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Information-communication technology impact on labor productivity growth of EU developing countries[*,1]

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Abstract

The aim of this study is to investigate the ICT impact on labor productivity growth of EU developing countries. Empirical studies of the role of ICT as one of the main determinants of productivity growth, for developing countries have produced disagreement. To help clear up the subject, this paper employs a Generalized Method of Moments (GMM) through a dynamic panel data approach on the sample of 25 European developed and developing countries over the period of 2001-2010. The results indicate a positive and significant impact of ICT on labor productivity growth in developed and developing countries, but the terms of impact in developing countries rely on human capital, a contribution of a higher educational level, advanced research qualifications and development activity. Comparing to developed countries, the growth accounting approach indicate that developing countries have similar relative ICT contribution to labor productivity growth, but their average growth rate of labor productivity is 6.8 times higher. The main conclusion is that education, especially of higher levels, is the critical factor of productivity and growth of EU developing countries and that must be taken as development policy implication in these countries.

Key words: *ICT, labor productivity growth, EU, Generalized Method of Moments (GMM)*

JEL classification: *O47; O33; C23*

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1. Introduction

After Information Age period, investigation of ICT effects on economic growth and productivity has been the subject of many researchers, yet primary focused on the developed world. Until the late 1990's the results were contradictory. Some have even shown a negative contribution to productivity growth, often called the productivity paradox. Numerous later studies confirmed that ICT is one of the main factors of productivity growth in the developed countries.

A number of studies for developing countries is very limited and these studies mainly use the neoclassical growth accounting procedure, rarely econometric modeling. The research on developing countries is not only lagging behind the developed ones but has also obtained contradictory results.

The main motivation behind this research is to help clearing up this problem, i.e. the disagreement of ICT impact on productivity growth of developing countries. There are only few studies for the post-socialist countries. However, they use a different methodology and do not investigate the problem in EU development countries sample in post transitional period. Thus, the subject matter of our research is EU developing countries and investigation of the relationship between ICT and their productivity growth over the last decade. *The main hypothesis of the paper is that the investment growth effect of ICT on the productivity in EU developing countries is positive and significant.*

The aim of our study is to fill in the gap within the empirical literature of developing countries, especially post-social transitional countries, econometrically investigating the ICT capital impact on labor productivity growth. It will be used a panel data and a dynamic model. As traditional panel data estimation methods (fixed or random effect estimation) are inappropriate for the dynamic model, we employ the GMM method to get efficient estimates.

ICT is a general purpose technology and because of its nature it is an interesting subject in growth analysis. ICT can impact economic growth not only through ICT production and by ICT use, but also through spillover effects. This indirect productivity-stimulating effect is a consequence of the ICT role on enhancing diffusion of knowledge, business models improvements and rising investments in human capital. Hence, by analyzing our research problem it can be possible to provide an insight into how economic policy can contribute to the realization of the growth potential.

There are several important reasons for such an analysis. First, we will investigate the problem in the period mainly after transition which is realized within the neighborhood of developed EU countries. We expect that this conductive environment provides an acceleration of the innovation and technology diffusion.

Beside this, the transition was going on parallel with two processes. First includes the markets integration of capital, goods and labor through the globalization and EU membership. The second important process is ICT technological revolution. The question is whether these countries have benefited from ICT as developed ones. Did they succeed in spite of the pre-transitional problems of poor infrastructure, old and not suitable institutional structure, lack of regulations, scarce capital and lack of appropriate technological education?

The paper is organized as it follows. Section 2 summarizes the results of relevant literature. Section 3 gives the theoretical framework and introduces model specification. Section 4 describes statistical data, sources and variables. In Section 5, the empirical results of the growth accounting analysis and econometric panel data GMM estimation are presented and discussed. The last section brings the conclusions.

2. Literature review

The primary interest of the researchers from the past century's final decade has become endogenous growth theories and they are the reaction to the traditional neo-classical growth models, which propose that returns to the capital stock is diminishing. As an opposite, endogenous growth theories (Levine and Renelt, 1992; Easterly and Levine, 2001) models argue that various formations of capital human and physical (Sala-I-Martin, 1990; Lucas, 1988; Rebelo, 1991) and also other improvements like public infrastructure investments (Barro, 1991), research and development (Romer, 1990) lead to non decreasing returns. In other words, these factors can be the instruments for growth enhancement.

The technological revolution of 1990's brings new technologies of production and distribution and has important qualitative impacts on managerial methods. ICT becomes a new source of productivity growth acceleration. The impact of ICT on output growth and labor productivity growth has been subject of many researchers. Early macro level studies showed that ICT effect on labor productivity is very small (Oliner and Sichel, 1994; Jorgenson and Stiroh, 1995). Some have even show a negative contribution to productivity growth (Roach, 1986; Berndt and Morrison, 1995; Baily and Chacrabarti, 1988), implying on productivity paradox (Solow, 1987). From the late 1990's till the recent studies, a significant evidence of ICT impact on productivity of developed countries is confirmed for US, EU-15 and OECD on macro level (Jorgenson, 2001; Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000; Colecchia and Schreyer , 2001; van Ark et al., 2002; Jelava and Pohjola, 2002), on industry level (Stiroh, 2002; Timer et al., 2003), on firm level (Brynjolfsson and Hitt, 1996, 2000; OECD, 2004).

It is obvious that there are numerous studies of the ICT impact on economic growth in developed countries. These investigations are based on a "growth accounting" technique of measuring the contribution of ICT to output growth (or productivity), decomposing output growth into the income weighted rise of factors input.

The number of research related to developing countries is very limited. The reasons are the problem of availability and quality of data and relatively low level of investments in ICT and human capital. Kraemer and Dedric (2001), Dewan and Kraemer (2000) and Pohjola (2001), using sample of more than 36 countries over the world, concluded that a highly positive and significant relationship exists between ICT and economic growth in developed countries, but there is no evidence of such relationship in developing countries. Dewan and Kraemer (2000) assume that the reason for these opposite results is in low levels of IT investment in developing countries and in the lack of knowledge-based structures for using IT goods. Dimelis and Papaioannou (2010) examined joint impact of ICT and foreign direct investments on productivity growth using panel of developed and developing countries in the period 1993-2001. The results confirmed that the joint effect of ICT and foreign direct investments on growth is positive and significant in all groups of world sample countries.

There are only few studies that investigate the ICT impact on output growth and productivity in post-socialist transition economies. Piatkowski (2003) investigated this matter for Polland over 1995-2000, and for eight transition economies of Central and Eastern European (CEE) over 1995-2001. He found that the impact of ICT on growth in the new five EU members was higher than the average for the EU-15, but it was not the case for other developing countries in the sample. Van Arc and Piatkowski (2004) found that ICT capital in CEE-10 has contributed as much to labor productivity growth as in the EU-15. All these research results are based on growth accounting approach. Econometric approach used by Kandžija et al. (2009) on the sample of 25 European developed and transitional countries. Econometric regression analysis is based on cross-country average annual growth rates data over the period 2000-2006. The ICT effects are not measured through ICT investments, but by ICT opportunity index (ICT-OI). Because of small cross-country data samples ICT impact for transition countries is estimated by included dummy variable.

3. Model specification and methodology

The impact of ICT on productivity growth can be analyzed by growth accounting approach and by econometric approach. We employ growth accounting model to get a comparative level of contribution to growth between developed and developing countries. It is a descriptive method with strong restrictive assumptions as perfect competition, constant returns to scale etc. Because of these less flexible characteristics, the main part of our research will be econometric approach. Econometric method explains and verify by testing the relation between ICT investments and productivity growth. The usual problems related with this approach are endogeneity and unobserved heterogeneity, but they will be overcome applying a GMM estimator.

3.1. Growth accounting contribution of information-communication technology

The general framework of growth model with the impact of ICT is expressed with ICT capital influence Y^{ICT} and other factors influence Y^{N} on gross output Y and can be presented:

$$Y_{it} = F(Y_{it}^{ICT}, Y_{it}^{N}) \quad , \tag{1}$$

where i=1,..N denotes cross-section units, t=1,…T denotes time dimension.

Assuming generalized form of Cobb-Douglas production function, gross output Y is expressed as dependent on ICT capital, other physical capital (K) and labor force (L):

$$Y_{it} = A_{it} K_{it}^{\alpha} ICT_{it}^{\beta} L_{it}^{\gamma} \quad , \tag{2}$$

where *A* denotes parameter which capture disembodied technological shifts over time. The parameters α, β and γ are the variables elasticity. A log-linear form of the function is:

$$y_{it} = a_{it} + \alpha \cdot k_{it} + \beta \cdot ict_{it} + \gamma \cdot l_{it} \quad , \tag{3}$$

The lower case letters indicate that a variable has been transformed into natural logarithms.

With the assumption of constant return to scale, the growth rate of output can be written as:

$$\dot{y}_{it} = \dot{a}_{it} + \alpha \cdot \dot{k}_{it} + \beta \cdot \dot{ict}_{it} + (1 - \alpha - \beta) \cdot \dot{l}_{it} \quad , \tag{4}$$

The dots above letters denote variables in logarithmic differences, $\dot{a}_{it}$ denotes the total factor productivity (TFP) growth rate and other terms are growth rates of the inputs (capital, ICT capital and labor). The parameters of variables (α, β, (1– α – β)) denote the average shares in total factor income. The equation denotes the output growth decomposition to TFP growth and weighted average of capital, ICT capital and labor growth.

Rearranging equation (4), the results can be presented in terms of average labor productivity growth defined as yl=Y/L, the ratio of output to persons employed, kl=K/L and ictl=ICT/L, the ratio of capital and ICT capital to the person employed:

$$\dot{y}l_{it} = \dot{a}_{it} + \alpha \cdot \dot{k}l_{it} + \beta \cdot i\dot{c}tl_{it} \qquad (5)$$

The term $\beta \cdot i\dot{c}tl_{it}$ represents the contribution of ICT capital deepening to labor productivity growth.

3.2. Econometric modeling and methodology

We start with the Cobb Douglas production function (2) assuming constant return to scale. Output per worker can be expressed in a log-linear form:

$$\ln YL_{it} = \ln A_{it} + \alpha \ln KL_{it} + \beta \ln ICT_{it} + u_{it} \qquad (6)$$

The symbols of variables include L denoting that the data are per worker.

We can get the growth equation writing log-linear function (2) in first differences:

$$lnYL_{it} - lnYL_{it-1} = c + (lnA_{it} - lnA_{it-1}) + \alpha(lnKL_{it} - lnKL_{it-1}) + \\ + \beta(lnICTL_{it} - lnICTL_{it-1}) + (u_{it} - u_{it-1}) \qquad (7)$$

Other variables are introduced in accordance with the growth literature and research. First one is the lagged output per worker, because the current period growth would depend on its values in the past and the negative impact is expected, lower for developed countries because of their lower growth rate (they are closer to the steady state of development). The human capital is also included because it is important for technology innovation and adoption. The positive influence of human capital on economic growth is established by many empirical studies. Human capital influences the growth through a country's ability to innovate (Romer, 1990; Nelson and Phelps, 1966) and to catch-up with more advanced countries (Nelson and Phelps, 1966). Educational attainment is used as a proxy for human capital. The tertiary school enrollment rate is used to measure reflects of advanced research qualifications and development activity, and it is important in absorption of new technologies. This variable can better capture high-level skills or knowledge associated with human capital than other ones. The other are control variables, like unemployment rate as a correction factor in a model to capture business cycle effects (Baltagi and Pinnoi, 1995), then openness of countries to international trade which is the channel for technology transfer and government spending as a share of GDP which is a proxy for the degree of public interference.

Specifically for panel data structure, the model specification comprises the unobserved factors affecting the depending variable. Consequently, the error term u_{it} is specified:

$$u_{it} = v_i + \varepsilon_{it},$$

Where v_i is an unobserved time invariant country effect and ε_{it} is the error term assumed to be independently distributed. The model is augmented involving lagged dependent variable to capture convergence effect among countries. The inclusion of lagged endogenous variable as explanatory means that we now have a dynamic panel data model and traditional panel data estimation method; fixed or random effect estimator is not suitable. There is endogeneity problem that has to be resolved by getting unbiased and consistent estimation which is overcome by using the Arellano-Bond, 1991) Generalized Method of Moments (GMM) estimator. GMM estimating of dynamic model is also proposed as more appropriate for the panel with relatively small time dimension compared to the number of cross sections (Roodman, 2006). This method converts the model to first differences:

$$\Delta(\ln YL_{it} - \ln YL_{it-1}) = \delta_0(\ln YL_{it-1} - \ln YL_{it-2}) + \delta'(X_{it} - X_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1}). \quad (8)$$

X_{it} denotes the vector of explanatory variables included as well as all control variables, except the lagged output per worker. δ is the vector of the corresponding parameters. Differencing eliminates the country specific effect, yet a new bias is introduced by the new error term ($\varepsilon_{it} - \varepsilon_{it-1}$) which is correlated with the lagged dependent variable ($\ln YL_{it} - \ln YL_{it-1}$). To resolve the problem, some moment conditions have to be fulfilled and it can be realized concerning the validity of instruments used in estimation. There are two specification tests to be used in GMM estimation: test for the absence of first and second order serial correlation in the first differenced residuals and Sargan test of overidentifying restrictions under the null hypothesis of the validity of instruments. In this paper we use two-step GMM estimator which is considered more efficient than one-step variant, because a standard errors bias resolves through two steps by a correction with covariance weighting matrix.

4. Data and variables

The analysis is based on a panel of 25 European countries over the period of 2001-2010.The research sample includes 24 EU members and Croatia[3], containing

[3] After performing the structural changes and implementing reforms, Croatia has finished accession negotiations in June 2011 and signed the Treaty of Accession to become the EU member in 2013.

14 developed countries and 11 developing countries. UNECE database are mainly used as the source, especially for GDP, number of workers, unemployment, gross fixed capital formation and openness of the country.

The capital stock data are estimated using the perpetual inventory method which generates an estimate by accumulating past purchases of assets over their estimated service lives:

$$K_t = I_t + (1-\delta)\cdot K_{t-1}, \tag{9}$$

where K is the capital stock, I is the value of gross fixed capital formation in constant prices and δ is a depreciation rate. It is assumed δ to be 10% as an attempt to capture the diversity of assets and to be constant across countries and time. The initial value of capital stock will be estimated by linear regression of the log of investment against time applying Nehru Dhareshwar method (1993:43). The fitted value of the initial investment level in the first period $\hat{I}_1$ and a g growth rate of investment over the sample period gives the initial value of capital stock K_0:

$$K_0 = \hat{I}_1 /(g+\delta)\cdot \tag{10}$$

ICT spending gives an indication to the magnitude of information technology adoption. The source is Digital Planet Report (2010) issued by World Information Technology Services Alliance (WITSA), a consortium of world information industry representatives. ICT spending on computer hardware, software, services and communication are expressed annually as a percent of GDP.

The European countries do not exhibit many variations on first and second level of education. Gross enrollment ratio of primary, secondary and tertiary education was included initially as a proxy for educational human capital, but the parameter of variable has unexpected sign in the group of all countries and developed ones. These are the reasons for replacing the variable with tertiary education. The source of the data is Human development indicators.

The government consumption is expressed as a percentage of GDP. It includes all government current expenditure for purchases of goods and services. The variable is a proxy for the degree of public interference. The source is Eurostat database.

Trade openness is measured as the sum of exports and imports as a percentage of GDP. The variable is a proxy for globalization, reflecting technology transfer from developed to developing countries. The source is UNECE database.

Table 1: Correlation matrix of the model variables

Variable	GYL(-1)	GKL	GWICTL	GHCT	GUL	OPEN	GOV
GYL(-1)	1.0000	0.5968	0.3236	0.1014	-0.3834	0.1657	-0.5171
GKL	0.5968	1.0000	0.4092	-0.0682	-0.4586	0.0414	-0.5173
GWICTL	0.3236	0.4092	1.0000	-0.0176	-0.3035	0.0966	-0.3121
GHCT	0.1014	-0.0682	-0.0176	1.0000	0.0783	-0.0079	-0.1003
GUL	-0.3834	-0.4586	-0.3035	0.0783	1.0000	-0.0456	0.2809
OPEN	0.1657	0.0414	0.0966	-0.0079	-0.0456	1.0000	-0.1894
GOV	-0.5171	-0.5173	-0.3121	-0.1003	0.2809	-0.1894	1.0000

Notes: The acronyms GYL, GKL, GWICTL, GHCT, GUL, OPEN, GOV denotes: output growth per worker, growth of fixed capital per worker, growth of ICT investment per worker, growth of tertiary gross enrollment rate, growth rate of unemployment per worker, a country openness, the government consumption as a percent of GDP.

Source: Author's calculation

From the correlation matrix of all variables used in the research (Table 1) we can assume the absence of serious multicolinearity. In Table 2 a descriptive statistics for the variables and groups of countries are presented. Developing countries exhibit higher growth rates for GDP per worker, fixed capital and ICT investments per worker. Significant higher are growth rates for GDP per worker and fixed capital per worker.

Table 2: Descriptive statistics of the model variables

Variable	Entire panel		Developed countries		Developing countries	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
GYL	0.0197	0.0276	0.0048	0.0264	0.0334	0.0517
GKL	0.0216	0.0433	-0.0005	0.0205	0.0498	0.0481
GWICTL	0.0218	0.0614	0.0041	0.0455	0.0445	0.0712
GHCT	0.0288	0.0571	0.0264	0.0361	0.0319	0.0760
GUL	0.0169	0.1815	0.0325	0.1423	-0.0030	0.2207
OPEN	100.38	36.26	87.99	36.41	116.15	29.42
GOV	44.40	6.66	47.46	5.98	40.49	5.311

Notes: The acronyms GYL, GKL, GWICTL, GHCT, GUL, OPEN, GOV denotes: output growth per worker, growth of fixed capital per worker, growth of ICT investment per worker, growth of tertiary gross enrollment rate, growth rate of unemployment per worker, a country openness, the government consumption as a percent of GDP.

Source: Author's calculation

5. Empirical results and discussion

5.1. Growth accounting results

Relation (5) represents a decomposition of labor productivity growth to the total factor productivity (TFP) growth and the contribution of capital and ICT capital deepening.

Input shares of capital (α) and ICT capital deepening (β) are calculated applying econometric method (Senhadji, 2000). We used fixed effect panel data estimator to estimate log– linear form of Cobb Douglas production function (6) with constant return to scale, for entire group of 25 countries and period 2001-2010. (Appendix). The contribution of ICT capital deepening to labor productivity growth is calculated as a product of estimated input share ($\hat{\beta}$ =0.14) and a real average growth rate of ICT per worker for each country. The results are presented in Table 3.

Developed countries exhibit a significant lower average growth rate of labor productivity (0.5%) in comparison to developing countries (3.3%). Relative ICT capital share in labor productivity growth in both groups of countries is similar, 19 and 20 %. On the one hand, capital accumulation has the highest contribution to labor productivity in developing countries, probably as a result of FDI increase after becoming the EU members. On the other hand, the highest contribution to labor productivity in developed countries relies on TFP.

Among developing countries, the highest ICT contribution has Romania, nearly twice higher than average. Slovakia and Lithuania have ICT contributions over average. If the focus is placed on Croatia as the only country in the group which is not an EU member, it becomes evident that there are no significant differences in results comparing to other in the developing group of countries EU members, except for TFP absolute contribution to labor productivity growth which has lower significance and is the only one marked as negative. Capital contribution is higher than average and ICT contribution is on the developing countries' group average.

Figure 1 shows the relation between GDP per person employed and absolute ICT contribution to labor productivity growth. Average GDP per person employed for the period 2001-2010 is calculated for each country and expressed as percentage of developed countries average to get a country comparative level contribution to labor productivity growth. The average absolute contribution of ICT differs between the groups of countries, 0.1 for developed and 0.64 for developing countries. However, although both groups of countries have similar relative average share of ICT capital contribution to the labor productivity growth, it is essential to point out that the average labor productivity growth rate of developing countries is 6.8 times higher than in the developed ones. Thus, it can be concluded that ICT capital deepening is still a source of developing countries' growth and convergence to the developed countries levels.

Table 3: Production factors' contribution to labor productivity growth in European countries, 2001-2010, growth accounting results

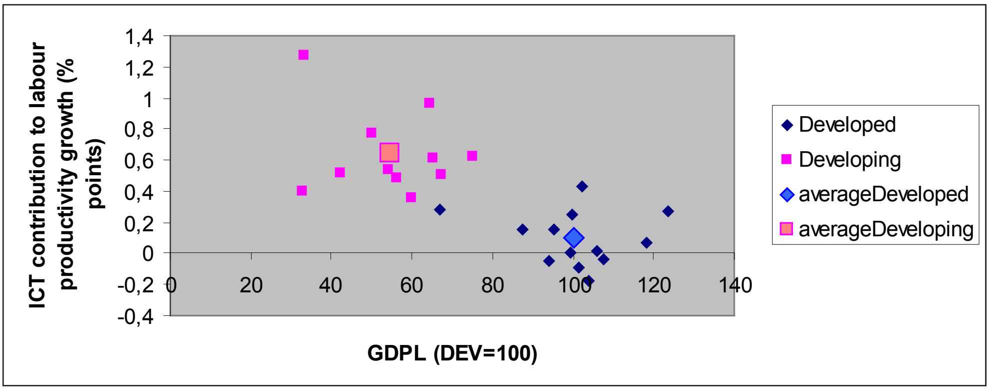
Country	Average growth rates	Absolute factors' share % - point contribution		
	GYL%	K%	ICT%	TFP%
Developed:				
Austria	0.37	-0.12	-0.03	0.52
Belgium	0.50	0.08	0.07	0.35
Denmark	0.30	0.43	0.16	-0.29
Finland	1.46	0.47	0.10	0.88
France	0.21	0.36	0.01	-0.15
Germany	0.44	0.82	0.01	-0.39
Greece	1.33	-0.31	0.15	1.49
Ireland	0.46	-0.78	0.27	0.97
Italy	-0.39	0.76	-0.09	-1.06
Netherland	0.50	-0.44	-0.18	1.11
Portugal	0.01	-0.47	0.28	0.20
Spain	-0.39	-0.16	-0.05	-0.19
Sweden	1.16	0.50	0.25	0.41
UK	0.95	0.02	0.43	0.50
Developing:				
Bulgaria	4.10	3.36	0.39	0.34
Czech	3.10	0.38	0.51	2.21
Estonia	2.84	1.39	0.54	0.91
Hungary	1.63	-0.08	0.36	1.35
Latvia	3.01	2.33	0.52	0.15
Lithuania	4.48	2.21	0.78	1.50
Poland	3.30	0.61	0.49	2.20
Romania	5.38	3.72	1.27	0.39
Slovakia	4.14	1.17	0.96	2.02
Slovenia	1.95	0.97	0.62	0.37
Croatia	2.84	2.48	0.61	-0.25
Developed	0.49	0.08	0.10	0.31
Developing	3.34	1.69	0.64	1.02
		Relative factors' share % - point contribution		
Developed	100.00	16.92	20.07	63.01
Developing	100.00	50.42	19.16	30.42

Notes: The factors' input shares are estimated by fixed effect panel data estimator; for capital is 0.33. for ICT capital is 0.14 (estimated results in Appendix). The acronyms GYL, K, ICT, TFP denotes: output growth per worker, capital, ICT capital, total factor productivity.

Source: Author's calculation

We can compare these obtained results with a similar study of Van Ark and Piatkowski conducted for CEE-7 and EU-14 for an earlier period, i.e. 1995-2001. For developing countries their results are very close: ICT capital intensity contribution is 0.6 % and average labor productivity growth is 3.5%. For developed countries their results are higher: ICT capital intensity contribution is 0.4 % and average productivity growth is 1.1%. Comparing the average absolute contribution of ICT, the results do not significantly differ in 1995-2001 between developed and developing countries, but in period 2001-2010 the absolute contribution is significantly higher in developing countries. Previously, the relative contribution was higher in favor of developed countries, but in period 2001-2010 is similar.

Figure 1: ICT capitals' contribution to labor productivity growth versus average GDP per person employed (developed=100), 2001-2010



Source: Table 3

European developing countries mainly passed the transitional period during the 1990s and it has brought a lot of changes. The process of restructuring was followed by the rise of capital intensity especially in ICT investment and rapid build up of the capital stock because in former socialist system, imports of high technology products was under the restrictions for the member countries of the Warsaw military pact. Productivity growth has been supported not only by capital intensity rise and technical change, but also with structural changes: large scale privatization instead of state-owned inefficient firms resulting in higher capacity utilization, the problem which was a phenomenon of centrally planned economy, then technology transfer, organizational and business skills improvements and increase in human capital. These changes surely contributed to significant increase in total factor productivity and labor productivity during transitional period.

5.2. Panel unit roots and cointegration analysis

Recent empirical procedure suggests preliminary testing of data series which will be used in econometric modeling. These are unit roots and cointegration test. The aim is to determine if variables data series used in research are trend stationary and if exists a relation of cointegration among them. The unit root tests are important because nonstationary variables may invalidate the assumptions of regression analysis. If a unit root exists, the usual way of removing non-stationary is by taking first differences of the relevant variable. There are various types of panel unit root test like Levin et al., 2002; Fisher ADF and PP test (Maddala and Wu, 1999; Hadri, 2000) etc. The cointegration tests determine whether a group of nonstationary data series is cointegrated, i.e. whether there is a long-run equilibrium relationship among them. There are few tests: Maddala and Wu, 1999; Pedroni, 1999; Kao 1999). The testing results are presented in Table 4. and Table 5.

Table 4: Unit root test results

Variable	Levin, Lin and Chu	ADF-Fisher chi square	PP-Fisher chi square
GYL	-6.5850	110.553	166.396
GKL	-5.2047	86.6788	95.1325
GWICTL	-7.4810	111.923	196.858
GHCT	-4.1198	70.8184	168.217
GUL	-10.5828	159.123	146.766
OPEN	-8.7207	118.389	269.506
GOV	-6.5339	156.270	204.806

Notes: Panel unit test assume the null hypothesis of non-stationary.

Models used include no intercept and no trend. The results are significant at 5% level.

Source: Author's calculation

Table 5: Kao cointegration tests results

Null	Statistic	Rho	Prob.	t-statistic	Prob.
No cointegration	DF	-6.4297	0.0000	-5.3746	0.0000
	DF*	-5.6081	0.0000	-5.1063	0.0000

Source: Author's calculation

The conclusion is that variables satisfied tested assumptions. This means that the model variables can be used to estimate the sources of labor productivity growth and gains to the long-run.

5.3. Econometric results

The estimations are performed using a balance panel of 25 European countries for the period 2001-2010. Separable estimations are also obtained for the groups of developed and transitional countries. The Wald test is applied to examine whether there is any significant difference between the coefficients for the two groups. There was the problem of applying Chow test in testing for parameter stability of regression because the equality of the residual variances assumption in two subsamples is not fulfilled. It was the reason that the Wald statistics for structural change with unequal subsample variance has to be performed.

Under the assumption that the parameter estimates b_i in subsample i are independent normal random variables, the difference b_1-b_2 has mean zero and the variance V_1-V_2, and the Wald statistics for the null hypothesis of no structural change and independent sample is:

$$W = (b_1 - b_2)'(V_1 + V_2)^{-1}(b_1 - b_2), \tag{11}$$

where b_i is parameter estimate in subsample i, for $i=1,2$, V_i are their covariance matrix in subsample i.

It has an asymptotic χ^2 distribution with the degrees of freedom equal to the number of estimated parameters in the vector b. To carry out this test the simple program in EViews is used (EViews6, 2007:176). The result indicates significant differences between the regression coefficients for the developed and transition countries.

The estimates are presented in Table 6. The variables are: output growth per worker (GYL) as a dependent variable, and as explanatory variables, we have lagged a dependent variable (GYL (-1)), a growth of fixed capital per worker (GKL), a growth of ICT investment per worker (GWICTL), a growth rate of unemployment per worker (GUL) , a growth of tertiary gross enrollment rate (GHCT), a country openness (OPEN), the government consumption as a percentage of GDP(GOV).

The consistency of GMM estimator was examined by two specification tests as Arellano-Bond (1991) proposed. In particular, the validity of instruments was examined by Sargan test. The second is testing the absence of second order serial correlation in the error terms. The Sargan test of validity of the instruments is asymptotically distributed as chi-squared, and it tests the hypothesis of the over-identifying instruments. The p values (the probability of incorrectly rejecting the null hypothesis) indicate whether the instruments used are independent of the error term and therefore suitable as instruments.

Table 6: Estimation results for labor productivity growth using Dynamic Panel Method and GMM estimator

Explanatory variable	Developed countries	Developing countries	Entire panel
GYL(-1)	-0.5222 (-12.79)	-0.3570 (-6.36)	-0.3669 (-7.28)
GKL	0.5346 (6.78)	0.6332 (9.09)	0.6199 (8.69)
GWICTL	0.0406 (2.47)	0.0694 (2.41)	0.0272* (1.17)
GUL	-0.0664 (-5.59)	-0.0702 (-5.10)	-0.0781 (-6.08)
GHCT	-0.0406* (-1.65)	0.2146 (4.14)	0.0263* (0.50)
OPEN	0.0010 (4.88)	0.0009 (4.34)	0.0010 (4.61)
GOV	-0.0021 (-7.01)	-0.0052 (-4.17)	-0.0036 (-4.37)
Observations:	140	110	240
Wald test:	484.89	474.34	495.71
Sargan test (p-value):	0.57	0.45	0.02
Arellano Bond test (p-value):	0.14	0.41	0.38

Notes: Numbers in parentheses are t-statistics. * $p > 0.10$

Source: Author's estimation

The test for the absence of second order serial correlation in the residuals can be carried out based on the standardized average residual autocovariances which are asymptotically N (0,1) variables, with the hypothesis that second-order autocovariances are zero. The p values are the probability of incorrectly rejecting the null hypothesis of lack of second order serial correlation in the errors. The Wald test is used for testing significance of estimated model. The results of these tests give the support for the credibility of estimated model and its implications.

All variables have signs that are consistent with theory predictions. They are significant at least on 5 % level except the variable GHCT and GWICT which are insignificant in entire group of countries and GHCT in developed one. As expected, the impact of lagged output per worker is significantly negative and the capital per worker is significant contributor to labor productivity growth. There are three control variables used in the model, OPEN, GOV and GUL. All of them are statistically significant and have estimated signs. The estimated coefficient of openness is strongly significant in all three samples and confirms other previous similar empirical evidence of the degree of openness to international trade as positive indicator of country's labor productivity. Owing to the fact that an increase in government consumption results in increasing amount of taxation, the negative impact on labor productivity is confirmed in estimated results. The government consumption variable has a negative and statistically significant effect on labor productivity growth and this impact is stronger in developing countries. Growth rate of unemployment has a negative impact on labor productivity and thus, the existing problem of the increasing unemployment in Europe was expected to be significant in the model.

Table 7: Estimation results for labor productivity growth using Dynamic Panel Method and GMM estimator

Explanatory variable	Developed countries	Developing countries	Entire panel
GYL(-1)	-0.5236 (-12.11)	-0.3939 (-7.65)	-0.3601 (-7.26)
GKL	0.5578 (7.18)	0.6567 (9.98)	0.6236 (8.57)
GWICTL	0.0414 (2.54)	0.0246* (0.89)	0.0307* (1.30)
GUL	-0.0648 (-5.46)	-0.0736 (-5.61)	-0.0790 (-6.09)
OPEN	0.0010 (5.16)	0.0010 (4.43)	0.0010 (4.49)
GOV	-0.0021 (-6.61)	-0.0055 (-5.06)	-0.0035 (-4.49)
Observations:	140	110	240
Wald test:	464.25	544.90	482.87
Sargan test (p-value):	0.55	0.28	0.03
Arellano Bond test (p-value):	0.15	0.82	0.41

Notes: Numbers in parentheses are t-statistics. * $p > 0.10$

Source: Author's estimation

The model is estimated once more without variable GHCT which has been insignificant for the group of all countries and developed one. The estimation results are presented in Table 7 and there is no substantial difference between the former results for the group of developed countries and the whole group. In the group of developing countries we have some important findings. The coefficient of GWICT is lower and it is not significant. These estimation results indicate that ICT have a significant impact on labor productivity growth in developed group of countries, but the terms of impact in transitional countries, rely on the inclusion of the variable GHCT. This provides support for the thesis that higher education has important role in facilitating technology transfer (Nelson-Phelps, 1966). The results are also the important evidence that ICT technology has finally yielded positive results on transition economies after a decade of ICT investment. This finding opposes results of Dewan and Kraemer (2000) that mainly developed countries have benefited from ICT. We have over 10 years gap in estimation data period and probably the commitment of the EU institution for a dynamic environment and interventions to stimulate productivity created in a common digital platform (i-2010) have resulted in positive achievements. Because of its nature as general purpose technology, substantial gains can be achieved only with additional infrastructure and organizational investment, lower equipment costs and all that have to be accompanied with adequate level of human capital.

6. Information-communication technology and the economic crisis

The international financial crisis of 2008-2009 generated economic slowdown, fall in production, trade, investment and employment. In 2020 strategy, the European Commission defines reinforcing priorities to come out stronger from the crisis in sustainable economy with high levels of employment, productivity and social cohesion. One of the three priorities is reinforcing innovative capabilities, improving education and exploiting the economic and social benefits of a digital society. ICT continues to be a main driver of productivity improvements. The benefits for European countries would be in increasing investments in ICT and changes that would improve the use of ICT.

The European Commission Digital Agenda analyses the performance of ICT sector in Europe during the economic crisis. Recent innovation wave of ICT industry appeared parallel with economic crisis. The new applications include smart phones, social networks, e-readers, apps stores and cloud computing. The benefits of them and growth prospects of EU developing countries in recovering uncertainties conditions would be the guidelines for a further research.

In the future, as more data will become available, it would be interesting to investigate a longer time dimension and also to compare the estimated results for EU countries to other developing countries.

7. Conclusion

The research hypothesis can be accepted but needs to include an additional condition, which is a necessity of a higher level of human capital for a significant ICT impact on labor productivity growth of EU developing countries. The ICT influence is analyzed by two different approaches in this paper.

The main results are obtained by econometric modeling. They indicate that ICT have a positive and significant effect on labor productivity growth in developed and developing group of countries, but the terms of impact in developing countries rely on the inclusion of the human capital proxy variable. It means that for rising up a labor productivity growth through the ICT, the higher level of educated workforce is required. The important implication of these results is related to the endogenous growth theories role of human capital, which can affect productivity growth through the ability of adoption the new technology and the ability of domestic innovation. Both factors involve direct and indirect productivity-stimulating effect of ICT. The panel cointegration techniques were applied and it is identified that estimated model can explain the sources of labor productivity growth and gains to the long-run.

The other approach, a growth accounting analysis is used to compare the ICT capital contribution to labor productivity growth in EU developed and developing countries. The obtained results indicate that ICT relative contribution to labor productivity growth in developing countries is positive and similar to developed countries, but we have to emphasize that the average growth rate of developing countries was nearly 7 times higher than in developed countries.

The study results provide important contribution on this topic in developing countries. We have identified the high education as the key factor for the realization of ICT potential for enhances labor productivity growth. Most of previous studies have been concerned by developed economies. This paper is focused to the post-socialist EU developing countries which have not been yet studied through the econometric method, a GMM dynamic panel data estimation which we have used in this research. Other important finding of the paper can be identified. The election of tertiary school enrollment rate as the human capital proxy variable was essential for the obtained results. In empirical literature, usually is employed secondary school enrolment rate or expenditure on education.

The limitation of the study may be addressed to the panel data sample size. Yet, the number of countries is defined by the membership of EU. Moreover, we are not able to use a long time series of data because it is not consistently available for developing countries for a relatively new technology as the ICT is. Beside this, ICT as general purpose technology needs a long time to yield relevant productivity gains, particularly in the ICT using sectors. Despite these facts, the obtained results are important, because as far as we know, this is the first research on EU developing countries with GMM dynamic panel data method. The estimation yields the efficient results.

The obtained results have some important implications on the economic policy for developing countries. Education is one of the most critical factors that policy makers have to consider to achieve positive spillovers on productivity and growth. The suggestion is introducing IT technology in early age in schools, complementary training programs, skill development. It is important enhancing the third level of education and domestic innovation which requires stronger national institutions' policies for competition and innovation.

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Utjecaj informacijsko-komunikacijske tehnologije na rast produktivnosti rada zemalja u razvoju Europske unije[1]

Ljiljana Lovrić[2]

Sažetak

Cilj istraživanja je utvrditi utjecaj informacijsko komunikacijske tehnologije (ICT) na rast produktivnosti rada zemalja u razvoju Europske Unije. U empirijskim istraživanjima ICT, kao jedne od glavnih odrednica rasta produktivnosti, postoje neslaganja kad se radi o zemljama u razvoju. Kako bi se pridonijelo razjašnjenju problema, u radu je primijenjena generalizirana metoda momenata (GMM) i dinamički pristup pomoću panel podataka na uzorku od 25 europskih razvijenih zemalja i zemalja u razvoju kroz razdoblje od 2001.-2010. Rezultati prikazuju pozitivan i signifikantan utjecaj ICT na rast produktivnosti rada u razvijenim zemljama i zemljama u razvoju, ali utjecaj u zemljama u razvoju je uvjetovan ljudskim kapitalom i to visoke razine obrazovanja, naprednih istraživačkih kvalifikacija i razvojnih aktivnosti. U usporedbi s razvijenim zemljama, rezultati dobiveni metodom računanja rasta (growth accounting method), zemlje u razvoju pokazuju sličan ICT prinos rastu produktivnosti rada, ali uz 6.8 puta veću prosječnu stopu rasta produktivnosti. Iz provedenog istraživanja izvodi se zaključak da je obrazovanje, posebno visokog stupnja, kritični čimbenik produktivnosti i rasta europskih zemalja u razvoju i to se mora uzeti u obzir kod kreiranja razvojnih politika u tim zemljama.

Ključne riječi: *ICT, rast produktivnosti rada, EU, GMM*

JEL klasifikacija: *O47; O33; C23*

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Appendix

Table 1: Estimation of production factors' input shares

Dependent Variable: GYL				
Method: Panel EGLS (Period SUR)				
Date: 08/06/12 Time: 11:06				
Sample: 2001 2010				
Periods included: 10				
Cross-sections included: 25				
Total panel (balanced) observations: 250				
Linear estimation after one-step weighting matrix				
White period standard errors & covariance (d.f. corrected)				
	Coefficient	Std. Error	t-Statistic	Prob.
C	0.008568	0.001567	5.469170	0.0000
GKL	0.325220	0.023211	14.01147	0.0000
GWICTL	0.140518	0.012901	10.89179	0.0000
	Effects Specification			
Period fixed (dummy variables)				
	Weighted Statistics			
R-squared	0.701212	Mean dependent var		0.859055
Adjusted R-squared	0.687403	S.D. dependent var		1.905841
S.E. of regression	0.992452	Sum squared resid		234.4208
F-statistic	50.77743	Durbin-Watson stat		1.793988
Prob(F-statistic)	0.000000			
	Unweighted Statistics			
R-squared	0.999901	Mean dependent var		0.019725
Sum squared resid	0.077800	Durbin-Watson stat		1.290989

Notes: The acronyms GYL, GKL, GWICTL denotes: output growth per worker, growth of fixed capital per worker, growth of ICT investment per worker.

Source: Author's estimation