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The ICT–Economic Growth Nexus: Revisiting the Impact of the Internet on GDP

Powiązania między ICT a wzrostem gospodarczym: ponowne spojrzenie na wpływ Internetu na PKB

Introduction

Over the past few decades, the growing prevalence of new technologies, mainly information and communication technologies (ICT), has transformed the world and created new opportunities across various areas. The importance of these emerging technologies is also reflected in government and international initiatives such as "Technology for Good" introduced by France (Tech for Good Summit, 2020), "Democracy-Affirming Technologies" established in the United States (The White House, 2021), "Future Tech Forum" launched by the United Kingdom (HM Government, 2022), and the Global Forum on Technology at the Organisation for Economic Co-operation and Development (OECD) level.

The world economy stands on the cusp of a new industrial revolution driven by automation and artificial intelligence. It is, therefore, worth revisiting the discussion on how the earlier revolution related to information and communication technologies influenced growth in gross domestic product (GDP). The debate addressed the question whether the impact on GDP growth was negligible, as initially suggested by Solow's "productivity paradox,"[1] or if it ultimately contributed to the invigoration of economic growth. Later studies produced inconclusive results but with a clear predominance of positive ones for newer data sets (Stanley, Doucouliagos & Steel, 2018; Vu, Hanafizadeh & Bohlin, 2020). Consequently, our objective is to re-examine the impact of Internet/broadband technologies on GDP. Our intention is twofold. First, we reproduce the research for a new data

[1] "You can see the computer age everywhere but in the productivity statistics" (Solow, 1987).

set covering a relatively large group of countries and a period of recent years. This new data set provides an opportunity to look at the role of the studied technologies in the mature period rather than in the initial period of introduction into use. Secondly, we check how the importance of the studied technologies changes with the level of economic development.

We begin the paper by reviewing the literature on ICT and economic growth nexus. We then analyse the relationship between Internet/broadband technologies and GDP, considering control variables. Our study covers 88 countries from 2006 to 2020. The estimation is based on data from the International Telecommunication Union (ITU) database (International Telecommunication Union, 2021), which offers a reliable data source despite not being widely used in prior literature.

1. Related literature

To establish a foundation for our analysis, it is essential to examine the channels through which ICT, including variables related to Internet/broadband technologies, can affect economic growth. Technological progress is expected to impact aggregate labour productivity (ALP), which reflects the output generated per unit of labour – represented either by the number of employed individuals or hours worked. ALP is a key economic indicator as it represents growth potential that is not attributable to additional working hours. The dynamics of ALP depend on three components.

On the one hand, labour productivity is driven by changes in capital and labour quality (human capital), where capital deepening refers to the decision-making process between increasing the number of employees or investing in new equipment, while labour represents the structure of human capital in terms of experience and skills. On the other hand, ALP is dependent on multifactor productivity (MFP), also known as total factor productivity (TFP), which is assumed to represent the impact of various factors. Primarily, changes in MFP are attributed to improvements in technology or a shift of resources from less productive sectors to more efficient ones (Brill, Chansky & Kim, 2018).

The existing literature can be classified based on various categories, including the methodology used to quantify the impact, the aggregation level, or the selected ICT measure. From the methodological standpoint, studies can be divided between those focused on growth accounting and parametric approaches, such as regression analysis. Considering papers based on growth accounting methodology, Byrne, Oliner and Sichel (2013), Oliner and Sichel (2000), and Jorgenson and Stiroh (2000) have found evidence supporting a positive relationship between changes in the MFP of the ICT-producing sector and the growth of aggregate labour productivity. Analysing the years after 1995, the increase in ALP contribution is estimated at 0.34 percentage points for non-agricultural sector and at 0.19 percentage points for the whole economy.

Conversely, Stiroh (2002) made a successful attempt to verify the spillover effects of ICT in the US economy. Using industry-level data (covering 61 industries), he demonstrated productivity acceleration within the ICT-using sector. These results are consistent with those obtained by Basu and Fernald (2007). Data for the US economy has also been analysed by Gordon (2016), but the author did not attribute such importance to information and communication technologies, which is reflected in his lack of conviction regarding their impact on long-term growth. The thesis is reiterated by Gordon and Sayed (2020), who examined the role of ICT in the US and ten Western European (EU-10) countries. They confirmed that the ICT-producing sector was a primary driver of productivity growth, while, at the same time, a lack of adequate ICT investments was responsible for the growth slowdown within the EU-10. Despite evidence supporting the relationship between ICT and productivity growth, the temporary nature of this impact has been emphasized (Gordon & Sayed, 2020).

Another strand of literature has explored the relationship through a review of existing papers and their findings. Prompted by undertaken governmental initiatives, Holt and Jamison (2009) focused on the US economy, examining the connection between ICT and economic growth, as well as narrowing their analysis to links between broadband and economic growth. Their results indicated a positive impact of broadband adoption. However, several challenges related to their methodology and data access were raised. According to the analysed studies, the impact of ICT is constantly evolving, covering periods of negative growth. Thus, proper verification of broadband impacts should take non-linear effects into account. Another challenge concerns the quality of the data, as the indices used do not fully capture the rapid technological changes and the variety of broadband products. The authors suggested that a single model is unlikely to adequately explain the impacts of broadband. They also indicated that studies should consider the net effect of broadband adoption, which results from replacing existing technologies with new ones (Holt & Jamison, 2009).

Cardona, Kretschmer and Strobel (2013) extended the study to European countries. They found evidence supporting the impact of ICT on productivity statistics. However, the authors also noted contradictory results concerning the differences in benefits between the United States and Europe. While aggregated data revealed notable discrepancies between countries, firm-level analyses have provided no evidence of such differences. At the same time, ICT has been assessed as a general-purpose technology (Cardona, Kretschmer & Strobel, 2013).

Vu, Hanafizadeh and Bohlin (2020) conducted a comprehensive review investigating the growth effects of ICT, analysing a total of 208 articles. The academic papers examined were classified based on multiple dimensions, including research methodology, date of publication, and the primary ICT variables used to verify the links between technology and growth. The authors found that the overwhelming majority of the papers reviewed provided evidence of a positive impact of ICT on economic growth. As advancements within ICT are proposed to raise the number of changes, the authors also suggested that the importance and number of papers in the coming years will increase. Among the directions for future research, they highlighted that attention should be paid to understanding why and how technologies affect economic performance, rather than merely focusing on whether the relationship exists (Vu, Hanafizadeh & Bohlin, 2020).

Mixed results of the impact of ICT on GDP growth were found by Stanley, Doucouliagos and Steel (2018). The authors conducted a meta-regression analysis of over 50 econometric studies to evaluate whether a link between ICT and economic growth occurs, as well as what factors impair the relationship. Among the outcomes, they listed (1) evidence supporting a positive contribution to economic growth at an average level, (2) varied impacts of ICT between developed and developing countries, and (3) varied impacts from different types of ICT. For developed countries, moderate benefits arose mainly from computing, cell phones, and landlines. In the case of developing countries, the evidence suggested a primary impact of cell phones followed by landlines; however, the impact was small in both cases. It appears that developed countries take advantage of ICT impacts to a greater extent compared to developing economies. Moreover, there is little evidence of the Internet's contribution to economic growth (Stanley, Doucouliagos & Steel, 2018).

The literature based on regression analysis is rich with research dedicated to various regions and selected ICT variables, with many focusing on the communication aspect of technologies. Czernich, Falck, Kretschmer and Woessmann (2011) estimated the effects of broadband infrastructure among OECD countries in the period of 1996–2007. The broadband penetration was measured as the number of broadband subscriptions per 100 inhabitants, with data obtained from the OECD Broadband Portal. Broadband was defined as a line that offers download speeds of at least 256 kbit/s. Based on the instrumental variable model, the authors found that the diffusion of broadband raised GDP per capita by 2.7–3.9% on average compared to the time before broadband was introduced. Additionally, increasing broadband penetration by 10 percentage points impacted the annual growth in GDP per capita by 0.9–1.5 percentage points. Despite the solid estimations, the authors indicated a limitation of the study that related to the interpretation of the broadband measure. As the line was defined as any bandwidth over 256 kbit/s, there was no possibility to consider differences resulting from average and maximum speeds across the countries, thus, the focus was only on the number of users (Czernich et al., 2011).

In response to these challenges, it is worth mentioning the work of Gruber, Hätönen and Koutroumpis (2014), in which the potential effect of discrepancies in speed level was verified. The authors examined the deployment of broadband infrastructure in accordance with the policy recommendations set out in Digital Agenda for Europe. The study was divided into two stages. The first stage concerned the gains from broadband infrastructure split between indicators such as the level of adoption and speed of the broadband. The second stage involved verifying the costs related to the implementation of more advanced broadband solutions. Cost estimation was based on various scenarios differentiated by technical performance (e.g. connection speed). The outcomes obtained in the paper confirmed the advantageous nature of public investment in broadband deployment, resulting in economic growth at the European Union (EU) level. Although the magnitude of impact differs at the country level, the cumulative benefits of moving from basic broadband to higher speed outweigh the cost by 32% (Gruber, Hätönen & Koutroumpis, 2014).

The impact of ICT on economic growth within the European Union was also assessed by Toader, Firtescu, Roman and Anton (2018). Using a set of ICT indicators focused on fixed-broadband subscriptions as well as the percentage of households with broadband Internet access via a home computer, the percentage of individuals using the Internet, and mobile cellular subscriptions, the authors evaluated the impact on GDP per capita from ICT infrastructure. The results suggested a positive and significant impact, although its size was differentiated by the type of technology. Thus, a 1% increase in ICT infrastructure usage would affect GDP per capita growth between 0.0767% for fixed-broadband subscriptions and 0.396% for mobile cellular subscriptions (Toader et al., 2018).

An interesting approach was undertaken by Meijers (2014), who reported no evidence for a connection between the Internet and economic growth. The paper examined the economic growth and international trade impact of Internet use. Using panel data for more than 100 countries, the author found no evidence to explain the direct contribution of the Internet to economic growth (GDP per capita). Simultaneously, it was confirmed that the Internet affected international trade (openness), while trade impacted economic growth (Meijers, 2014).

A detailed econometric analysis of the relationship between the development of technologies and economic growth was prepared by Próchniak and Witkowski (2016). Technology development was reflected in consideration of numerous areas and variables, including those related to the Internet and digitalization, development of the ICT sector, patents, and research and development (R&D) expenditure. From an econometric perspective, the estimation was based on panel and cross-sectional data but also included verification of spillovers between selected groups of countries (e.g., EU, OECD). Considering the economic growth of single countries within selected groups, in the majority of cases, the authors confirmed a positive growth effect of technology development. However, no evidence for spillover effects was demonstrated. Among the variables that presented the highest impact were those related to the ICT sector and R&D (Próchniak & Witkowski, 2016).

In addition to regression studies based on specific, selected variables, there are also index-oriented papers. Fernández-Portillo, Almodóvar-González and Hernández-Mogollón (2020) focused on economic growth within EU countries that belong to the OECD. The impact of ICT was verified based on the Digital Economy and Society Index database, with time series between 2014 and 2017. Additionally, the authors decided to narrow the sample of countries down, aiming to eliminate the heterogeneity of ICT impact resulting from varying economic levels of the evaluated countries. The outcome led to the conclusion that ICT positively affects economic growth within EU countries. It should be noted that EU policy should target not only ICT infrastructure but also ICT use.

Appiah-Otoo and Song (2021) examined the ICT–economic growth relationship differentiated by income level of selected countries. The study was based on an ICT index constructed using indices such as mobile, Internet, and fixed broadband and its impact on labor productivity. Using a data panel for 123 economies over the period of 2002–2017, the authors investigated the impact of ICT indicators on high-income (HIC), middle-income (MIC), and low-income countries (LIC). The results provide evidence of higher gains in the case of middle and low-income countries. When compiling the overall impact of ICT, the increase in HIC, MIC, and LIC labor productivity was 0.07%, 0.37%, and 0.22%, respectively (Appiah-Otoo & Song, 2021).

The literature reviewed here demonstrates that the relationship between ICT and economic performance offers a wide range of opportunities for examination. With diverse methodologies, selected variables, and groups of countries/regions (including distinctions between high- and low-income economies), the majority of studies confirm a positive link between the development of ICT and growth in terms of either GDP or productivity. However, it is important to note that a full consensus on the results has not been reached. Therefore, further research on this topic remains both relevant and valuable.

2. Data sources and research methodology

The starting point is the empirical equation of economic growth.

$$(1) \quad \Delta lnGDP_{it} = \beta_0 + \beta_1 lnGDP_{i,t-1} + \beta x_{it} + \alpha_i + \varepsilon_{it}$$

where: $lnGDP_{it}$ is the log of GDP per capita of country i in period $t = 1,\dots,$ T; x_{it} is the vector of explanatory variables, ε_{it} is the random component, and α_i is the individual effect for a given country. $\Delta lnGDP_{it}$ represents GDP growth. The lagged GDP on the right side of the equation is due to the convergence hypothesis. This equation is transformed to:

$$(2) \quad lnGDP_{it} = \beta_0 + (\beta_1{+}1) lnGDP_{i,t-1} + \beta x_{it} + \alpha_i + \varepsilon_{it}$$

This is the standard form of the economic growth model in empirical research, known as Barro regression (Durlauf, Johnson & Temple, 2005; Próchniak & Witkowski, 2016).

Our main explanatory variables are data showing Internet infrastructure taken from the International Telecommunication Union (ITU, 2021) database. The control variables were selected in accordance with the theory of economic growth and the results of previous empirical research, i.e., variables that have been identified as statically significant for economic growth in previous studies: economic openness, government expenditure, investments, inflation, and government effectiveness (Afonso, 2022; Azam & Khan, 2022; Barro, 2013; Bergh & Henrekson, 2016; Chang, Kaltani & Loayza, 2009; Gupta, Stander & Vaona, 2023; Röthel & Leschke, 2023). Detailed information about the data is provided in Table 1 (p. 125).

The dataset consists of annual observations for 88 economies, covering the period between 2006 and 2020. The panel size (considering the number of countries and the length of the series) reflects the highest data availability rate of all used variables.[2]

This resulted in a balanced panel of 88 countries and 15 periods, referred to as a short panel (i.e., the number of countries exceeds the number of periods). For such a case, a group of econometric tools is dedicated (Baltagi, 2021), which include GMM estimators, for example. In the case of dynamic panels, the use of OLS (Ordinary Least Square) as an estimation method causes many problems that are difficult to overcome – for example, those related to endogeneity. OLS requires strictly exogenous explanatory variables. System GMM estimators solve many of the problems associated with dynamic panels. Among other things, potential endogeneity of explanatory variables.

Due to the characteristics of the data (including the strong relationship between GDP and lagged GDP values), we chose the system GMM estimator (Arellano & Bover, 1995) and robust standard errors of estimation. This method is used in numerous other studies on the determinants of economic growth (Ahmad & Khan, 2019; Cieślik & Goczek, 2018; Markakkaran & Sridharan, 2022; Prochniak & Wasiak, 2017; Zhuo, O, Muhammad & Khan, 2021). Due to the statistics describing the quality of the model, we decided to study up to three lags of the dependent variable (i.e., lnGDP). System GMM estimates can potentially suffer from instrument proliferation problems. However, in our case, the number of instruments does not exceed the rule of thumb that the number of instruments should not exceed the number of groups. Only in the case of part of our study divided into income levels did we use the collapse function from the package prepared by Roodman (2009). In addition, the Hansen test can also be used to indicate possible proliferation problems – too large p-value (close to 1) indicates an incorrect model specification. To ensure the correctness of the model and test the requirements, we carried out the Arellano-Bond test for autocorrelation. We then performed

[2] A complete list of the countries of: (1) high-income: Austria, Bahrain, Belgium, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea (Rep. of), Lithuania, Luxembourg, Malta, Netherlands, Norway, Oman, Panama, Poland, Portugal, Qatar, Romania, Saudi Arabia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Trinidad and Tobago, United Arab Emirates, United Kingdom, United States, Uruguay; (2) low- and medium-income: Algeria, Angola, Bangladesh, Bhutan, Bolivia, Cabo Verde, Côte d'Ivoire, Egypt, Honduras, Hong Kong, China, Iran, Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Brazil, Bulgaria, Colombia, Costa Rica, Dominican Rep., Ecuador, Georgia, Jamaica, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Malaysia, Mali, Mauritius, Mexico, Moldova, Mongolia, Morocco, Namibia, North Macedonia, Pakistan, Russian Federation, Rwanda, Senegal, Serbia, Thailand, Tunisia, Turkey, Zimbabwe.

the Hansen test to test the validity of the instruments. The results of these tests help confirm the reliability and robustness of our findings.

Table 1. Variables and source of data

Short name of variables	Variable	Source
lnGDP	Log of gross domestic product	The World Bank (2023a)
Internet	Internet users (%); i99H	International Telecommunication Union (ITU, 2022)
fix_broad	Fixed broadband subscriptions per 100 inhabitants; i992b	International Telecommunication Union (ITU, 2022)
Internet_home	Estimated proportion of households with Internet access at home; xHH6_IDI	International Telecommunication Union (ITU, 2022)
open	Trade (% of GDP); NE_TRD_GNFS_ZS	The World Bank (2023a)
gov	General government final consumption expenditure (% of GDP); NE_CON_GOVT_ZS	The World Bank (2023a)
inv	Gross fixed capital formation (% of GDP); NE_GDI_FTOT_ZS	The World Bank (2023a)
infl	Inflation, GDP deflator (annual %) NY_GDP_DEFL_KD_ZG	The World Bank (2023a)
GE	Government Effectiveness: Estimate; GE_EST	The World Bank (2023b)

Source: own elaboration.

3. Empirical analysis

The results presented in Table 2 show that all technological variables were statistically significant, at least at the 5% significance level, for all models. This indicates a significant impact of technological development on GDP growth, regardless of the chosen variable. Moreover, the estimation for the control variables aligns with both economic theory and previous empirical studies. A positive impact arises from government effectiveness (GE), which represents the quality of public policies and the government's commitment to implementing them. A positive impact is also observed for economic openness (open), which is calculated as the sum of exports and imports as a share of GDP, as well as for the level of investment (inv), which indicates the positive effects of capital accumulation. A negative relationship is observed for two variables: government consumption expenditures (gov) and inflation (infl). The negative signs of these parameters are consistent with the existing literature (Prochniak & Witkowski, 2016). The negative role of inflation (especially double-digit inflation) in long-term patterns of economic growth is well documented in empirical research (Azam & Khan, 2022), as is the negative role of government consumer spending (see systematic review and discussion of the issues Bergh & Henrekson, 2011, 2016).

All of the listed technological variables had a positive impact on economic growth. This finding is consistent with previous research by Czernich et al. (2011), Gruber, Hätönen and Koutroumpis (2014), and Fernández-Portillo, Almodóvar-González and Hernández-Mogollón (2020), with the latter emphasizing the importance of usage of ICT technology. Considering the results for fixed broadband (per 100 inhabitants), it appears to be possible to quantify the effect on GDP growth. The parameter for this variable was 0.0045, meaning that an increase in fixed broadband by 10 should, *ceteris paribus*, result in growth of lnGDP by 0.045. However, as noted by Próchniak and Witkowski (2016), such quantified information should be treated exclusively as a visualisation rather than an absolute outcome. The assumption of *ceteris paribus* is challenging to be met; therefore, the focus should be on the direction and significance of the obtained results.

Table 2. Results of the estimation

Variable	Model 1	Model 2	Model 3
lnGDP L1.	1.1004*** (0.0548)	0.8442*** (0.0852)	1.0969*** (0.0591)
Internet	0.0010*** (0.0002)	–	–
fix_broad	–	0.0045*** (0.0010)	–
Internet_home	–	–	0.0009*** (0.0002)
open	0.0001** (0.0001)	0.0002** (0.0001)	0.0001** (0.0001)
gov	-0.0020*** (0.0006)	-0.0028** (0.0014)	-0.0021*** (0.0006)
inv	0.0010*** (0.0004)	0.0017*** (0.0007)	0.0010*** (0.0004)
infl	-0.0002*** (0.0001)	-0.0003*** (0.0001)	-0.0002*** (0.0001)
GE	0.0324*** (0.0089)	0.0529*** (0.0166)	0.0365*** (0.0100)
AR(1) p-value	0.000	0.001	0.000
AR(2) p-value	0.509	0.100	0.454

Variable	Model 1	Model 2	Model 3
AR(3) p-value	0.931	0.552	0.392
AR(4) p-value	0.792	0.269	0.803
Hansen p-value	0.165	0.175	0.153
N of observation	1320	1320	1320

Standard errors are reported in parentheses. Significant coefficients are denoted with stars (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). AR(1), AR(2), AR(3) and AR(4) contain the p-values of the Arellano-Bond test for autocorrelation and the Hansen p-value of the Hansen test for over-identifying restrictions.

Source: own elaboration.

Models 1 and 3 confirm the positive effect of the Internet, which has been observed with mixed evidence in the existing literature. The papers of Meijers (2014), Cheng, Chien, and Lee (2021) found no positive impact. In the latter, the authors found no evidence for Internet–GDP relationship for middle- and low-income countries. These results are in line with the work of Stanley, Doucouliagos and Steel (2018). It should be noted, however, that the discrepancy in the obtained results may be a consequence of the selection of different groups of countries.

To verify the importance of selecting countries for the sample, we divided our sample into high-, medium-, and low-income countries. The division was made in accordance with the classification proposed by the World Bank (The World Bank, 2023c), with middle-income and low-income countries placed in one group due to the small number of observations. The results are presented in Table 3. A significant impact of the variables depicting Internet infrastructure was observed in high-income countries but was not visible in the other group of countries. Such results were confirmed in previous studies (Stanley, Doucouliagos & Steel, 2018; Cheng, Chien & Lee, 2021). Thus, it can be stated that the selection of countries affects the impact of technological development, interpreted as the usage of the Internet. Fixed broadband showed a positive and significant correlation for both groups of countries, although the relationship was more distinct for low-income countries. It can be hypothesised that these results may be due to the fact that Internet connections in high-income countries are mainly broadband. In countries at a lower level of development, the ICT infrastructure is worse, and therefore, despite the potential availability of the Internet, it does not fulfil its pro-efficiency role. Hence, the importance of broadband Internet is reflected in the results for other variables illustrating the development of the Internet.

Table 3. Results of the estimation division between group of countries

Variable	High-income countries			Middle- and low-income countries		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lnGDP L1.	0.8356*** (0.0798)	0.8841*** (0.0979)	0.8517*** (0.0813)	1.2123*** (0.0709)	1.0367*** (0.0747)	1.1857*** (0.0737)
Internet	0.0018*** (0.0005)	–	–	0.0001 (0.0002)	–	–
fix_broad	–	0.0018** (0.0008)	–	–	0.0036*** (0.0009)	–
Internet_home	–	–	0.0019*** (0.0005)	–	–	0.0001 (0.0002)
open	0.0003*** (0.0001)	0.0003*** (0.0001)	0.0003** (0.0001)	0.0001 (0.0001)	0.0000 (0.0001)	0.0001 (0.0001)
gov	-0.0022 (0.0021)	-0.0019 (0.0018)	-0.0029* (0.0016)	-0.0024*** (0.0006)	-0.0025** (0.0010)	-0.0025*** (0.0006)
inv	0.0020* (0.0011)	0.0027*** (0.0010)	0.0017 (0.0010)	0.0010*** (0.0003)	0.0014*** (0.0003)	0.0011*** (0.0003)
infl	0.0008 (0.0006)	0.0008 (0.0007)	0.0010 (0.0007)	-0.0002*** (0.0000)	-0.0002*** (0.0001)	-0.0002*** (0.0001)
GE	0.0641*** (0.0133)	0.0624*** (0.0140)	0.0608*** (0.0149)	0.0057 (0.0054)	0.0237* (0.0122)	0.0096* (0.0067)
AR(1) p-value	0.015	0.008	0.009	0.000	0.000	0.000
AR(2) p-value	0.132	0.190	0.194	0.737	0.411	0.729
AR(3) p-value	0.771	0.761	0.280	0.805	0.679	0.746
AR(4) p-value	0.130	0.065	0.134	0.447	0.646	0.473
Hansen p-value	0.667	0.622	0.673	0.362	0.347	0.364
N of observation	615	615	615	705	705	705

Standard errors are reported in parentheses. Significant coefficients are denoted with stars (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). AR(1), AR(2), AR(3) and AR(4) contain the p-values of the Arellano-Bond test for autocorrelation and the Hansen p-value of the Hansen test for over-identifying restrictions.

Source: own elaboration.

Conclusion

The findings of this paper validate the relationship between ICT, measured by the rate of Internet users, fixed broadband subscription, and estimated proportion of households with Internet access at home, and GDP growth as explained variables. The study was based on a dataset for 88 countries within the period 2006–2020. The results indicate a positive and significant correlation between all selected technological variables and GDP growth, taking into account the control variables. At the same time, it is worth mentioning that the selection of the group of countries affected the impact of ICT on technological development. The division of the countries into high-, low- and middle-income groups resulted in discrepancies of the results. The Internet-related variables (apart from broadband) were not significant for low- and medium-income economies.

Considering the results in the context of the upcoming Industry 4.0 revolution and extrapolating our findings, any positive results for economic growth may depend on the initial level of GDP per capita. In addition, the positive impact of automation may be visible with a significant delay, as was the case with ICT. Given the obtained results, it should be presumed that upcoming technological developments should be the subject of in-depth analysis. However, their impact should be assessed at various aggregation levels and in a long time.

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Summary

Over the past decades, the intensive development of information and communication technologies (ICT) has prompted numerous studies assessing the relationship between ICT and economic growth. Initial doubts about the importance of the Internet for economic growth have recently been replaced by conclusions supporting the positive significance of this technological revolution. However, despite the abundant research conducted in recent years, the obtained outcomes do not allow for a consensus, particularly regarding the impact of specific types of ICT. This paper investigates the connection between Internet usage and economic growth. The estimation is based on a broad group of economies (88 countries) from 2006 to 2020 using data from the International Telecommunication Union database. The results suggest a statistically significant relationship between Internet usage and GDP growth.

Keywords: ICT, economic growth, Internet, ICT infrastructure

Streszczenie

Intensywny rozwój technologii informacyjno-komunikacyjnych (ICT) w ostatnich dziesięcioleciach zaowocował licznymi badaniami oceniającymi związek pomiędzy ICT a wzrostem gospodarczym. Początkowe wątpliwości co do znaczenia Internetu dla wzrostu gospodarczego zostały ostatnio zastąpione wnioskami potwierdzającymi pozytywne znaczenie tej rewolucji technologicznej. Jednak pomimo licznych badań prowadzonych w ostatnich latach, uzyskane wyniki nie pozwalają na osiągnięcie konsensusu, szczególnie w zakresie wpływu poszczególnych technologii ICT. W artykule zbadano związek pomiędzy korzystaniem z Internetu a wzrostem gospodarczym. Szacunek opiera się na szerokiej grupie gospodarek (88 krajów) od 2006 do 2020 r. z wykorzystaniem danych z bazy Międzynarodowego Związku Telekomunikacyjnego. Wyniki sugerują istotną statystycznie zależność pomiędzy korzystaniem z Internetu a wzrostem PKB.

Słowa kluczowe: ICT, wzrost gospodarczy, Internet, infrastruktura ICT

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