# Kako IKT utječe na ljudski razvoj? Dokaz zemalja u razvoju naspram razvijenih zemalja

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# How does the ICT affect human development? Evidence from developing vs. developed countries*

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***Abstract***

*This study aims to assess the impact of information and communication technology (ICT) on human development (measured with the human development index – HDI). The authors have analyzed the countries with different development levels in order to identify the possible differences in these impacts when observing the level of income (development of the country). The paper uses a static panel data regression analysis, while a fixed-effects estimator (FE) is used for estimation. To address the possible endogeneity problem caused by reverse causality, we also perform a dynamic panel data regression using the Generalized Methods of Moments (GMM) estimator. The results support our hypothesis and show that ICT use and tertiary education positively affect human development, although the results vary by estimator. While in the case of the FE estimator, the effects are significant and positive across all observed countries, the results with the GMM estimators show a significant impact of ICT only in the case of upper-middle-income countries. However, it also implies that the lagged value of the HDI has significant and positive effects on the observed HDI. For economic policy, the results pinpoint the importance of ICT as a relevant instrument that can positively influence people's lives directly or indirectly.*

***Key words:*** *ICT, human development, tertiary education, SDGs, panel data analysis, fixed effects, GMM*

***JEL classification:*** *O11, O15, O33*

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# 1. Introduction

Human capital is often seen as wealth that can create further wealth at the micro and macro levels (Barro, 2001; Oluwatobi & Olurinola, 2015), so the determinants of human development are topical issues in the economic literature. Decent work, productive employment, and sustainable growth are one of the UN Sustainable Development Goals (SDGs). To achieve these goals, it is essential to understand the factors that influence human development. It is well known that the use of technology, especially information and communication technology (ICT), benefits human development by facilitating access to knowledge and education, access to information, access to healthcare, social interaction, finding better and higher-paying jobs while creating new business opportunities, etc.

Since the 1980s, endogenous growth theories have considered technological development (including ICT) and human capital as engines of economic growth as an alternative to neoclassical growth theory (Romer, 1986; Lucas, 1988; Grossman & Helpman, 1991). According to endogenous growth theories, knowledge-based businesses, especially information technologies and other high-tech industries, are becoming increasingly important in developed and emerging economies (Hayes, 2021). Considering that most private and business activities today are highly dependent on ICT, various applications and software, there is good reason to believe that ICT is one of the most important determinants of economic and human development.

In the past, it took much more time for the ICT impact to become visible such as the effects of PCs only reflected in productivity after about a ten-year period. However, nowadays, the influence of ICT is developing rapidly and is visible, especially so during the Covid 19 pandemic lockdown, which physically blocked the world but has increased the role of ICT. Today, ICT technology is fundamentally changing the economy and people's lives, and a world without technology is no longer imaginable. ICT technology expands human freedoms (Sen, 2010) and leads to more efficient human actions, activities, work, and personal development. Information and communication technologies (ICTs) facilitate dissemination and easy accessibility of information and communication. Personal computers, mobile devices, and the Internet can be used to describe these technologies.

Given the current development of the importance of ICT technology and the speed of digitization of the world, it is to be expected that ICT will take an even more important place in people's lives. Despite the obvious importance and dominant position of ICT in daily life, there is a gap in the literature on the relationship between ICT technology and human development from the perspective of countries with different levels of development.

In our analysis, we use the Human Development Index (HDI) as a proxy variable for human development, which is the most complete indicator of human development to date. The Human Development Index is a composite index

composed of three indices: life expectancy index, education index, and GNI index. The life expectancy index represents the health dimension, which is assessed by life expectancy at birth. The education index represents the education dimension and is measured by the average number of years of schooling for adults aged 25 and older and the expected number of years of schooling for children of school entry age. The GNI index stands for the standard of living dimension and is measured by gross national income per capita (UNDP, 2022). ICT technology and education should be at the forefront of every country's development strategies, as they can indirectly contribute to the achievement of the Sustainable Development Goals (SDGs). The Arksey and O'Malley (2005) approach was used for the literature review.

Thus, the objective of this study is to examine the role of ICT on human development in countries with different levels of development. The level of development is classified according to the World Bank's GNI 2020 classification, which divides countries into high-income countries, upper-middle-income countries, lower-middle-income countries, and low-income countries. This analysis builds on that of Karaman Aksetijević et al. (2021), but in addition, the variables of the enrolment in higher education and political stability are included in the analysis to control for factors that might influence human development in countries at different levels of development. In addition, both static and dynamic regression analyses are performed in this paper to compare differences in the coefficients of the elasticities. The main hypothesis of this paper is that ICTs have positive effects on human development, but that these effects differ for countries at different levels of development.

The paper is divided into six parts. After the introduction, the second part of the paper contains a literature review on ICT technology and human development. The third part of the paper presents the research methodology, while the fourth part describes the research data and variables. The fifth part of the paper presents the results of the analysis. The sixth part discusses the main findings and concludes the paper.

## 2. Literature review

The role of ICT technology deployment in human and, by extension, economic growth and development has received considerable attention from economists, researchers, and policymakers. However, there is still relatively little empirical literature establishing a link between ICT technology and human development. Moreover, there is no standard measure of ICT technology use and human development, so different papers use different measures. Table 1 provides information on the relevant empirical literature on the relationship between information and communication technology and human development. The literature review is based on Arksey & O'Malley's (2005) framework, which includes identifying relevant studies by selecting, organizing, and summarizing them by presenting findings. The Web of Science Core Collection database (2022) was the source for data for the literature review.

Table 1: Summarized literature on ICT and human development relationship

| Author/Year | Methodology | Data & variables | Findings |
|---|---|---|---|
| Oyerinde & Bankole (2019) | Data Envelopment Analysis (DEA) | All countries in Sub-Saharan Africa, Northern Africa, and selected countries in Europe and Northern America; 2010 – 2016; time series data; educational attainments; literacy rates; individuals with computers, internet and mobile phones | ICT infrastructure has a strong impact on educational attainment and adult literacy rates. |
| Oluwatobi et al. (2016) | SGMM, panel data | 32 Sub-Saharan Africa (SSA) countries; 2001-2012; Human capital, GDP, Government Education Expenditure, ICT | ICT has a more significant role in facilitating school enrolment at the secondary and tertiary levels of education. There is a statistically significant and direct relationship between ICT infrastructure and usage and school enrolment in SSA. |
| Asongu et al. (2017) | GMM, panel data | 44 Sub-Saharan African countries; 2000-2012; Inclusive human development, ICT (internet penetration and mobile phone penetration), four main CO2 emission variables | ICT can be used to dampen the potentially negative effect of environmental pollution on human development. |
| Alfaro Cortes & Alfaro Navarro (2011) | Factor analysis, cluster analysis, Analysis of variance (ANOVA) | European Union 27; 15 most relevant variables for the research objective (9 structural indicators and 6 policy indicators) | ICT has a strong influence on economic and human development. Results show the existence of four clearly distinct groups of countries that register significant differences. |
| Petrić et al. (2020) | Dynamic panel model | European Union countries; HDI and Digital Economy and Society Index (DESI) | ICT variable influences the HDI of EU countries. Broadband Internet usage, individual-level of Internet use and e-commerce use positively contribute to the EU economic development. The use of e-government services and the increase number of the ICT professionals employed have a negative impact. |
| Perez-Castro et al. (2021) | Descriptive analysis and regression analysis | Mediterranean countries; 2010-2015; HDI, ICT Development index (IDI) | Increased technological development has a positive impact on human development. The increase in the IDI was much greater than in the HDI. Variation rates were greater in less developed countries. The increase in technological infrastructure, access to ICT, and improvement in their use level improve the quality of life of a population. |

| Author/Year | Methodology | Data & variables | Findings |
|---|---|---|---|
| Karaman Aksetijević et al. (2021) | Dynamic panel data regression analysis with GMM estimator | 130 world countries; HDI, ICT use GINI coefficient, Rule of law | HDI has statistically significant and positive effects on contemporary human development. ICT is important for human development and has a positive impact on the HDI in the case of developing countries (middle- and low-income countries). In the case of developed countries, the results are ambiguous and not significant. |
| Ibrahim R. L. et al. (2022) | Two-step system GMM and Panel Fixed Effects (FE) | Panel of 43 Sub-Saharan African countries; 1990-2019; non-renewable energy consumption, technology proxy (ICT service exports), and quality of life (HDI, life expectancy at birth, education, GDP per capita) | The indicators of non-renewable energy are statistically significant and negatively signed when HDI, life expectancy, and GDP per capita are the outcome variables but positive for education. Technology proves to enhance the quality of life. |
| Machfud & Kartiwi (2018) | Pearson Correlation analysis | Six major islands of Indonesia; 2012-2016; HDI, expected years of schooling and mean years of schooling, expenditure per capita, percentage of poor people | The better the human development of a region, the better the development of ICT in that region; the worse the poverty level, the lower the ICT development. |
| Samoilenko & Osei-Bryson (2013) | MR analysis | Group of transition economies; the Leaders (have some characteristics of developed economies) and the Followers (have some characteristics of less-developed economies); GDP, ICT Labour, ICT revenues, ICT capital, HDI, TFP (total factor productivity) | HDI has a statistically significant impact on GDP and TFP only in the case of the Leaders. In the case of the Leaders, the levels of telecom labour and HDI serve as statistically significant predictors of GDP. In the case of the Followers, the levels of capital investment and the labour have statistically significant impacts on GDP. |
| Khan et al. (2019) | Autoregressive distributed lag (ARDL) and vector error correction model (VECM) | 1990 -2014; ICT, economic growth (GDP), HDI, FDI, trade, urbanization | ICT stimulates the human development process, and trade declines human development with both Internet and mobile penetrations. Urbanization has a positive impact on human development with mobile penetration and does not contribute with Internet penetration. |

| Author/Year | Methodology | Data & variables | Findings |
|---|---|---|---|
| De la Hoz-Rosales et al. (2019) | Data panel technique, fixed effects regression, panel corrected standard errors (PCSE) | 145 countries; HDI, SPI (Social Progress Index), Total entrepreneurial activity rate of innovation, Network Readiness Index, Individual use of ICT, Business use of ICT, Government use of ICT, Economic Freedom Index, Pillar Political and Regulatory Environment, Development Level | Regardless of a country's level of development, the individual use of ICT has a positive impact on human development; especially on dimensions measured by HDI. The use of ICTs for commercial purposes has a positive impact on human development at the global level, but considering only developed countries, the relationship of this variable with human development is no longer significant. The impact of government use of ICT on human development is significant on developed countries. |
| Njoh (2018) | Multiple regression, double logarithmic form | HDI, cellular phone subscription, broadband subscription, fixed phone subscription, and internet access | There is a strong positive link between the examined ICTs and HDI. Cellular phone subscription and Internet access are associated with HDI in a statistically significant manner while holding the other ICTs in the model constant. However, fixed phone and broadband subscription are not linked to HDI in a statistically significant manner in Africa for the period studied. |
| Miranda & Lima (2012) | Multi-logistic analytical procedure for evolutionary time series | Internet hosts, the Internet penetration index, the ICT development index and the software/ protocols development | The number of countries in the low range of HDI values decreased from 2002 to 2007, at the same time the number of countries entering high range increased. There is a group of countries whose improvements in their operational ICT index are disconnected from their corresponding improvements in the human development, whereas for countries with top medium and high human development levels there is a close correlation between the two indices. |
| Zelenkov & Lashkevich (2020) | ANOVA, fuzzy regression, Possibilistic Linear Regression combined with the Least Squares | Four groups of countries (112) with different levels of GDP per capita ; HDI, Network Readiness Index, Global Innovation Index | For developed countries, the positive and balanced impact of innovation and ICT on living standards has been confirmed. For two groups of developing countries (upper and lower middle income), the GII coefficient is negative. In the group of developing countries with upper middle income, ICT has a much more significant impact on human development. |
| Remeikiene et al. (2021) | Second generation panel cointegration and causality tests regarding the cross-sectional dependence | 11 post-transition EU members; 1996-2015; shadow economy size (% of GDP), mobile cellular subscriptions, individuals using the internet, HDI | ICT indicators and human development had significant effects on the size of shadow economy in both short and long run. Growing ICTs lead to reduction on the size of the shadow economy. |

| Author/Year | Methodology | Data & variables | Findings |
|---|---|---|---|
| Martin et al. (2013) | Regression, ANOVA | SMEs in Romania; the proportion of employees who use ICT during activity, variable levels of ICT adoption | The adoption of ICT in the enterprise will generate economic growth, which in turn will lead to an increasing complexity of the production process. The proportion of employees who use ICT during activity score explain the variation in the level of ICT adoption. |
| Ahmed (2017) | Cobb-Douglas production function estimation | (ASEAN5), Malaysia, Indonesia, Philippines, Singapore, and Thailand; three East Asian Countries (China, Japan, and South Korea) no. of telephone lines/1000 persons, proxy for ICT, expenditure in education proxy for human capital | ICT and human capital contribution to the ASEAN-5 productivity |
| Ramlan & Ahmed (2009) | Stationarity, cointegration and structural break tests | Malaysia, Time series data 1965 to 2005, relationship between telecommunications investment and aggregate output | ICT in a long-run equilibrium relationship with GDP, capital and employment Human capital is significant in the development of the ICT and long-run economic growth |
| Orji et al. (2020) | Classical Linear Regression Model | 1981 – 2016; school enrolment, telephone subscriptions, electricity consumption, infant mortality, population growth | ICT, power supply and population affect positively on human capital development, while infant mortality has a negative impact on human capital development in Nigeria. |
| Acheampong et al. (2021) | Lewbel two-stage least squares | 79 energy-poor countries from South Asia, sub-Saharan Africa, and Caribbean-Latin America for the period 1990–2018; HDI, human capital, life expectancy, maternal mortality, under-five mortality, access to electricity, access to clean energy, trade openness, urbanisation, foreign direct investment, financial development, remittance, gender empowerment, ICT, employment, industrialisation | Employment, industrialisation, economic growth, ICT, and gender empowerment are some of the important channels through which energy accessibility influence human development. |
| Asongu (2021) | Tobit regressions | 49 sub-Saharan African countries; 2000-2012; inclusive development (IHDI), mobile phone, education quality, innovation, Internet, GDP per capita, private credit, remittances, foreign investment | Mobile phone penetration and associated innovation in SSA improve inclusive human development irrespective of the country's level of income, legal origins, religious orientation and the state of the nation. |

Source: Author's elaboration

To some extent, previous studies have already identified the connection between ICT and human development using many different approaches, methods and variables. However, the findings regarding the link between country's level of development and ICT are ambiguous which indicates there is a need for further research to clarify that connection. Since it has been proven that ICT stimulates the human development process it is necessary to investigate in which countries, considering the different income groups, this link is more significant and in which countries it can be enhanced through different policies. The given literature overview identifies tertiary education and ICT as factors which positively affect human development, which is why we have decided to build upon these findings and contribute to the field's literature.

## 3. Methodology

The aim of this paper is to estimate the impact of information and communication technology on human development. The empirical analysis is based on a regression analysis of panel data. To assess these impacts, the paper estimates the following econometric model:

$$humdev_{it} = \beta_0 + \beta_1 ICT_{it} + \beta_2 higheduc_{it} + \beta_3 polstab_{it} + \\ + \beta_4 incomegroup_{it} + u_{it} \quad (1)$$

where the $humdev_{it}$ is a dependent variable and represents human development. $i$ stands for specific country and $t$ stands for specific year. $ICT_{it}$ is an independent variable which represent the use of ICT technology (aggregate indicator that includes the development of Internet users, Broadband Internet subscriptions, Internet bandwidth, Mobile broadband subscriptions, Mobile telephone subscriptions, Fixed telephone lines) in each country $i$ in year $t$. $higheduc_{it}$ is also independent variable that represents the enrolment in higher (tertiary) education in country $i$ in time $t$. $polstab_{it}$ is an independent variable that represents political stability of the country $i$ in time $t$. In the model are included four dummy variables $incomegroup_{it}$ which have value 1 if the country belongs to specific income group of countries. The dummy variables stand for high, upper-middle, lower-middle and low-income countries and are included in the empirical model to control for the level of development of the country. $\beta_0$ is constant while $\beta_1$, $\beta_2$ and $\beta_3$ are parameters of independent variables. $u_{it}$, represents error term.

In static panel data analysis, the standard and most common estimators are Pooled Ordinary Least Square (POLS), Fixed Effects (FE), and Random Effects (RE). In such data, the variance at the panel unit level is mainly not homogeneous, which makes POLS a bad estimator that often provide biased and overestimated results. Therefore, a fixed or random effect estimator should be used instead. To choose

which estimator to use, in the first step, we performed the Hausman test, a common test used to decide which estimator, FE or RE, is better for panel data analysis. According to the results of the Hausman test, zero hypothesis ($H_0$) is rejected, which means that FE is a better estimator for the analysis (Greene, 2008). Fixed effects (FE) are used when evaluating the effects of variables that vary over time. FE explores the relationship between independent and dependent variables within an entity (in our case, within a particular country), which is why they are also called Within Estimator. Each entity, in our case a country, has its characteristics that have become fixed over time, such as language, and these characteristics may affect the dependent variable. FE takes these characteristics into account, i.e. eliminates characteristics that are fixed over time to estimate the net effects of independent variables on the dependent variable. To address the possible source of endogeneity due to reverse causality or omitted variables, we use a dynamic regression analysis (Wooldridge, 2009) with a Generalized Method of Moments (GMM) estimator (Arellano & Bond, 1991) as a robustness check of the original model. The GMM estimator uses differentials and lags of the regressand and regressors as instruments and yearly fixed effects and in this way provides unbiased and consistent results (Wang et al., 2019).

## 4. Empirical data and analysis

The data for the analysis comes from various sources. Dependent variable Human Development Index is obtained from UN Human Development Report, while independent variables ICT use and enrolment in tertiary education (in %) are obtained from World Economic Forum, Global Competitiveness Report. ICT variable represents aggregate indicator composed of various indicators (Internet users, Broadband, Internet subscriptions, Internet bandwidth, Mobile broadband subscriptions, Mobile telephone subscriptions, Fixed telephone lines) where 1 stands for not developed at all and 7 for extremely well developed. Since there was not available data for the years 2018 and 2019, we extrapolated ICT use for those years using linear extrapolation. The analysis is based on the country level data.

The variable Political Stability and Accountability is obtained from the Worldwide Governance Indicators (WGI). The database covers the period from 2007 to 2019 for 130 world countries divided into four groups classified based on the World Bank's GNI Classification 2020, presented in the Table 2. The analysis is based on panel data covering 13 years. Although a period of more than 10 years is generally sufficient to capture certain effects when analysing panel data, we must acknowledge that effects may extend over longer periods before being proliferated, as Kondratieff cycle theory states (Wilenius, 2014).

Table 2: GNI Classification 2020 (income group)

| Country group | GNI/PC |
|---|---|
| High-income | > USD 12,535 |
| Upper-middle-income | > USD 4,046 < = 12,535 |
| Lower-middle-income | > USD 1,036 < = 4,045 |
| Low-income countries | < $1,036 |

Source: World Bank, 2020

Table 3 presents summary statistics of all variables. Since we are working with panel data, in the summary statistics are presented variations between panel units (country) and within each panel unit (country). Since we have heterogeneous countries in the dataset, the higher standard deviation can be seen between panel units than within, that is especially visible in the variable enrolment in tertiary education (*higheduc*).

Table 3: Summary Statistics

| Variables | | Average | Standard deviation | Minimum | Maximum | Observations |
|---|---|---|---|---|---|---|
| *humdev* | overall | .6874468 | .1629223 | .262 | .957 | N = 3,198 n = 164 T = 19.5 |
| | between | | .159506 | .32805 | .93755 | |
| | within | | .0333507 | .5647468 | .7764968 | |
| *ICT* | overall | 3.333955 | 1.744304 | 1 | 6.9882 | N = 1,032 n = 137 T = 7.53285 |
| | between | | 1.661597 | 1.038263 | 6.677641 | |
| | within | | .5307836 | 1.788089 | 5.349432 | |
| *higheduc* | overall | 38.2476 | 26.58405 | 0 | 116.6216 | N = 1,333 n = 131 T = 10.1756 |
| | between | | 25.85016 | .575594 | 98.19245 | |
| | within | | 6.524298 | 2.814188 | 86.93794 | |
| *polstab* | overall | -.0079106 | .9876491 | -3.314937 | 1.965062 | N = 3,536 n = 189 T = 18.709 |
| | between | | .9432671 | -2.686243 | 1.868903 | |
| | within | | .3246228 | -1.752202 | 1.68854 | |

Source: Authors' calculation

In this section are presented the results of the estimations with POLS estimator, FE estimator and GMM estimator. Since the POLS usually provides biased and overestimated results we use it just as a benchmark for the comparison with other estimators. Table 4 presents the results of the estimation with POLS, while Table 5 presents the results of the estimation with FE estimator.

Table 4: Results of the regression with POLS estimator

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | High-income countries | Upper-middle-income countries | Lower-middle-income countries | Low-income countries |
| Variables | *humdev* | *humdev* | *humdev* | *humdev* |
| *ICT* | 0.0111*** | 0.0107*** | 0.0113*** | 0.0261*** |
| | (0.000669) | (0.00119) | (0.00289) | (0.00829) |
| *higheduc* | 0.000306*** | 0.000983*** | 0.00280*** | 0.00330*** |
| | (6.27e-05) | (0.000100) | (0.000298) | (0.000649) |
| *polstab* | 0.00675** | 0.0110*** | 0.00327 | 0.000605 |
| | (0.00272) | (0.00269) | (0.00302) | (0.00372) |
| Constant | 0.793*** | 0.679*** | 0.533*** | 0.414*** |
| | (0.00540) | (0.00589) | (0.0116) | (0.0173) |
| Observations | 373 | 257 | 202 | 94 |
| Number of panel | 48 | 35 | 27 | 13 |

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: Authors' calculation

The results of the estimation with POLS show that ICT has significant positive effects on human development, and the coefficients are even higher the lower the country's income group. Enrolment in tertiary education also has positive and significant impact on human development, i.e., the higher the percentage of students enrolled in tertiary education, the higher the human development, and the coefficient is higher in the case of middle-income and high- income country group. Political stability and accountability seem to be significant only for upper-middle income and high-income countries. However, as mentioned in the methodology section, POLS often provides overestimated and biased results. Therefore, we focus on the results of the FE estimation and the GMM estimation.

Table 5: Results of the regression with FE estimator

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | High-income countries | Upper-middle-income countries | Lower-middle-income countries | Low-income countries |
| Variables | *humdev* | *humdev* | *humdev* | *humdev* |
| *ICT* | 0.0106*** | 0.0106*** | 0.0115** | 0.0250** |
| | (0.00102) | (0.00224) | (0.00525) | (0.00852) |
| *higheduc* | 0.000216** | 0.000797*** | 0.00264*** | 0.00297** |
| | (0.000107) | (0.000221) | (0.000370) | (0.00126) |
| *polstab* | 0.00292 | 0.0132** | 0.00328 | -0.000264 |
| | (0.00464) | (0.00550) | (0.00404) | (0.00532) |
| Constant | 0.804*** | 0.687*** | 0.536*** | 0.419*** |
| | (0.00762) | (0.00802) | (0.0119) | (0.00894) |
| Observations | 373 | 257 | 202 | 94 |
| R-squared | 0.593 | 0.555 | 0.494 | 0.315 |
| Number of panel | 48 | 35 | 27 | 13 |

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: Authors' calculation

In the fixed-effects estimation, the coefficients of results are lower than in POLS, but still significant and positive, suggesting that ICT plays an important role in human development, especially for the lower-middle income and low-income countries. Enrolment in tertiary education has positive significant effects on human development across all income groups of countries, but the effects are higher in upper-middle income countries. Considering that some low-income countries struggle with enrolment in primary education, it is clear that tertiary education is above their means. Political stability and accountability appear to be significant only for human development in upper- middle income countries. These results support previous findings on the determinants of human development, particularly with regard to ICT technology and its significant impact on human development in developing countries. Table 6 below shows the results of the robustness check with the GMM estimator.

Table 6: Results of the regression with GMM estimator

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | High-income countries | Upper-middle-income countries | Lower-middle-income countries | Low-income countries |
| Variables | *humdev* | *humdev* | *humdev* | *humdev* |
| *HDI lag.* | 0.884*** | 0.825*** | 0.929*** | 0.369 |
| | (0.110) | (0.0911) | (0.0758) | (0.723) |
| *ICT* | 0.00112 | 0.00500*** | -0.000908 | 0.0156 |
| | (0.00102) | (0.00139) | (0.00249) | (0.0317) |
| *higheduc* | -2.17e-05 | 0.000165 | -1.10e-05 | 0.00195 |
| | (9.20e-05) | (0.000217) | (0.000176) | (0.00163) |
| *polstab* | 0.00312 | 0.00734 | 0.00541* | 0.000605 |
| | (0.00450) | (0.00511) | (0.00296) | (0.0115) |
| Constant | 0.0980 | 0.117** | 0.0531 | 0.264 |
| | (0.0910) | (0.0587) | (0.0440) | (0.288) |
| Observations | 373 | 257 | 202 | 94 |
| Number of panel | 48 | 35 | 27 | 13 |
| Number of instruments | 51 | 51 | 51 | 51 |
| AR (1) p-value | 0.001 | 0.013 | 0.002 | 0.236 |
| AR (2) p-value | 0.314 | 0.356 | 0.259 | 0.148 |
| Hansen statistics | 0.158 | 0.158 | 0.158 | 0.158 |
| Hansen p-value | 1 | 1 | 1 | 1 |

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: Authors' calculation

The results of the dynamic panel data regression with the GMM estimator show that the lagged value of dependent variable, i.e., human development (HDI), has significant positive effects on human development, which means that human development in the previous period has significant and positive effects on human development in the present. However, ICT is significant and positive only in the case of upper-middle income countries, while it is not significant in the case of other income groups. Political stability and accountability also have much weaker effects and are significant and positive only in the case of lower- middle-income countries. The diagnostic tests for autocorrelation in different residuals, that is, it tests whether the idiosyncratic error term is serially correlated. The test rejects the null hypothesis that there is no first-order serial correlation in the first differences - AR (1) but does not reject it in the case of low-income countries. The AR (2) does not reject the null hypothesis that there is no second-order serial correlation.

The Hansen test validates our instruments. If the Hansen test for over identifying restrictions does not reject the null hypothesis at any conventional significance level (p-value =1), this is an indication that the model has valid instrumentation, although we must concede that Hansen p=1 is suspiciously good.

## 5. Results and discussion

The results of this research support our original hypothesis that ICT has a positive and significant impact on human development, but the impact varies for countries at different levels of development. Our results also show that tertiary education has a significant impact on human development. Although the outcome coefficient varies across estimates with different estimators, we can draw several conclusions. First, ICT is significant for human development in all countries, but it has stronger effects on less developed countries. The upper-middle-income countries could benefit most from the adoption of ICT technologies. Therefore, economic policies should focus on supporting the adoption of ICTs in business, education, and all other public and private sectors, which can lead to a better quality of life, easier access to education, jobs, information, public services, etc. In terms of education, the upper-middle-income countries could benefit most from higher enrolment rates in tertiary education.

This research contributes to the current literature on human development by supporting previous findings in the field and also offering new insights into the dynamic relationship between ICT and human development from the perspective of countries at different levels of development. The findings suggest that upper middle-income countries could rethink their economic policies by investing more in ICT and its implementation and enrolling more students in tertiary education to achieve higher levels of human development.

## 6. Conclusion

This research addresses the relationship between ICT, enrolment in tertiary education, and human development in countries belonging to the different income groups. In order to do the analysis, we performed the static panel regression analysis with the FE estimator. As a robustness check of the original model, we also performed a dynamic regression analysis with the GMM estimator. This study's static analysis results show significant and positive effects of ICT and enrolment in tertiary education on human development across all income group countries. As for the dynamic analysis results with the GMM estimator, they show significant and positive ICT effects only for the upper-middle-income countries. In addition, the results show significant effects of the lagged value of the human development

index on the present human development index. This research contributes to understanding the role of information and communication technologies in human development. Despite the fact that the data reveals that ICT technology has strong and positive effects in all four income groups of countries, these effects are significantly much more outstanding in poorer countries. The findings highlight the importance of investing in ICT and education to reach higher levels of human development. ICT technology and education should be at the forefront of each country's development strategies, as they can help accomplish the Sustainable Development Goals.

The main limitations of this research are reflected in the use of aggregated data, where some information is sometimes lost through the aggregation itself. Due to available data, the analysis is based on a time span of 13 years. The longer time period could help to explore the long-term effects of ICT and to have more accurate insight into the real effects of ICT on human development. However, the rest of the empirical literature on this topic is mainly based the analysis on the macroeconomic level. Future research might be oriented towards microeconomic analysis based on the survey on firm level and focus on the relationship between ICT and employer development.

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# Kako IKT utječe na ljudski razvoj? Dokaz zemalja u razvoju naspram razvijenih zemalja

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***Sažetak***

*Cilj ovog istraživanja je procijeniti utjecaj informacijske i komunikacijske tehnologije (IKT) na ljudski razvoj (mjerene indeksom ljudskog razvoja). Utjecaj se proučava za zemlje s različitim razinama razvoja kako bi se identificirale moguće razlike u tim utjecajima kada se uzme u obzir razina dohotka (razvijenost zemlje). Istraživanje se temelji na statičkoj regresijskoj analizi panel podataka s procjenom fiksnih učinaka (FE). Kako bismo riješili mogući problem endogenosti zbog obrnute uzročnosti, također izvodimo dinamičku regresiju panel podataka koristeći procjenitelj Generalizirana metoda momenata (GMM). Rezultati podupiru naše pretpostavke i pokazuju kako i tercijarno obrazovanje i korištenje IKT-a imaju pozitivne učinke na ljudski razvoj, iako rezultati variraju ovisno o procjeniteljima. Dok su u slučaju FE procjenitelja učinci značajni i pozitivni u svim promatranim zemljama, rezultati s GMM procjeniteljem pokazuju značajne učinke IKT-a samo u slučaju zemalja s višim srednjim dohotkom, ali također impliciraju da vrijednost HDI s vremenskim pomakom ima značajne i pozitivne učinke na promatrani HDI. Za ekonomsku politiku rezultati znače da IKT treba uzeti u obzir kao relevantan instrument koji može izravno ili neizravno pozitivno utjecati na živote ljudi.*

***Ključne riječi:*** *IKT, ljudski razvoj, tercijarno obrazovanje, SDGs, panel analiza, fiksni efekti, GMM*

***JEL klasifikacija:*** *O11, O15, O33*

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