Uluslararası Avrasya Sosyal Bilimler Dergisi / *The International Journal of Eurasia Social Sciences*
Cilt/Volume: 16, Sayı/No: 61, Yıl/Year: 2025, ss. / pp.: 1705-1720
E-ISSN: 2146-1961
URL: https://rrpubs.com/index.php/ijoess

The impact of economic growth on cybersecurity: Evidence from ICT development index

Şerife Deniz KOLAT[1], Gül Nazik ÜNVER[2]

[1]Batman University, Social Science Vocational Schools, Batman, Türkiye
[2]Batman University, Career Development Application and Research Center, Batman, Türkiye

Araştırma Makalesi/*Research Article-*		**DOI:** 10.70736/ijoess.1711
Gönderi Tarihi/ *Received:* 12.05.2025	Kabul Tarih/ *Accepted:* 13.09.2025	Online Yayın Tarihi/ *Published*: 15.09.2025

Abstract

In the contemporary digital era, cybersecurity has emerged as a pivotal concern for individuals, enterprises, and nations alike. Technological advancements, while providing many advantages, have resulted in an increase in cyberattacks, data breaches and cybercrimes. In this context, it is evident that economic growth and the development of technological infrastructure can directly influence the way countries formulate their cybersecurity strategies. The enhancement of ICT infrastructure in response to economic growth can facilitate increased investments in cyber security, thereby fortifying defenses against digital threats. This study investigates the effects of economic growth on cybersecurity. Within the scope of the study, the ICT Development Index (IDI) data, which encompasses 171 countries, was utilized to represent cybersecurity. The findings obtained by using the multidimensional nested panel data analysis method, which provides information on different unit dimensions nested within each other, show that there is a statistically significant and positive relationship between economic growth and IDI. The analysis method, which provides information on countries grouped according to different levels of economic development as well as the country effect, shows that there are larger increases for countries in the low and lower-middle income groups than for countries in the high and upper-middle income groups.

Keywords: Economic growth, Cybersecurity, ICT development index, Panel data analysis

Ekonomik büyümenin siber güvenlik üzerine etkisi: ICT gelişim endeksinden kanıtlar

Öz

Modern dijital çağda siber güvenlik, bireylerin, şirketlerin ve devletlerin karşılaştığı en önemli sorunlardan biri haline gelmiştir. Teknolojik ilerlemeler, birçok avantaj sağlamakla birlikte, siber saldırıların, veri ihlallerinin ve siber suçların artmasına zemin hazırlamaktadır. Bu bağlamda, ekonomik büyümenin ve teknolojik altyapının gelişmesinin ülkelerin siber güvenlik stratejilerini oluşturma biçimlerini doğrudan etkileyebileceği açıktır. Ekonomik büyümeye yanıt olarak BİT altyapısının güçlendirilmesi, siber güvenliğe yapılan yatırımların artmasını kolaylaştırabilir ve böylece dijital tehditlere karşı savunmayı güçlendirebilir. Bu çalışma ekonomik büyümenin siber güvenlik üzerine etkilerini araştırmaktadır. Çalışma kapsamında siber güvenliği temsilen 171 ülkenin yer aldığı ICT Gelişim Endeksi (IDI) verileri kullanılmıştır. Birbiri içerisine yuvalanmış farklı birim boyutları hakkında bilgi sağlayan çok boyutlu yuvalanmış panel veri analizi yönteminden yararlanılarak elde edilen bulgular, ekonomik büyüme ile IDI arasında istatistiksel olarak anlamlı ve pozitif bir ilişki olduğunu göstermektedir. Ülke etkisinin yanı sıra farklı ekonomik gelişmişlik düzeylerine göre gruplanan ülkeler hakkında bilgi sunan analiz yöntemi düşük ve alt-orta gelir grubunda yer alan ülkeler için yüksek ve üst -orta gelir grubunda yer alan ülkelere nazaran daha büyük artışların olduğunu göstermektedir.

Anahtar Kelimeler: Ekonomik büyüme, Siber güvenlik, ICT gelişim endeksi, Panel veri analizi

Sorumlu Yazar/ Corresponded Author: Şerife Deniz KOLAT, **E-posta/ e-mail:** serifedeniz.us@batman.edu.tr / thanisss@gmail.com

INTRODUCTION

Cybersecurity can be defined as the protection of a nation's digital infrastructure and the secure provision of information flow. In recent years, cybersecurity and the development of information and communication technology (ICT) have become a significant research area in the digitalization of economies. Developments in information and communication technologies have also been reflected in socio-cultural and economic life. This has also exposed vulnerabilities in the security of information and communication technologies. Elevated levels of digital security are conducive to economic growth, given that they serve to mitigate the economic ramifications of potential data breaches and cyberattacks. Inadequate provision of resources for cybersecurity, particularly in developing countries, has the potential to impede the effective utilization of ICT infrastructure and exert a detrimental effect on economic growth (Ahmed, 2021, p. 413, pp. 416-417).

Since the 2000s, the ICT Development Index (IDI) has been utilized as a metric to assess the digital development of countries. The index in question provides a quantitative metric by which to assess the digital infrastructure, internet access, digital skills and network security of nations worldwide, thereby determining their position within the global digital economy. A high IDI is indicative of a nation's investment in digital technologies and the subsequent impact these technologies exert on economic development (Ahmed, 2021, p. 422, 427). Kumari and Singh emphasize that enhancing the ICT infrastructure exerts a substantial influence on the economic growth of the nation. The enhancement of this infrastructure has the potential to expedite the economic development of nations by facilitating their digital progression. While a robust ICT infrastructure is conducive to economic growth, it is also imperative to enhance cybersecurity measures to ensure the sustainability of this growth (Kumari & Singh, 2024, pp. 7069-7072, p. 7087).

It is demonstrated that elevated levels of the IDI are indicative of a nation's enhanced digital infrastructure, which in turn exerts a favorable influence on the economic development process (Saba et al., 2024, p. 14700). Nevertheless, while the enhancement of digital infrastructure is conducive to economic growth, it is also imperative to augment the cyber security measures necessary to ensure the sustainability of this growth. Therefore, cybersecurity ensures the continuity of economic development by ensuring the security of digital infrastructure. In recent years, a plethora of studies have been conducted which analyses the

IDI levels between different countries or the network infrastructures of information and communication technologies, internet access opportunities, e-commerce, etc. The relationships between the developments in telecommunication infrastructure, the economic performance of the countries and their capacity to combat and prevent cyber threats are revealed by these studies.

Empirical studies on the ICT-growth relationship have attracted considerable attention in recent years, and a range of results and policy implications have emerged due to various factors, including different theoretical frameworks, econometric models, study periods, and countries. As countries become increasingly dependent on ICT for economic transactions, the risks posed by cyber threats have also increased. In this context, cybersecurity has become an important element in ensuring national security. While it is acknowledged that advanced ICT systems can contribute to economic growth, it is also important to recognize the potential vulnerabilities they may create against cyber-attacks. It is important to note that countries with higher levels of ICT development, as measured by the IDI, may be more vulnerable to complex cyber threats due to their dependence on digital infrastructures, even though they have advanced cybersecurity frameworks.

In recent years, a number of studies have examined the impact of ICT on economic growth from different perspectives. There are different theoretical approaches that investigate the relationship between economic growth, ICT and cybersecurity. Albimana and Sulong (2018, pp.649-650) and Suzuki (2024, p. 12, p. 16) adopted the Network Externalities Theory. It is suggested by this theory that the value of the network increases with the number of participants, but that this is accompanied by an increase in cybersecurity risks. Gomes, Mihet, and Rishabh (2024, p. 5, p. 17, p. 26) emphasize that technological advances provide economic growth using the Endogenous Growth Theory, but also highlight the critical role of security measures for the digital economy. Singh and Alshammari (2020) and Pradhan et al. (2022) stated that digital security and ICT infrastructure are affected by legal and institutional factors using Institutional Theory. In accordance with these theories, the establishment of secure digital infrastructures is contingent upon the incorporation of technological innovations and the implementation of policy frameworks.

Convergence theory posits that the correlation between economic growth and technological development will result in a convergence of digital infrastructure and cybersecurity levels between nations over time (Barro & Sala-i-Martin, 1992; Kuzior et al., 2022). According to this theory, economic development and the strengthening of ICT infrastructure accelerate the improvement of cybersecurity practices in developing countries, leading to a narrowing of the digital divide. In particular, it is accepted by experts that the acceleration of improvements in cybersecurity, in tandem with the developing economy and technological advancement, serves as an indication of this convergence (Kuzior et al., 2022; Rath et al., 2023). Nevertheless, the follow-up theory posits that the progression of ICT is a perpetual process, and that cybersecurity strategies must develop in tandem with economic growth (Stephens et al., 2008; Vasiu & Vasiu, 2018). In this process, a mutual and dynamic interaction exists between economic growth and cybersecurity measures. It has been observed that economic development increases cybersecurity investments, and that strengthened cybersecurity infrastructure also positively affects economic growth (World Economic Forum, 2025).

Empirical research has confirmed the beneficial influence of ICT indicators on the economic growth of nations. This impact has been identified in studies conducted by scientists such as Dewan and Kraemer, Ahmed and Ridzuan, and Saidi et al. (Dewan & Kraemer, 2000; Ahmed & Ridzuan, 2013; Saidi et al., 2015). However, some studies examining the effects of ICT on growth have found the effect of ICT indicators on growth to be insignificant or negative (Salahuddin & Alam, 2015; Ishida, 2015; Niebel, 2018). Fernández-Portillo et al. examined the relationship between ICT development and economic growth for OECD European Union countries, and it was found that ICT use drives economic growth (Fernández-Portillo (et al.), 2020). Appiah-Otoo and Song also observed that the impacts of ICT on rich and poor countries are not uniform (Appiah-Otoo & Song, 2021). According to Pradhan et al.'s analysis of the short- and long-term relationships between financial inclusion, economic growth, and ICT infrastructure development in 20 Indian states, it is suggested that these factors are critical for sustainable economic development (Pradhan et al., 2021). Some studies have examined the impact of ICT on economic growth, but these studies have not reached any positive or negative conclusions. According to some studies the relationship between ICT and economic growth do not necessarily casually relate each other (Shiu & Lam, 2008; Pradhan et al., 2016a, b). To summarize, the extant literature does not demonstrate a consensus on the relationship between ICT and economic growth. The underlying causes of these variations are attributable to a range of theoretical and methodological approaches, the period of study, and geographical regions. Studies have generally investigated the impact of ICT on economic growth. However, there has been a lack of analysis that simultaneously addresses the link between ICT diffusion and economic growth (Saba et al. 2024, pp. 14706-14709).

The purpose of this study is to illuminate the global repercussions of the progression of digital infrastructures with regard to economic growth and security. In this study, the IDI is employed as an indicator of cybersecurity. This Index considers both cybersecurity measures and developments in information and communication technologies together. Moreover, an investigation is conducted into the impact of economic growth performance on IDI, utilizing econometric analysis methodologies.

METHOD

Desing of the research

The study used nested panel data analysis method to examine the relationship between economic growth and the ICT of Development Index (IDI), which is a cybersecurity indicator for the 171 countries in the IDI. Eleven nations excluded from the sample due to insufficient dataset. The panel data model employed in analysis was chosen according to LR test results which determines the presence of unit effects. Due to structural changes made in the IDI, which have prevented data collection since 2017, the data could not have been collected till 2023. This is the reason why data period covers the years 2023-2024. A three-dimensional two-way panel data model estimated under the assumptions of fixed effect and random effects respectively. Hausman test is used for model selection criteria. Furthermore, due to the existence of unit effects two-dimensional panel data model is estimated.

Data collection tools

This study covers 171 countries included in the IDI (ICT Development Index) between the years 2023-2024. The reason for focusing on these years is that the IDI published by ITU between 2009 and 2017 underwent significant changes starting from 2017, and due to these changes, data limitations caused the index calculation to be carried out for all countries only as of 2023.

Table 1. Data set

Variables	Dimensions	Representation	Source
IDI	Country	μi	ITU reports
GDP per capita	Level of economic development	γj	Word bank
	Time	λt	

The dataset used in this study is shown in Table 1. The variables of GDP per capita and ITU reports is obtained from World Bank and ITU database respectively. The unit dimension of the data is based on the countries' level of economic development included in IDI, while the time dimension is represented by the years.

Bhutan, Liberia, Liechtenstein, Monaco, Palestine, San Marino, Sierra Leone, Syrian Arab Republic, Tonga, Venezuela and Yemen are among the countries in the IDI which were not included in the sample because of insufficient data. By integrating all nations in the IDI, - this study offers a more comprehensive perspective than previous research in the existing literature, which typically focuses on certain country groups based on region, income level, etc. and other features.

Data analysis

Multidimensional panel data analysis method, where unobserved effects are nested within the variables, is employed to make the predictions. The countries and country groups classified according to their level of economic development represent the unit dimension and the years represent the time dimension. Thus, in additions to country effects, the general pattern of the groups formed according to economic development levels can be observed. Yerdelen Tatoğlu (2016) derived fixed and random effect estimators for nested multidimensional panel data models by using all specifications for unnested multidimensional panel data models suggested by various researchers. Equation (1) displays the three dimensional and three effect panel data model specification.

$$\mathrm{Y_{ijt}} = \alpha + \beta\,\mathrm{X_{ijt}} + \mu i + \gamma j + \lambda t + \mathrm{u_{ijt}} \quad i=1,\ldots,N,\ j=1,\ldots M,\ t=1,\ldots T \quad (1)$$

Where i represents the unit effect of country, j represents the unit effect of countries s' economic development level, t represents the unit effect of time, $\mathrm{u_{ijt}}$ represents the error term. Under the assumption of fixed-effects, there are two different approaches one is within-group estimator and another is least square dummy variable estimator (LSDV). The LSDV estimator results are biased and cannot reveal the information about nested units within one another due to multicollinearity. The fixed-effects within-group estimator has been utilized in this study. The within-group transformation for equation (1) is shown in equation (2).

$$\left(Y_{ijt} - \overline{Y}_{i} - \overline{Y}_{j} - \overline{Y}_{t} + 2\overline{Y}\right) = \beta\left(X_{ijt} - \overline{X}_{i} - \overline{X}_{j} - \overline{X_{t}} + 2\overline{X}\right) + (u_{ijt} - \overline{u}_{i} - \overline{u}_{j} - \overline{u}_{t} - 2\overline{u}) \quad (2)$$

Where X_{ijt} represents the i[th] country in j[th] economic development level in time t. $\overline{X}$ represents the overall average, $\overline{X}_{i}$ represents the average according to unit i, $\overline{X}_{j}$ represents the average according to unit j, $\overline{X}_{t}$ represents the average according to unit t. The dependent variable and error term were also calculated in the same way.

All effects and fixed parameter are dropped from the model because of transformation. The fixed-effect within-group estimator for three three-dimensional panel data model is obtained by estimating equation (2) with pooled ordinary least squares (OLS).

Generalized OLS and maximum likelihood approaches can be used for the estimation of the random effects model. The maximum likelihood estimator has been used under the assumption of the presence of the random effects in this study. All variables are included in the model in logarithmic form where i and j represents unit dimension of country and the economic development level of that country respectively, and t represents the time dimension.

The IDI data included as dependent variable in the model is obtained from ITU Report (ITU 2023; ITU 2024) and GDP per capita included as the independent variable in the model is obtained from World Bank data source. The dimension of the economic development level is consisting of four groups as, high-income group, upper- middle-income group, lower-middle-income group, and low-income groups. The presence of unit effect is investigated through the LR test.

Table 2. LR test results

Null hypothesis	LR statistics	p value
H_0: = μi=γj=λt=0	460.96	0.00
H_a: μi=0	333.69	0.00
H_a: γj=0	141.93	0.00
H_a: λt=0	0.17	0.3381

Based on the LR test which examines the joint significance of each unit effect, the findings shown in Table 2 indicates that the null hypothesis was rejected. Under the alternative hypothesis which suggests at least one unit effect is significant, each effect was examined independently to determine which one is significant. Test results indicate that while the unit effects representing country and the economic development level are significant, the time effect is not.

Given this information, the time impact was eliminated from the model shown in equation (3) to obtain three-dimensional two-unit effect model used in this study in equation (4).

$$\mathrm{LIDI}_{\mathrm{ijt}} = \alpha + \beta\,\mathrm{LGDP}_{\mathrm{ijt}} + \mu i + \gamma j + \lambda t + \mathrm{u}_{\mathrm{ijt}} \quad (3)$$

$$\mathrm{LIDI}_{\mathrm{ijt}} = \alpha + \beta\,\mathrm{LGDP}_{\mathrm{ijt}} + \mu i + \gamma j + \mathrm{u}_{\mathrm{ijt}} \quad (4)$$

$$i=1,\ldots\ldots,N,\ j=1,\ldots M\ ,\ t=1,\ldots.T$$

In this case, α represents the model fixed term, β represents the independent variable of per capita income coefficient, $\mathrm{u}_{\mathrm{ijt}}$ represents the error term, μi, γj and λt represents country, economic development level and time unit effects respectively. Equation (5) and (6) indicate the within-group transformation for the model in equation (4):

$$\widetilde{\mathrm{LIDI}_{\imath\jmath t}} = \mathrm{LIDI}_{\mathrm{ijt}} - \overline{\mathrm{LIDI}_{\imath}} - \overline{\mathrm{LIDI}_{\jmath}} + \overline{LIDI} \quad (5)$$

$$\widetilde{\mathrm{LGDP}_{\imath\jmath t}} = \mathrm{LGDP}_{\mathrm{ijt}} - \overline{\mathrm{LGDP}_{\imath}} - \overline{\mathrm{LGDP}_{\jmath}} + \overline{LGDP} \quad (6)$$

The within-group estimators of the fixed effects model are provided by the estimators that are generated by estimating the model using the pooled OLS method by using the additional variables that are derived from these transformations. Where $\bar{X}$ represents the overall average, $\overline{\mathrm{X}_{\jmath}}$ represents the average according to unit j, $\overline{\mathrm{X}_{\mathrm{t}}}$ represents the average according to unit t and $\widetilde{\mathrm{X}_{\imath\jmath t}}$ represent the within-group estimators. The representation for the dependent variable is similar with independent variable which is shown in equation (6).

FINDINGS

After determining the panel data model to be used in the analysis, fixed and random effects model estimations were made.

Table 3. Fixed-effect and random-effect estimator results

Name of Test	Fixed effect- within group estimator	p value	Random effect maximum likelihood estimator	p value
LGDP	0.2097	0.000	0.1361	0.000
Wald statistic			122.47	0.000
F statistic	1615.62	0.000		

Table 3 displays the results of fixed and random effects models. It is evident from analysis that GDP per capita has positive and statistically significant impact on IDI according to both fixed effect within-group estimator and random effect maximum likelihood estimator. The overall significance of the models have been tested by using Wald test and F test. Both the Wald test for the random effects model and the F-test for the fixed effects model have shown the model's overall significance. According to the results an increase in per capita GDP leads an increase in IDI referring that economic development has statistically significant and positive impact on IDI.

Table 4. Test of homoscedasticity, parameter heterogeneity and model selection

Name of test	Test Statistics	p value
Hausman test	218.85	0.000
Breush-Pagan/Cook-Weisberg test	265.28	0.000
S test (Swamy 1970)	1892.62	0.000

Table 4 displays the presence of heteroscedasticity, the results of parameter heterogeneity test and model selection criteria. The presence of heteroscedasticity was tested by using Breusch-Pagan/Cook-Weisberg (1980-1983) test. Swamy's (1970) S test was used to test for parameter heterogeneity by income groups. The test results supported the alternative hypothesis, showing that the parameters are not homogeneous. Hausman test employed for model selection. Based on the Hausman test statistics the alternative hypothesis which asserts that the fixed effects model is consistent and random effect model is inconsistent was accepted. According to fixed effects estimator results a 1% increase in per capita income is approximately associated with a 0.21% increase in IDI for the 160 countries included in the analysis.

The findings of the LR test show the influence of both country and economic development level of countries. Beside that S test (Swamy, 1970) results supports parameter heterogeneity. Based on this heterogeneity, estimations were made using a two-dimensional panel data model divided by economic development level.

Table 5. Two-dimensional panel fixed effect and random effect estimation results according to economic development level

	Variables	Fixed effect estimator	Random effect estimator	Hausman test statistics	F test sstatistics
High-Income group	LGDP Constant	**0.0667***** **3.8139*****	0.0635*** 3.8446***	0.13	15.04***
Upper- Middle Income group	LGDP Constant	**0.2755*** **1.9046**	0.1694*** 2.8472***	0.47	32.81***

	Variables	Fixed effect estimator	Random effect estimator	Hausman test statistics	F test sstatistics
Lower-Middle Income group	LGDP Constant	**0.4667**** **0.5106**	0.3768*** 1.2018***	0.18	22.72***
Low- Income group	LGDP Constant	3.6662*** -20.050	**0.4637***** **0.4783**	11.67***	15.01***

Note: The models shown in dark color are the ones recommended according to the Hausman test statistics. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. The presence of unit effects was tested using the F-test.

Table 5 presents the random effects and fixed effects estimators for the groups based on economic development levels. All parameters are statistically significant in each model. The Hausman test statistic were used to choose the models for each group. While the random effects estimator is effective for low-income countries, the fixed effects estimations are consistent for lower- middle income, upper-middle income and high-income groups. For high-income countries, a 1% increase in per capita income results in a 0.06% increase in the ICT Development Index, while for countries with a low level of economic development, a 1% increase in per capita income causes a 0.46% increase in the ICT Development Index. For countries in the upper-middle income group, a 1% increase in per capita income leads to a 0.27% increase in the ICT Development Index, while for countries in the lower-middle income group, it leads a 0.46% increase in the ICT Development Index. Therefore, it can be said that larger increases are observed for countries in the low and lower-middle-income groups compared to those in the upper-middle and high-income groups.

DISCUSSION AND CONCLUSION

This study has provided a significant analysis by evaluating the impact of economic growth on digital infrastructure development and its reflection on cyber security capacities through the IDI. The multidimensional model encompassing 171 countries, founded upon panel data analysis, has demonstrated that economic growth exerts a statistically significant and positive influence on IDI. This result demonstrates that technological progress can serve as an endogenous source of economic growth, as predicted by the Endogenous Growth Theory. Furthermore, it has been observed that this phenomenon can indirectly impact security capacity through the process of digitalization.

The findings demonstrate that the effect of economic growth on IDI is more pronounced, particularly in low and lower-middle income countries. This situation demonstrates that the marginal returns on investments in information technologies are higher in these countries, and that digitalization and security capacity are undergoing a faster transformation. This phenomenon aligns with the principles of Convergence Theory. It is evident that developing countries have the potential to bridge the digital divide with those already developed by means of technology transfer, infrastructure investments and institutional capacity building. However, it is evident that an increase in IDI levels does not necessarily guarantee an enhancement in the realm of cybersecurity. As posited by various scholars in the relevant literature, the development of digital infrastructure has been demonstrated to result in the creation of more complex and wide-ranging attack surfaces. In contrast, Salahuddin and Alam (2015) posit the view that the impact of ICT investments on economic growth in high-income countries may be constrained. However, the findings of this study demonstrate that, at this stage of digitalization, the direction of investment should be directed more towards security and institutional quality.

When evaluated in the context of Institutional Theory, in order for the increase in IDI caused by economic growth to have a permanent cybersecurity effect, this growth must be supported by institutional capacity. As demonstrated by researchers Pradhan et al. (2022) and Singh and Alshammari (2020), the efficacy of digital security policies is contingent on the enhancement of institutional capacity and the effective implementation of the legal framework. The resources provided by growth should be directed not only to infrastructure, but also to areas such as legal regulations, human resources and institutional capacity. Whilst researchers such as Dewan and Kraemer (2020), Ahmed and Ridzuan (2013), and Saidi et al. (2015) have indicated that investments in ICT have a positive effect on economic growth, Salahuddin and Alam (2015) and Niebel (2018) have argued that this effect may be statistically weak or insignificant in some cases. Moreover, the contribution of the study to the extant literature is twofold. Firstly, it demonstrates the use of IDI as an indicator of digitalization. Secondly, it reveals that this index is a structural indicator that can reflect cybersecurity capacity. In this respect, IDI can be regarded as a two-way indicator, in the sense that it reflects both technological development and increasing cyber risks. The evaluation of IDI, which is predominantly incorporated within growth-focused analyses in the extant literature, is offered from a security perspective in this study, thereby providing a novel perspective on conventional approaches. When evaluated within the framework of Endogenous Growth Theory, these results gain greater significance. While this theory posits that technological advances are an intrinsic source of economic growth, the findings of the study also demonstrate that economic growth exerts an indirect influence on cybersecurity levels, particularly through investments in information and communication infrastructure. However, it is important to note that advancements in digital technology can also increase the risk of cyber threats. Indeed, as has been emphasized in the extant literature, countries with advanced IDI levels are also exposed to a higher risk of cyber-attack. In this context, it is evident that regulations and preventive strategies for cybersecurity should be developed in a synchronized manner with the augmentation of digital capacity.

Consequently, economic growth has been identified as a catalyst for digitalization. However, a multifaceted approach is imperative to ensure the seamless execution of this transformation, with due consideration for security concerns. The findings of this study indicate that policy makers should consider integrating macroeconomic development strategies with cybersecurity policies. This is particularly pertinent in the context of developing countries, where the enhancement of regulatory frameworks, the cultivation of human resources, and the dissemination of cyber risk awareness are of paramount importance. These measures are essential to ensure that the digitalization engendered by economic growth does not concomitantly engender an escalation in security vulnerabilities. Conversely, the pursuit of growth-based digitalization may exacerbate economic vulnerabilities over time.

Suggestions

In order to address the impact of economic growth on cybersecurity more comprehensively, it’s vital for the data of all nations included in the IDI to be available. This will enable observation of the changes in terms of different economic level. In this context, it is recommended to provide a data on country-by-country basis and to analyze longer time series.

The most important restriction of the study is that the analysis cannot be encompass all 171 nations listed in the IDI owing to data insufficiency. The ability to gather data on a country-by-country basis will allow for more comprehensive analyses to be carried out with the infrastructure investments that will occur in the upcoming years.

In summary, this study contributes to the existing literature by examining the relationship between economic growth and cybersecurity for all countries included in the IDI, differentiating itself from research that focus on specific country groups or regions. Thus, it paves the way to considering of larger samples and different econometric methods for future research.

Limitations and strengths

The study is not without its limitations. A primary constraint arises from data availability: although the ICT Development Index (IDI) encompasses 171 countries, eleven nations were excluded from the sample owing to insufficient datasets. Moreover, the period of analysis was confined to 2023–2024 due to structural revisions in the IDI after 2017, which prevented the construction of longer time series. This temporal restriction narrows the capacity to observe cyclical dynamics and long-run causalities between economic growth and cybersecurity capacities. In addition, the study is based exclusively on secondary data obtained from ITU and World Bank sources. While these sources are globally recognized, the potential for reporting inconsistencies or measurement discrepancies cannot be fully discounted. Taken together, these factors necessitate cautious interpretation of the results, particularly when extrapolating them beyond the short time horizon or across diverse geopolitical contexts.

Nevertheless, the study demonstrates significant strengths that reinforce the robustness of its findings. Methodologically, the use of a multidimensional nested panel data analysis provides a distinct advantage over conventional approaches, as it allows for the simultaneous assessment of both country-specific and income-level effects. This multilevel perspective enables a more nuanced understanding of how economic development interacts with digital infrastructure and cybersecurity. Another notable strength lies in the breadth of the dataset: by including nearly the full spectrum of countries across income groups, the study offers a more comprehensive comparative analysis than prior research, which frequently focused on selected regions or specific income categories. Furthermore, the employment of rigorous statistical procedures—such as LR tests, Hausman tests, and heteroscedasticity diagnostics—bolsters the reliability and validity of the empirical results. Finally, by conceptualizing the IDI not only as a measure of digital infrastructure but also as a structural indicator of cybersecurity capacity, the study introduces a novel theoretical contribution, thereby bridging economic growth literature with the emerging discourse on digital security.

REFERENCES

Ahmed, E. M. (2021). Modelling information and communications technology cyber security externalities spillover effects on sustainable economic growth, *Journal of the Knowledge Economy*, (12), 412-430, https://doi.org/10.1007/s13132-020-00627-3.

Ahmed, E. M., & Ridzuan, R. (2013). The impact of ICT on East Asian economic growth: Panel estimation approach, *Journal of the Knowledge Economy*, *4*(4), 540-555. http://doi.org/10.1007/s13132-012-0096-5

Albimana, M. M., & Sulongb, Z. (2018). Information and communication technology, production and economic growth: A theoretical nexus, *International Journal of Academic Research in Business and Social Sciences*, *8*(12), 642–657. http://doi.org/10.6007/IJARBSS/v8-i12/5062

Appiah-Otoo, I., & Song, N. (2021). The impact of ICT on economic growth-comparing rich and poor countries, *Telecommunications Policy*, *45*(2). https://doi.org/10.1016/j.telpol.2020.102082

Barro, R. J., & Sala-i-Martin, X. (1992). Convergence, *Journal of Political Economy*, *100*(2), 223-251. http://doi.org/10.1086/261816

Cook, R. D., & Weisberg, S. (1983). Diagnostics for heteroscedasticity in regression, *Biometrika, 70*(1), 1-10. https://doi.org/10.1093/biomet/70.1.1

Dewan, S., & Kraemer, K. L. (2000). Information technology and productivity: Evidence from country level data, *Management Science*, *46*(4), 548–562. https://doi.org/10.1287/mnsc.46.4.548.12057

Fernández-Portillo, A., Almodóvar-González, M., & Hernández-Mogollón, R. (2020). Impact of ICT development on economic growth. A study of OECD European union countries, *Technology in Society*, (63), https://doi.org/10.1016/j.techsoc.2020.101420

Gomes, O., Mihet, R., & Rishabh, K. (2023). Cyber risk-driven innovation in the modern data economy, *SSRN Electronic Journal*, https://serval.unil.ch/en/notice/serval:BIB_199C41D40028

Ishida, H. (2015). The effect of ICT development on economic growth and energy consumption in Japan, *Telematics and Informatics*, *32*(1), 79-88. https://doi.org/10.1016/j.tele.2014.04.003

ITU (2023). Measuring digital development - ICT development index 2023, https://www.itu.int/hub/publication/d-ind-ict_mdd-2023-2/

ITU (2024). Measuring digital development - ICT development index 2024, https://www.itu.int/itu-d/reports/statistics/idi2024/

Kumari, R., & Singh, S. K. (2024). Impact of ICT infrastructure, financial development, and trade openness on economic growth: New evidence from low- and high-income countries, *Journal of the Knowledge Economy*, (15), 7069-7098. http://doi.org/10.1007/s13132-023-01332-7

Kuzior, A., Vasylieva, T., Kuzmenko, O., Koibichuk, V., & Brozek, P. (2022). Global digital convergence: Impact of cybersecurity, business transparency, economic transformation, and AML efficiency, *Journal of Open Innovation: Technology, Market and Complexity*, *8*(4), 195, https://doi.org/10.3390/joitmc8040195

Niebel, T. (2018). ICT and Economic growth-comparing developing, emerging and developed countries, *World Development*, (104), 197-211. https://doi.org/10.1016/j.worlddev.2017.11.024

Pradhan, R. P., Arvin, M. B., & Hall, J. H. (2016a). Economic growth, development of telecommunications infrastructure, and financial development in Asia, 1991–2012, *The Quarterly Review of Economics and Finance*, (59), 25-38. https://doi.org/10.1016/j.qref.2015.06.008

Pradhan, R. P., Arvin, M. B., Mittal, J., & Bahmani, S. (2016b). Relationships between telecommunications infrastructure, capital formation, and economic growth, *International Journal of Technology Management*, *70*(2-3), 157-176. https://doi.org/10.1504/IJTM.2016.075158

Pradhan, R. P., Arvin M. B., Nair, M. S., Hall, J. H., & Bennett, S. E. (2021). Sustainable economic development in India: The dynamics between financial inclusion, ICT development, and economic growth. *Technological Forecasting and Social Change*, (169), 120758. https://doi.org/10.1016/j.techfore.2021.120758

Pradhan, R. P., Arvin M. B., Nair M., Hall J.H., & Bennet S.E. (2022). Institutional development in an information-driven economy: Can ICTs enhance economic growth for low- and lower middle-income countries?, *Information Technology for Development*, *28*(3), 468-487. https://doi.org/10.1080/02681102.2022.2051417

Rath, B. N., Panda B., & Akram V. (2023). Convergence and Determinants of ICT Development in case of emerging market economies, *Telecommunications Policy*, *47*(2), https://doi.org/10.1016/j.telpol.2022.102464

Saba, C. S., Ngepah, N., & Odhiambo, N. M. (2024). Information and communication technology (ICT), growth and development in developing regions: Evidence from a comparative analysis and a new approach, *Journal of Knowledge Economy*, (15), 14700-14748. http://doi.org/10.1007/s13132-023-01571-8

Saidi, K., Hassen, L. B., & Hammami, M. S. (2015). Econometric analysis of the relationship between ICT and economic growth in Tunisia, *Journal of the Knowledge Economy*, *6*(4), 1191-1206. http://doi.org/10.1007/s13132-014-0204-9

Salahuddin, M., & Alam, K. (2015). Internet usage, electricity consumption and economic growth in Australia: A time series evidence, *Telematics and Informatics*, *32*(4), 862-878. https://doi.org/10.1016/j.tele.2015.04.011

Shiu, A., & Lam, P. L. (2008). *Causal relationship between telecommunications and economic growth: A study of 105 countries.* In 17th Biennial Conference of the International Telecommunications Society, Montreal, 24-27.

Singh, H.P. & Alshammari T. S. (2020). An institutional theory perspective on developing a cyber security legal framework: A case of Saudi Arabia, *Beijing Law Review*, *11*(3), 637-650, https://doi.org/https://doi.org/10.4236/blr.2020.113039

Stephens, K. K., Sornes, J. O., Rice, R. E., Browning, L. D., Sætre A. S. (2008). Discrete, sequential, and follow-up use of information and communication technology by experienced ICT users, *Management Communication Quarterly*, 22(2), 197-231. https://doi.org/10.1177/0893318908323149

Suzuki, R. (2024). Impact of 5GTechnology on Mobile Internet Usage in Japan. *International Journal of Technology and Systems*, *9*(4), 12 – 22. https://doi.org/10.47604/ijts.2818

Swamy, P. A. (1970), Efficient inference in a random coefficient regression model, *Econometrica: Journal of the Econometric Society, 38*(2), 311-323. https://doi.org/10.2307/1913012

Vasiu, I. & Vasiu, L. (2018). Cybersecurity as an essential sustainable economic development factor, *European Journal of Sustainable Development*, *7*(4), https://doi.org/10.14207/ejsd.2018.v7n4p171

Yerdelen Tatoğlu, F. (2016), Various approaches for the estimation of the three-dimensional fixed and random effect models, Eurasian Academy of Sciences Eurasian Econometrics, *Statistics & Emprical Economics Journal*, (5), 60-70.

World Bank Development Indicators https://databank.worldbank.org/source/world-development-indicators

World Economic Forum (2025). Global Cybersecurity Outlook, https://www.weforum.org/publications/global-cybersecurity-outlook-2025/

KATKI ORANI *CONTRIBUTION RATE*	**AÇIKLAMA** *EXPLANATION*	**KATKIDA BULUNANLAR** *CONTRIBUTORS*
Fikir ve Kavramsal Örgü *Idea or Notion*	Araştırma hipotezini veya fikrini oluşturmak *Form the research hypothesis or idea*	Şerife Deniz KOLAT Gül Nazik ÜNVER
Tasarım *Design*	Yöntem ve araştırma desenini tasarlamak *To design the method and research design.*	Şerife Deniz KOLAT Gül Nazik ÜNVER
Literatür Tarama *Literature Review*	Çalışma için gerekli literatürü taramak *Review the literature required for the study*	Gül Nazik ÜNVER
Veri Toplama ve İşleme *Data Collecting and Processing*	Verileri toplamak, düzenlemek ve raporlaştırmak *Collecting, organizing and reporting data*	Şerife Deniz KOLAT
Tartışma ve Yorum *Discussion and Commentary*	Elde edilen bulguların değerlendirilmesi *Evaluation of the obtained finding*	Şerife Deniz KOLAT Gül Nazik ÜNVER

Destek ve Teşekkür Beyanı/ *Statement of Support and Acknowledgment*

Bu çalışmanın yazım sürecinde katkı ve/veya destek alınmamıştır.

No contribution and/or support was received during the writing process of this study.

Çatışma Beyanı/ *Statement of Conflict*

Araştırmacıların araştırma ile ilgili diğer kişi ve kurumlarla herhangi bir kişisel ve finansal çıkar çatışması yoktur.

Researchers do not have any personal or financial conflicts of interest with other people and institutions related to the research.

Etik Kurul Beyanı/ *Statement of Ethics Committee*

Bu araştırma yalnızca ikincil verilerin analizine dayandığından ve insan veya hayvan deneklerin doğrudan katılımını içermediğinden, kurumsal bir etik kuruldan onay alınmasını gerektirmemektedir.

As this research relies solely on the analysis of secondary data and does not include any direct involvement of human or animal subjects, it does not require approval from an institutional ethics committee.