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Procedia - Social and Behavioral Sciences 110 (2014) 1271 – 1282

Procedia
Social and Behavioral Sciences

Contemporary Issues in Business, Management and Education 2013

Impact of information and telecommunication technologies development on labour productivity

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Abstract

The paper discusses the theoretical aspects of information and communications technologies (ICT) development and presents the theoretical frameworks of ICT development impact on labour productivity and economic growth, identify indices and indicators for measuring ICT development. The study concludes that ICT development indicators can be divided into four groups: ICT infrastructures, ICT uses, ICT readiness and ICT productions & trade. After analysis previous studies of ICT development effect on the countries productivity, formed the research model. There is assessing relationship between ICT infrastructure, ICT use, ICT skills development, ICT trade and labour productivity. The study confirms the assumption that low, medium and high productivity countries labour productivity influence by different factors. In some of the high and medium productivity countries the relationship between labor productivity and ICT development did not found.

Keywords: Information and communication technologies; ICT development; ICT contribution on productivity; labour productivity.

1. Introduction

Within the context of process of globalization and economic integration, the objective of economic politics of every country is strengthening of national competitiveness. To stay competitive in global markets, countries are

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doi:10.1016/j.sbspro.2013.12.974

forced to search for factors, new alternatives stimulating economic development. Productivity is among quantities reflecting the level of competitiveness. „Productivity is an important quantity to discuss economic conditions and national power" (Souma, Ikeda, Iyetomi, & Fujiwara, 2009). According to Blinder & Baumol (1993), nothing can reduce poverty rates, increase leisure quality and ability of a country to finance its education system, health care, environmental safety and art better than the growth of productivity. Krugman (1992), Gomez, Musso, Stocker & Turunen (2006), Bagley (2010), Frankel & Kendrick (2008) also agrees that the ability of a country to improve living standard depends on its ability to prompt labour productivity and efficiency growth. It should be noted the total factor – land, labour and capital – productivity or individual factor productivity may be calculated. According to Bagley (2010), a number of authors suggest using labour productivity as the quantity reflecting wellness of the state economy. Van Ark & Monnikhof (2000) also states that the development of a state or sector (industry) economy may be reflected the efficiency of employed labour force. When evaluating competitiveness of countries based on his quantity, big differences in competitiveness are highlighted not only in the world context but also in separate groups of countries. Substantial and big differences in labour productivity are observed among EU-27 states. In 2011 even in 15 states out of EU-27 labour productivity, expressed in added value per employee, was below the EU average, in Bulgaria with the lowest productivity the added value per employee was 4 times lower than in Luxemburg with the highest productivity. Thus, it is essential to seek for methods and measures to increase labour productivity in countries with both average and low productivity. As stated by Audretsch & Welfens (2002), under the conditions of the new economy, the development of ICT have become one of the most important sources for increase of labour productivity. However, results of retrospective researches of correlation between labour productivity and ICT development differ depending on the period, country, and research level (micro, mezzo, macro). Taking this under consideration, the study will aim to establish if ITC development be treated as the source of labour productivity growth in EU-27 countries using the data of 2000–2011, as not all data of 2012 is provided in statistical databases. Considering this, ***the aim of the study*** **–** to evaluate the impact of the development of ICT on labour productivity in EU-27states.

2. Theoretical basis for the impact of ICT on labour productivity

It is not easy to evaluate cause-effect and impact of technological, economic and social development in order to prove that ICT are the factor of economic increase of efficiency, productivity and growth. Nevertheless, it can be presumed the huge progress in the field of ICT is the main cause of economic changes of both commercial companies and the whole country, and these changes, first of all, are expressed by the growth of labour productivity. According Davidavičienė (2008), the importance of information's system that based on ICT has dramatically increased during the past decade as an increasing number of business have implemented them. More effective information processing using communication technologies may increase the efficiency of the whole present economic system, and this, in turn, may cause changes in economy of companies, industries and a country and influence the growth of added value. A number of authors reveal the impact of ICT development on the growth of economy, including also the growth of labour productivity, on the theoretical level.

According to Zhen-Wei Qiang, Pitt & Ayers (2003), there are three channels through which ICT can influence labour productivity and economics growth: 1) TFP growth in sector producing ICT; 2) Capital Deeping and 3) TFP growth through reorganization and ICT usage. According authors (Zhen-Wei Qiang, Pitt & Ayers, 2003), the ICT revolution partly consist of higher productivity growth in industries producing ICT, driven by rapid technological progress. The main characteristic of this revolution is the rapidly increasing computing power of new ICT products. In particular memory chips, with a long as "Moore's law" holds, double their computing power every 18 months. Such performance increases are equivalent to rapid TFP growth in ICT-producing sectors, which in turn raise the average TFP growth of the economy.

The ICT can influence productivity when higher levels of financial investment in ICT bring about new products and falling prices. This may lead to an increase in the real capital stock per worker – that is, ICT-related capital deepening across the economy (implying a lower of the marginal cost of capital). To the extent that ICT as a substitute for other firms of capital and labour, it frees productive resources to expand the overall output of economy to the extent that is a complement, it raises productivity of the existing capital stock and of labour.

Authors (Zhen-Wei Qiang, Pitt & Ayers, 2003) noted, that advances in ICT have the potential to significantly reorganize how goods and services are new markets, new products and new ways of organizing how society operates – in much the same way electric motor, the telephone and the computer chip have done previously. Technological changes across the entire economy naturally effect TFP growth and demonstrate ICT's potential to stimulate productivity. ICT can reduce administrative procedures, disseminate information cheaply and efficiently and trigger new business models that are more productive than existing models. While these predictions may be exaggerated, sector such as retail, financial services and transportations are benefiting from ICT utilization.

Taking into consideration these facts the authors formed model of the ICT impact on economic growth.

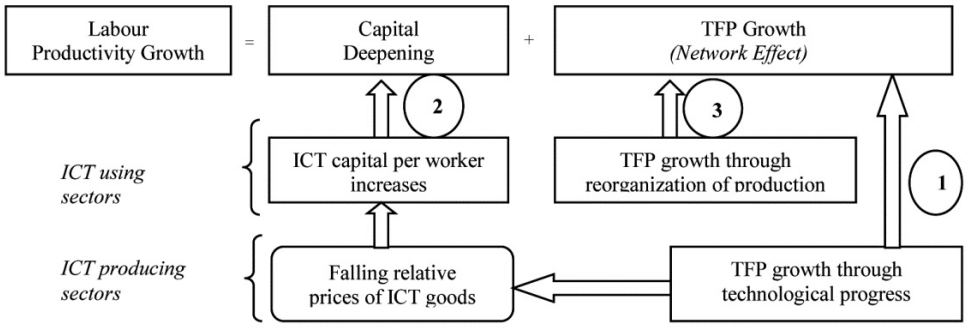

Fig. 1. Channels of contribution to labour productivity growth by ICT. Source: Zhen-Wei Qiang, Pitt, & Ayers (2003)

As it is stated by Серикова (2003), the theory of economic growth has been developed by other authors who draw attention to the fact that in production process some factors may cause increasing income depending on the number of operations and efficiency level. Such factors can be, for instance, information accumulation, information management, and availability of external relations. We can assume that innovations in the field of technologies interfere with the usual relation between development and company growth and induce so called growth spurts that can be determined by general purpose technologies (Internet), used potentially in various industries. According Lipaj & Davidaviciene (2013), information systems that are based on ICT helps improving business goals, target and strategies. General purpose technology modifies the current business model and predetermines a big growth of sectors, as well as long-term growth of added value. To reveal the economic essence of the impact of ICT development, Н. К. Серикова (2003) suggest discussing the five cause-effect chains:

Logical ***cause-effect chain 1***: *ICT development → implementation of organizational novelties and management reorganization → effectiveness and productivity growth → economic growth.* ICT implementation influences economic growth due to changed internal and external business processes that are components of the added value creation system, i.e. ICT implementation reduces company costs of internal and external contracts.

When information processing is improved and new communication tools are implemented, the first thing that changes is the rate of decision taking. This influences productivity growth due to changes in strategy formation and business coordination processes. Interactive company expenditures change and create new possibilities for efficiency increase. Reduction of cooperation and coordination costs with the help of integrated management systems predetermines more flexible and sensitive responses to changes of market conditions and taking better decisions.

Cause-effect chain 2: *ICT development → more efficient mechanism of distribution of market transactions and market → effectiveness and productivity growth → economic growth.* This construction is based on the assumption that when ICT is developed, economic growth may be achieved due to changes of market processes. This is related to the fact that ICT processes are handled by new and developed technologies, and this determines shorter processes of distribution of goods and services between the seller and the purchaser and among companies. This means that ICT may level current market shortages. For instance, there may change the rate of the company response to the market situation: contracts in the market can be concluded faster, efficiency of production organization may increase and etc. This should basically improve the demand to supply ratio, since demand could be met quickly.

Cause-effect chain 3*: ICT development→ growth possibilities of income, depending on operational scale* → new and improved final products → economic growth. ICT implementation is related to installation of innovative items, creating new image of goods, which conditions the attraction of new customers and increase company earnings. And this results in productivity increase and economic growth. It should be noted that new products can be treated as a final good and as an intermediate good or a component of innovative process. It should also be noted that the limit value of information saturated products is low; therefore, when investing into productions of such goods, potential profit needs to be evaluated very precisely.

Cause-effect chain 4*: ICT development → social and cultural changed within a society* → effectiveness and productivity growth → economic growth. At a first glance it may seem that small business can suffer from globalization processes; still, the role of small companies in the local level remains big. Moreover, small companies with the established good reputation can become global players if they succeed in finding their niche in the global market. They may also become members of some strategic alliances. In addition, small companies play an important role in strengthening the customer's positions, acts like mediators between the consumer and the producer when collecting information about needs of consumers. Small companies may also become sales agents of special companies and perform customer search.

Cause-effect chain 4*: ICT development → development possibilities of education and knowledge management innovations → strengthening of* innovative processes → *economic growth* → progress in *ICT development.* This is probably the most important mechanism under conditions of new economy. New ICT result in the development of information exchange processes not only among companies but also among scientific institutions and among scientific institutions and business. Efficient usage of knowledge contributes into strengthening of innovative processes that is one of the factors of economic growth. New initiatives are widely observed in the field of ICT, and they illustrate a growing competition among companies in the field of knowledge. Knowledge is more and more valued as a real company capital.

Dedrick, Gurbaxani & Kraemes (2003) analysed around 50 empiric studies, which results were published in the period of 1985–2002, evaluated gaps found in them and developed the conceptual system (see Fig. 2) defining correlations between ICT and economic growth.

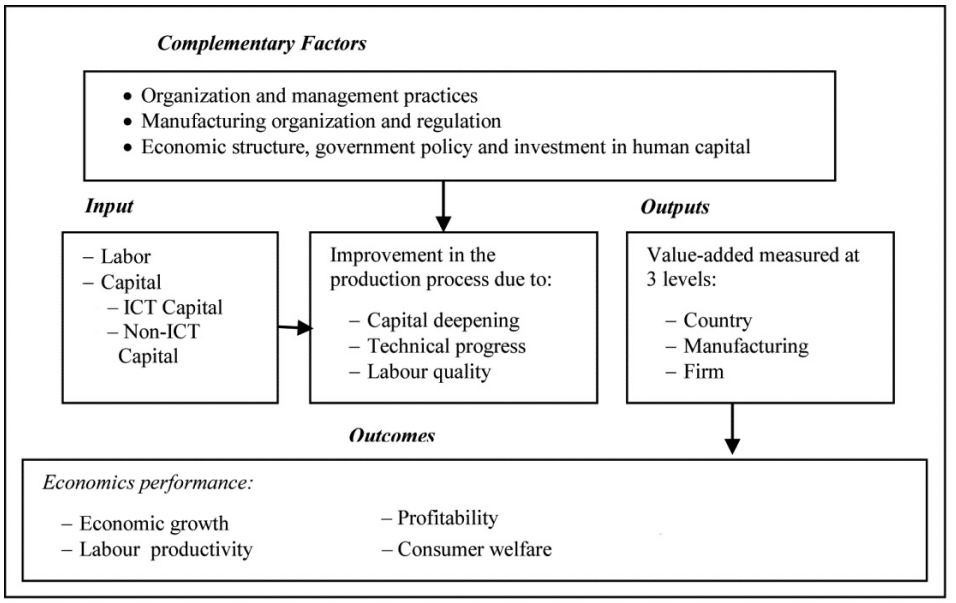

Fig. 2. ICT and Economic Performance. Source: Dedrick, Gurbaxani & Kraemes (2003)

According to the authors (Dedrick, Gurbaxani & Kraemes, 2003), the system helps establish and define the main variables and relations discovered in different studies. As seen, the system (from left to right) includes various

resources (labour and capital divided into ICT and other capital) used in production process and supplementary factors that influence it. The system enables evaluation of the impact of labour, ICT capital and non-ICT capital costs on the production output in the level of a company, an industry and a country, and also the impact on different operational results: economy growth, labour productivity, profitability, and consumer welfare.

The impact of ICT on economic rates was discussed by Katz (2009) in theoretical level and based on retrospective studies. The author notes that ICT has been found to have a direct influence on the economy at four levels: Productivity; Creation/relocation of enterprises; Employment, Economic growth. It should be noted that improvement of productivity, particularly in those industries that are ICT-intensive but also in those that are not.

Summarizing theoretical concepts of the impact of ICT development on the growth of productivity and economy, it could be stated that the impact of ICT on labour productivity can be observed in the level of a company, an industry and a country.

3. Review of retrospective studies of the impact of ICT on labour productivity

Having discussed and summarized theoretical models of the impact of ICT on labour productivity and having identified impact channels, and in order to perform the empiric study of the impact of ICT on productivity of EU-27 states, it is appropriate to analyse and structure results of such type retrospective studies and review methods employed therein. This would enable selection of quantities that reflect ICT development best and formation of the evaluation model of ICT impact on labour productivity. Correlations between ICT or IT on labour productivity have been studied by many authors. As indicated by Brynjolfsson (1993, 1994), Dedrick, Gurbaxani & Kraemes (2003), Rangriz & Raja (2011), the first studies of IT impact on productivity were performed in 1987–1991. Roach (1987, 1991), Loveman (1988), Baily & Chakrabarti (1988) and etc. studies found no impacts of investment in ICT on productivity at the level of firms, industries, or the economy as a whole. According to Rangriz &, Raja (2011), later Brynjolfsson (1993), Brynjolfsson & Hitt (1995, 1998), Oliner & Sichel (2000), Colecchia & Schyler (2001), Jorgensen (2001); Stiroch (2001), Jorgensen, Ho Mun & Stiroch (2005) and others who performed studies using larger scale data and more complicated research methods established a positive and significant impact of ICT on productivity of companies and countries. Discrepancies of results encouraged scientists to continue studies of the impact of ICT on labour productivity. Results of some of them are given on Table 1.

Table 1. Results of retrospective studies of ICT impact on labour productivity (prepared by authors)

Authors	Study period	Research sample / level	The main results
Oulton (2001)	1950–1973; 1973–1979; 1979–1989; 1989–1999	United Kingdom / Macro and sectoral (ICT, non-ICT) level	From 1989 to 1998, ICT output contributed a fifth of overall GDP growth. Since 1989, 56% of capital deepening has been contributed by ICT capital, and 88% since 1994. ICT capital deepening accounts for 23% of the growth of labour productivity over 1989-98 and 39% over 1994-98. But even when output growth is adjusted for the new ICT estimates, both labour productivity and TFP growth are still found to slow down after 1994.
Pilat, Lee & van Ark (2002)	1990–1995; 1996–2000	19 OECD countries / Industries (ICT-producing, ICT-using) level	The United States and Australia are almost the only OECD countries where there is evidence at the sectoral level that ICT use can strengthen labour productivity and MFP growth. For most other OECD countries, there is little evidence that ICT-using industries are experiencing an improvement in labour productivity growth, let alone any change in MFP growth.
Khan & Santos (2002)	1988–2000	Canada / Macro level	Compared with the US, there was no acceleration in the contribution of ICT use to output growth in the late 1990s. Similarly, contributions from capital deepening in ICT use to labour-productivity growth did not exhibit any acceleration.
Van Ark, Inklaar, McGuckin (2003)	1990–2000	European countries and US, 51 industries / Industries level	United States productivity has grown faster than in the EU because of a larger employment share in the ICT producing sector and faster productivity growth in services industries that make intensive use of ICT.
Van Ark, Piatkowski (2004)	1995–2002	EU-15, CEE-10, US / Macro and industries levels	Labour intensity have been an important source of productivity convergence during the 1990s and are likely to remain so in the near future. ICT capital in the CEE-10 has contributed as much to labour productivity growth as in the EU-15

Belorgey, Lecat & Maury (2006), used 25 countries in 2000 across a large number of countries (77 without ICT spending and 49 with) statistical date. Acording authors (Belorgey, Lecat & Maury, 2006), an analysis of the 1990s demonstrates that the GDP share of ICT spending and the GDP share of ICT production may have a *separate* and positive impact on the productivity growth rate. Of the components of ICT spending, the computer sector appears to have a far more influential role than the telecommunications sector. The positive and significant role played by ICT is confirmed in an examination of productivity levels. Sharpiro & Mathur (2001) used US (macro and industries levels) 1991–2009 dates for investigate and concluded that in US ICT's contribution to GDP has risen nearly 25 percent since the 1990s, increasing from 3.4 percent of GDP in 1991–1993 to an average of 4.2 percent over the years 2005–2009. In 2009 ICT itself was responsible for some $600 billion in value-added, or 4.2 percent of GDP. ICT investments by other industries were responsible for an additional $400 billion in value-added produced by those industries.

As obvious, results of further researches are controversial. They depend on research sample, period, country and its level (micro, mezzo, macro). Thus, it is not possible to generally state that ICT development is the main source of labour productivity increase, and it is necessary to perform a study using data of a particular country and a period of particular years. Still, to build a substantiated study model of the impact of ICT on labour productivity, first, it would be reasonable to overview methods employed in retrospective studies and their indicators. Having analysed scientific publications and reports of various institutions (International Telecommunication Union-ITU, Organisation for Economic Co-operation and Development-OECD, World Economic Forum-WEF and etc.), it was established that ICT development is usually measured with aggregated indices or groups of indicators. According to Paliulis, Mačiulytė-Šniukienė, Vizbaras (2012), OECD present five groups of indicators that can be used to measure ICT development: 1) the group of ICT infrastructure and access indicators, 2) the group of indicators of ICT access and usage by individuals and in households, 3) the group of indicators of ICT usage in companies, 4) the group of indicators of ICT sector and ICT trade, 5) the group of indicators of ICT usage in education system. ITU measures ICT development with the aggregated ICT development index (IDI), consisting of 3 sub-indices: ICT infrastructure and access, ICT use, ICT skills (ITU, 2011). The WEF annually publishes The Global Information Technology Report, presenting the Network Readiness Index with 4 sub-indices: Environment Sub-index, Readiness Sub-index, Usage Sub-index and Impact Sub-index (WEF, 2013). All these indices may be used to evaluate the status of ICT development, correlations of ICT development with changes in labour productivity and economic growth; however, in such case only general conclusion are possible. The study of the kind provides no possibilities to make a strategic ICT development plan, since it does not point into ICT fields for the most successful investments and cases leading to the highest efficiency. Mačiulytė-Šniukienė, Vizbaras (2012) used statistical data of 2000–2010 to examine correlations of ICT development and labour productivity in EU-27 states. The study led to the conclusion that ICT development has a positive impact on productivity in EU-27 states. Furthermore, since to measure ICT development the study uses the aggregated index (IDI), consisting of 11 indicators, and to be able to provide recommendations on ICT fields as the most appropriate for investments in a particular country, it is essential to prolong the study and indicate the impact of changes of certain indicators on labour productivity. For this reason, single indicators best reflecting ICT development that includes development of ICT infrastructure, usage, literacy, production and trade, shall be identified. To achieve this goal, retrospective studies are involved.

After analyzing previous scientific publication of Oliner & Sichel (2000), Oulton (2001), Pahjola (2001), Jorgenson (2001), Khan & Santos (2002), Van Ark, Inklaar & McGuckin (2003), Bhat, Sivakumar & Axhausen (2003), Zhen-Wei Qiang, Pitt & Ayers (2003), Van Ark & Piatkowski (2004), Lopez Sanchez (2004), Harindranath & Sein (2007), Taylor & Zhang (2008), Kamel, Rateb & El-Tawil (2009), Katz (2009), Hava & Azer (2011) and reports related to ICT development of OECD (2011), INSEAD (2012, 2013), UNCTAD (2012), ITU (2009, 2010, 2011, 2012), WEF (2013) were identified key indicators of ICT:

- *ICT infrastructure:* Fixed telephone lines per 100 inhabitants (I-1), mobile cellular telephone subscriptions per 100 inhabitants (I-2), International Internet bandwidth per internet users (bit/s) (I-3);
- *ICT use:* Internet users per 100 inhabitants (U-1), Fixed Broadband Internet Subscriptions (U-2), Mobile broadband subscriptions per 100 inhabitants (U-3);
- *ICT readiness:* Adult literacy rate (%) (R-1), Secondary gross enrolment ratio (R-2) and School enrollment, tertiary (% gross) (R-3);

- *ICT producing& trade:* Percentage of the ICT sector on GDP (PT-1), ICT export (PT-2), ICT import (PT-3).

While analysing mentioned sources, methods used to measure the impact of ICT on productivity of countries and other indicators were reviewed. In most cases, the influence of ICT production and trade on economic growth in countries is estimated based on the specific weight of added value created in ICT sector within the total added value, ICT export ratio in the scope of the whole country export, and ICT import ratio in the scope of the whole country import. Correlations of ICT development indicators with labour productivity are mainly studied by means of the correlation analysis. These methods are integrated into the model used to evaluate the impact of ICT development on labour productivity (see Fig. 3).

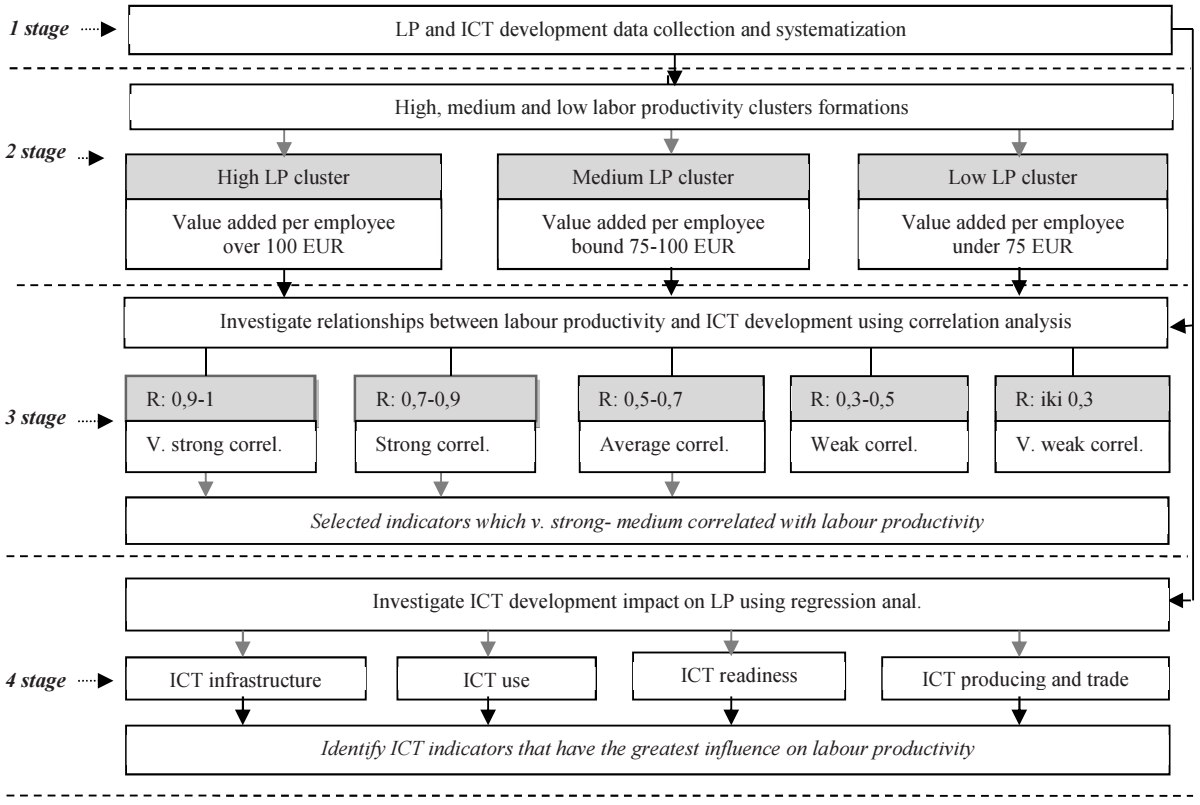

Fig. 3. Evaluation model for the impact of ICT development on labour productivity (prepared by authors)

In the first stage of the study, data on indicators of EU-27 reflecting labour productivity and ICT development in 2000–2011 are collected and structured for the analysis. The data is collected from databases and reports of ITU, World Bank, Eurostat, OECD.

In the second stage, EU-27 states are divided into three groups: countries of high, medium and low labour productivity. The goal of such division is to identify if single country groups can be attributed the same factors affecting labour productivity.

The third stage involves the correlation analysis to establish relations between EU-27 labour productivity and single ICT development indicators. The relation is measured with the correlation coefficient *R*. The coefficient reliability is verified by statistics of sample *t*, at the reliability level of 95 % *($\alpha = 0.05$)*. In the cases when *t* is biger than *t critical,* it can be stated that the derived R is reliable. The estimated $t_{crit} = 1.782$.

Having set out relations of EU-27 labour productivity with ICT development indicators and analysed them, in the cases when a very strong, strong and average positive relation is established, *the fourth stage* starts with calculations

of regression coefficients *b*. The estimated regression coefficient *b* shows an average change of labour productivity in a country when the indicator reflecting ICT development increases by one point. The estimate a shows the average value gained by the labour productivity indictor if such is not affected by the factor of ICT development. The adequacy of results of the regression analysis to a real situation is controlled by computing the *F* statistics and comparing it with the critical value, at the reliability level of 95% ($\alpha = 0.05$). When the estimated *F* value is bigger than *F critical* value, the statement that the results of the regression analysis are adequate to the real situation becomes possible. *F critical* = 4.9646. The Ceteris Paribus assumption is applied in the correlation and regression analyses.

4. Assessment of ICT impact on labour productivity

To assess the impact of ICT on labour productivity, as this was intended in the study model, the data of indicators reflecting labour productivity and ICT development within the analysed period 2000–2011 were first collected and structured. *In the second stage* EU-27 countries were divided into three clusters:

- High productivity countries cluster: Luxembourg, Ireland, Belgium, France, Austria, Sweden, Netherlands, Denmark, Finland, Italy, Spain, United Kingdom and Germany
- Medium productivity countries cluster: Greece, Malta, Cyprus, Hungary, Slovakia, Slovenia, and Portugal
- Low labour productivity countries cluster: Czech R., Estonia, Poland, Lithuania, Latvia, Romania and Bulgaria

In the third study stage, correlations of labour productivity with indicators reflecting ICT development in high, medium and low labour productivity EU countries are examined by means of the correlation analysis. After the analysis, there were selected EU countries with established and validated direct very strong, strong and average correlation of labour productivity and ICT indicators. The results are given in Table 2.

Table 2. Results of correlation between labour productivity and ICT development (prepared by authors)

ICT dev. Indic.	**Correlation with labour productivity**					
	Medium LP countries			*Low LP countries*		
	Very strong	Strong	Average	Very strong	Strong	Average
ICT infrastructure						
I-1	–	GRE	–	–	ROU	–
I-2	POR, HUN	SLO, SVK	CYP	BUL, CZE, EST, LAT, LTU	POL, ROU	–
I-3	–	CYP, POR	SLO	–	BUL, POL	LAT, LTU, ROU
ICT use						
U-1	SVK	POR, HUN	CYP, SLO	BUL, EST, LAT, LTU, POL	CZE, ROU	–
U-2	SVK, HUN	CYP, POR	SLO	BUL, EST, LAT, LTU, ROU	CZE, POL	–
U-3	POR	CYP, SVK, ESP	HUN	–	BUL, EST, LAT	POL, LTU
ICT readiness						
R-1	HUN	SVK, POR	ESP, CYP	POL, ROU	BUL, LAT, LTU	CZE, EST
R-2	–	SVK	–	EST	ROU	LAT
R-3	SVK, HUN	SLO, POR	ESP, CYP	LTU, POL, ROU	BUL, CZE	–
ICT production and trade						
PT-1	–	–	–	–	–	–
PT-2	SVK	HUN	SLO	BUL, LAT	LTU, ROU, CZE	POL
PT-3	SVK	HUN	SLO	ROU	CZE, LAT, LTU	BUL, EST, POL

As the received and structured results of the analysis show, very strong, strong or medium strong correlation was established almost among all ICT development indicators and labour productivity in all seven countries of low productivity. No direct correlation exists only among labour productivity and: Fixed telephone lines (except for Romania); Percentage of the ICT sector on GDP; International Internet bandwidth in Czech Republic and in Estonia;

Secondary gross enrolment ratio in Bulgaria, Czech Republic, Lithuania, Poland and Romania; School enrolment in Latvia and Estonia; ICT export in Estonia.

It should be considered that even though low productivity countries export comparatively small quantities of ICT production, ICT export scales significantly increased within the analysed period: in Bulgaria – 15 times, in Czech Republic – 18 times, in Latvia – 40 times, in Lithuania – 4 times, in Poland – 10 times, Romania – 9.5 times (estimated according to World bank data). Meanwhile, in Estonia with not verified correlation of ICT export with labour productivity, ICT export volumes increased by 2.5 only.

In the case of medium labour productivity countries, correlation of labour productivity with Percentage of the ICT sector on GDP was not absolutely verified. Very strong correlation of labour productivity with ICT export was established in Slovakia only, average – in Slovenia. Labour productivity and ICT import correlation was proved in Slovakia only, where import volumes within the analysed period increased by around 11 times (estimated according to World Bank data).

Medium labour productivity countries demonstrated correlation of labour productivity with ICT infrastructure, ICT use and ICT readiness in single cases only. Thus, *it cannot be stated that labour productivity is affected by the same factors in individual country groups.*

It should be noted that in the case of high labour productivity countries correlation of labour productivity with the indicators ICT use and ICT readiness was not proved. Correlations of labour productivity with the indicators ICT infrastructure and ICT production & trade were verified in the following cases only:

- Labour productivity – fixed telephone lines per 100 inhabitants: *strong correlation* in Belgium, Germany, France, Italy and Austria; *average correlation* in Denmark and Finland
- Labour productivity – Percentage of the ICT sector on GDP: *strong correlation* in Austria, Belgium, France and Italy; *average correlation* in Germany and Finland
- Labour productivity – ICT export: *strong correlation* in Germany; average correlation in Sweden
- Labour productivity – ICT import: average correlation in Sweden

Very strong correlation was established in no cases.

In the fourth stage, in the cases when very strong, strong and average correlation was established between labour productivity and ICT development, there was the regression analysis performed, and three key factors leading to changes in labour productivity were selected according to the gained value of the regression coefficient, considering also the determination coefficient, in cases of every single country. The results are given in Tables 3 and 4. Before analysing the data given in the tables, it should be noted first that the impact of ICT development on labour productivity was not observed Ireland, Luxemburg, Netherland, Sweden, United Kingdom and in Malta, as a country of medium productivity.

Table 3. Assessment of the impact of ICT on labour productivity in high productivity countries (measured and created by authors using ITU and World Bank dates)

Countries	***Indic.***	***b***	***Indic.***	***b***	***Indic.***	***b***	***Countries***	***Indic.***	***b***	***Indic.***	***b***	***Indic.***	***b***
Belgium	PT-1	7.34	I-1	1.49	–	–	Austria	PT-1	1.95	I-1	0.49	–	–
Denmark	I-1	0.09	–	–	–	–	Finland	PT-1	0.64	I-1	0.08	–	–
Germany	PT-2	5.95	PT-1	3.17	I-1	0.28	Spain	R-3	0.28	U-3	0.11	U-1	0.05
France	PT-1	3.48	I-1	1.85			Italy	PT-1	16.27	I-1	0.91	–	–

Among high productivity countries, all countries, except for Denmark and Spain, demonstrated labour productivity dependence on the percentage of the ICT sector and fixed telephone lines per 100 inhabitants. Within the analysed period, the percentage of the ICT sector on GDP reduced by 1.21 percentage points in Belgium, 0.58 in Germany, 1.11 in France, 0.81 in Italy, 2.1 in Austria (estimated according to the data of OECD). This resulted in the reduction of labour productivity in these countries.

Negative changes in productivity were also affected by the reduction of Fixed telephone lines per 100 inhabitants within the analysed period: in Belgium it reduced by 6.1 lines, in Germany – 2.1, in France – 3.6, in Italy – 18.2, in Austria – 11.2, in Finland – even by 31.8 lines (estimated according to ITU). The reduction of this indicator by 24.6

lines had a negative impact on changes in labour productivity in Denmark, too. Meanwhile, Spain, out of all ICT development indicators, is the most conditioned on the gross of school enrolment (tertiary) and the number of mobile broadband subscriptions. However, the impact is not significant. When the number of Internet users per 100 inhabitants increases by one unit, the added value per employee would increase in Spain by 5 euro cents on average, and by 11 Euro cents if Mobile broadband subscriptions per 100 inhabitants increase by one unit.

Table 4. Assessment of the impact of ICT on labour productivity in medium and low productivity countries

Countries	*Indic.*	*b*	*Indic.*	*b*	*Indic.*	*b*	*Countries*	*Indic.*	*b*	*Indic.*	*b*	*Indic.*	*b*
Medium productivity countries							*Low productivity countries*						
Greece	I-1	0.3	–	–	–	–	Bulgaria	U-2	0.59	R-3	0.57	U-3	0.29
Cyprus	U-2	0.44	R-3	0.2	U-1	0.19	Czech R.	U-2	0.41	R-3	0.24	U-1	0.15
Portugal	R-3	0.31	U-2	0.26	U-1	0.14	Estonia	U-3	2.14	U-2	0.87	U-1	0.47
Slovakia	U-2	1.42	R-3	0.8	U-3	0.71	Latvia	U-2	0.54	U-3	0.4	U-1	0.2
Slovenia	U-2	0.21	R-3	0.21	I-2	0.15	Lithuania	U-2	0.73	U-3	0.51	U-1	0.29
Hungary	U-2	0.48	R-3	0.35	U-3	0.27	Poland	U-2	0.52	R-3	0.49	U-3	0.24
							Romania	I-1	3.51	U-2	1.56	U-1	0.7

Source: measured and created by authors using ITU and World Bank dates

As the results of the regression analysis in the table show, so much as five countries out of six ones with medium productivity and all low productivity countries are affected by Fixed Broadband Internet Subscriptions. The difference is in its intensive only. If Fixed Broadband Internet Subscriptions increased buy one unit, the biggest growth of labour productivity would be observed in Slovakia (even 1.42 EUR), and the smallest one – in Slovenia (0.21 EUR). Cyprus, Portugal, Czech Republic, Estonia, Latvia, Lithuania and Romania are affected by Internet users per 100 inhabitants indicator. One unit increase in Internet users per 100 inhabitants would cause the biggest growth in Estonia (0.47 EUR), and the smallest – in Portugal (0.14 Eur).

If Mobile broadband subscriptions per 100 inhabitants add on one unit, labour productivity increases: in Slovakia (0.71 EUR), in Estonia (2.14 EUR), in Latvia (0.4 EUR), in Lithuania (0.51 EUR) and in Poland (0.24 EUR).

All medium labour productivity countries (except Greece) Bulgaria, Czech Republic and Poland are affected by the indicator of school enrolment (tertiary). If School enrolment gross increases by one percentage point, the biggest growth of labour productivity will most increase in Bulgaria (0.57 EUR) and least in Cyprus (0.20 EUR). In Greece, out of all twelve indicators of ICT development, only Fixed telephone lines per 100 inhabitants are affected (I-1). *Such conclusions are made assuming that other factors are constant.*

It is should be also noted that in low productivity countries and in three medium productivity countries (Slovakia, Slovenia and Hungary) labour productivity also depends on ICT export and import; however, the impact of these factors is so insignificant that they are not even included into the list of factors affecting labour productivity.

5. Conclusions

The impact of ICT on labour productivity reveals in a company, an industry and a country level. The development of ICT results in the increase of labour productivity both in the sector producing ICT and in the sector using ICT. ICT development provides a possibility to improve systems of company management processes, ensures a more efficient mechanism of market distribution, stimulates the development of network economy, influences social and cultural changes within a society, has a positive impact on SMB development perspectives, and builds foundation for development of ICT and other innovations, which, in turn, results in productivity growth of individual companies, as well as industries, and national or country groups.

The results of the retrospective studies of the impact of ICT development on labour productivity and economic growth of a country are controversial. They depend on research sample, period, country and its level (micro, mezzo and macro). Thus, it is not possible to generally state that ICT development is the main source of labour productivity increase, and it is necessary to perform a study using data of a particular country and a period of particular years.

The main indicators reflecting ICT development could be divided into 4 groups: 1) ICT infrastructures: Fixed telephone lines per 100 inhabitants, mobile cellular telephone subscriptions per 100 inhabitants, International

Internet bandwidth per internet users (bit/s); 2) ICT uses: Internet users per 100 inhabitants, Fixed Broadband Internet Subscriptions, Mobile broadband subscriptions per 100 inhabitants, 3) ICT readiness: Adult literacy rate (%), Secondary gross enrolment ratio, School enrolment, tertiary (% gross), 4) ICT production and trade indicators: Percentage of the ICT sector on GDP, ICT export, ICT import.

The analysis of labour productivity in all EU-27 countries, expressed by the added value per single employee, and correlation of indicators reflecting ICT development was performed using the correlation-regression analysis and helped establish that ICT development has no impact on labour productivity in Ireland, Luxembourg, Sweden, the United Kingdom and Malta.

In case of high labour productivity countries, correlation of labour productivity with ICT use and ICT readiness was not verified. Negative changes in labour productivity in high productivity countries mainly result from Percentage of the ICT sector on GDP and the reduction of ICT export.

Labour productivity of low and medium labour productivity countries is basically determined by two indicators of ICT use and, in some cases, by is Fixed telephone lines per 100 inhabitants (attributed to the indicator group ITC of infrastructure) and School enrolment, tertiary (% gross), falling into the group of ICT readiness indicators.

Acknowledgements

This work was partly supported by project "Promotion of Student Scientific Activities" (VP1-3.1-ŠMM-01-V-02-003) from the Research Council of Lithuania (Mačiulytė-Šniukienė, A., Gaile-Sarkane, E.). This project is funded by the Republic of Lithuania and European Social Fund under the 2007–2013 Human Resources Development Operational Programme's priority 3.

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