2.3	4.3	-1.8	0.1	-8.4	-4.8	0.8	-4.1
02	Forestry	2.2	3.4	9.6	5.5	-3.3	6.1	-2.1	1.7	-9.3	-4.8	-0.1	-4.5
05	Fishing	0.0	13.2	12.8	-3.0	11.5	2.4	-0.2	-5.6	-2.4	7.7	-8.7	-2.1
10-14	Mining	3.5	-0.7	7.7	6.0	6.0	3.4	-4.1	-0.3	-9.5	-14.7	-8.0	-2.5
40-41	Utilities	5.3	-0.1	0.1	2.1	4.8	-19.4	-3.0	-1.0	-0.8	-3.4	-1.4	1.3
45	Construction	0.5	-0.1	-3.3	0.2	3.6	3.6	0.5	3.7	-3.2	3.4	-0.1	-2.4

Source: Van Ark and Piatkowski (2004)