Analyzing the Influence of Digitalization on Income Inequality: A Comparative Analysis of Developed and Developing Economies

Saima Perveen (Corresponding Author), Department of Economics, Quaid-e-Azam University, Islamabad, Pakistan
Email: psaima262@gmail.com

Muhammad Tariq Majeed, Department of Economics, Quaid-e-Azam University, Islamabad, Pakistan

ABSTRACT

This study aims to analyze the influence of digitalization on income inequality, conducting a global-level analysis as well as analyses for developed and developing nations. The analysis is performed using a sample of 127 countries over the period 2000–2022 and employs panel data techniques such as pooled OLS, fixed effects, random effects, and System-GMM. The study uses three key ICT indicators: internet users, mobile penetration rates, and broadband service subscribers. The results show that digitalization decreases income inequality at the global level. However, the analysis of developed and developing countries reveals contrasting findings. In developed countries, digitalization is found to increase income inequality, while in developing countries, it decreases income inequality. The findings of this study have significant policy implications. To harness the knowledge economy and reduce inequality, policymakers in developing nations need to prioritize ICT infrastructure, while those in developed nations need to focus on the distributional implications of ICT investments.

Keywords: Digitalization, income inequality, Panel data analysis, Developed economies, Developing economies

JEL classification codes: O33, D63, F43, I32, O47

1. INTRODUCTION

Digitalization, or the process of incorporating digital technologies into numerous aspects of society and the economy, is transforming the way we live and work. This change has important implications for income inequality, as individuals' access to and engagement in the digital economy might affect their earning potential and overall economic performance. The term *digitalization* was first introduced by Schwab (2016) to describe the considerable impact of digital technologies on various facets of society and business. It has gained popularity in recent years due to the rapid advancement of digital technologies.

The digital economy includes all economic activities that rely on digital technologies, such as e-commerce, online services, digital payments, and digital platforms. The use of these technologies creates opportunities for economic growth and innovation (Majeed & Ayub, 2018; Brynjolfsson & McAfee, 2014) but also raises concerns about job displacement and income inequality (Behar, 2016).

Inequality can be defined as a deviation from equality. Thus, if any individual earns less than their proportionate share of total income, the distribution of income would be considered unequal (Schutz, 1951). It is widely recognized that the highest 5% of earners account for 40% of total income, while the top 1% receive approximately 15% of the overall revenue. However, according to Braun (1997), merely 1% of global income is distributed to the 20% of people living in poverty.

This issue is pervasive and not confined to any single country. Scholars like Milanovic (2005) have highlighted the global expansion of income inequality. Furthermore, various studies demonstrate that inequality levels vary significantly across countries and regions (Shah & Krishnan, 2023).

Income inequality is a significant economic issue, particularly in the context of the rapid expansion of digitalization. The advancement of ICT and digital technology has profoundly influenced the distribution of wealth in modern society. This trend underscores the critical importance for social activists, economists, and policymakers to address income disparity in the digital age and create equitable economic opportunities for all. While the relationship between income inequality and digitalization has been extensively studied, few comprehensive studies have employed panel data methodologies to examine these connections across countries on a global scale. Given that the effects of digitalization vary between developed and developing nations, it is essential to compare these economies. Further research is needed to better understand this relationship and its implications for societal and economic progress.

Researchers have extensively studied the relationship between digitalization and income inequality (Yin & Choi, 2022; Consoli *et al.*, 2023; Richmond & Triplett, 2018; Setyadi *et al.*, 2023). These studies suggest that advancements in digital technologies can influence social wealth disparities. Numerous authors have argued that digitalization helps reduce economic inequality (Yin & Choi, 2022; Moraes *et al.*, 2023). The digital economy fosters opportunities for economic growth, innovation, and job creation. Individuals with digital skills and access to digital services are more likely to secure higher-paying positions in industries such as software development, digital marketing, and information technology. This increased earning potential for digitally proficient individuals can contribute to reducing economic disparity.

However, concerns remain that digitalization might exacerbate economic inequality (Behar, 2016). Unequal access to digital resources and skills creates a digital divide, leaving some populations unable to participate fully in the digital economy. This divide highlights the need for inclusive policies to ensure that the benefits of digitalization are equitably distributed across all segments of society.

The significance of this study lies in uncovering the various ways digitalization influences income distribution within society. By examining the effects of digital advancements on income inequality, the study aims to provide valuable insights for policymakers and business leaders. Understanding these dynamics is essential for formulating effective policies that can redistribute the benefits of digitalization equitably, particularly as automation risks marginalizing certain groups. The findings of this study will help identify potential policy solutions to address emerging inequalities, ensuring a more equitable distribution of income and fostering inclusive economic growth in the digital age.

The primary objective of this study is to develop a comprehensive understanding of the impact of digitalization on income inequality at a global level. Additionally, the study investigates the variations in this relationship between developed and developing nations. While existing international research explores the intersection of wealth and technology, a broader assessment that considers the distinct circumstances of developed and developing countries remains necessary. To fill this research gap, this study employs a quantitative analysis of panel data from 127 countries spanning the period from 2000 to 2022. The analysis will first examine the overall global relationship between digitalization and income inequality trends. Subsequently, it will conduct a comparative analysis to identify and contrast the dynamics of this relationship within the contexts of developed and developing economies. This approach aims to provide valuable insights into how a nation’s level of economic development shapes the nexus between digitalization and inequality.

The outline of this paper is as follows: Section 2 provides a summary of previous studies; Section 3 outlines the study's methodology; Section 4 describes the data; Section 5 discusses the empirical findings; and Section 6 concludes with recommendations.

2. LITERATURE REVIEW

Digitalization can reduce income inequality through several mechanisms. According to Noh and Yoo, (2008), it enhances economic performance by lowering transaction costs and increasing productivity. Additionally, it promotes equality by creating employment opportunities through outsourcing and ICT-based entrepreneurship. Furthermore, digitalization enables more efficient resource utilization and provides disadvantaged groups with improved access to markets, information, and resources, thereby contributing to income growth (Majeed, 2020).

The relationship between income disparities and digitalization has been the focus of several studies. However, limited research has explored the effects of digitalization on economic inequality, despite the 1990s being a pivotal era for the emergence of digital technology (Danziger & Gottschalk, 1990). Over time, researchers began to delve deeper into this connection. Autor *et al.* (1992) emphasized the growing importance of computer skills in the labor market and how their adoption has widened the wage gap between skilled and unskilled workers. Similarly, Krueger (1997) highlighted the significance of digital literacy in economic life, demonstrating that employees who used computers at work earned substantially more than those who did not.

During the early 2000s, research further explored how digitalization was transforming the global economy. Brynjolfsson and Hitt, (2000) analyzed the impact of IT investments on worker productivity and income. Their findings revealed that while IT investments significantly enhanced efficiency and earnings, these benefits were not evenly distributed, favoring higher-skilled individuals and thereby widening the income gap. Building on these insights, Atkinson (2002) investigated the macroeconomic effects of digitalization. He highlighted that while digital technologies drive economic growth, they also exacerbate income disparities among workers due to varying levels of digital proficiency. However, more recent research by Setyadi *et al.* (2023) challenges this narrative, demonstrating that advancements in ICT may actually reduce income inequality rather than exacerbate it.

From an empirical perspective, numerous studies at various levels of analysis have shown that digitalization can contribute to reducing income disparity. Research conducted globally supports the notion that digitalization helps mitigate income inequality (Garrity, 2015; Richmond & Triplett, 2017; Canh *et al.*, 2020; Moraes *et al.*, 2023; Lin *et al.*, 2017; Ndjobo & Otabela, 2023). Regional studies have also highlighted both positive and negative effects of digitalization on wealth inequality (Cioaca *et al.*, 2020; Yin & Choi, 2022; Adams & Akobeng, 2021; Mutiiria *et al.*, 2020). Furthermore, several studies demonstrate that digitalization reduces income disparities at the individual level (Tchamyou *et al.*, 2019; Yao & Ma, 2022).

Richmond and Triplett (2017) examined the empirical relationship between ICT and income inequality in a global context. Their findings indicate that the impact of ICT on income inequality varies depending on the type of ICT being utilized. For instance, an increase in smartphone users tends to reduce inequality, whereas fixed internet access can sometimes exacerbate income disparities.

Between 2002 and 2014, Canh *et al.* (2020) analyzed the impact of ICTs on economic disparities in 87 economies worldwide, including 41 high-income and 46 low- to middle-income countries. Their findings closely align with those of Triplett and Richmond (2017). Similarly, Moraes *et al.* (2023) explored the relationship between income disparities and both digital and physical banking access using dynamic panel data from 2001 to 2019, covering 116 countries. The study revealed that both forms of financial access contribute to reducing inequality.

Lin *et al.* (2017) employed a spatial quantile regression model to investigate how the digital divide influences income disparities in high- and low-income countries. Their findings indicate that internet usage significantly reduces economic disparity by enhancing production and accelerating technological advancements. These results align with those of Moraes *et al.* (2023), Canh *et al.* (2020), and Richmond and Triplett (2018). However, the findings of Richmond and Triplett (2018) and Canh *et al.* (2020) diverge from Lin *et al.* (2017) in the context of low-income economies, where internet usage was found to exacerbate income disparities.

At a regional level, Cioaca *et al.* (2020) analyzed the impact of the digital society transition on income distribution within the European economy, using panel data from 28 European Union member states between 2008 and 2018. The study revealed a negative correlation between the shift toward a digital society and income disparity, suggesting that digitalization may contribute to reducing inequality in this context.

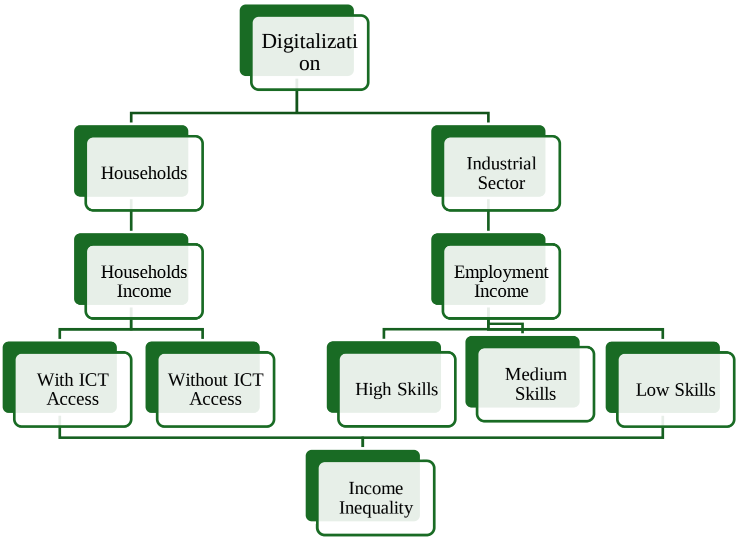
In a study focused on G20 countries, Yin and Choi, (2022) examined the impact of digitalization on economic disparity, using data from 2008 to 2018. They assessed digitalization through the separate effects of internet, mobile, and fixed broadband usage, enabling a nuanced analysis of the distinct influences of these various ICTs. Their findings for the entire G20 sample reveal a negative relationship between internet usage and income disparity, while mobile and broadband usage did not show any significant effects. Comparing these results to existing literature is challenging, as, to the best of our knowledge, there are no studies that specifically analyze the individual effects of different ICTs on income inequality across both middle- and high-income economies.

Richmond and Triplett (2018) find that internet usage does not significantly impact income disparity in middle- or high-income nations. However, it is important to note that their study does not analyze these country samples collectively, unlike Yin and Choi (2022), so it is difficult to conclude that their results are inconsistent. Conversely, Cioaca *et al.* (2020), who studied European Union member states, which include a mix of middle- and high-income countries, also find that the internet reduces income inequality. However, their study does not provide a comparison regarding the effects of mobile and broadband subscriptions.

The findings are less consistent in studies focused on low- or lower-middle-income countries, as compared to those examining regions or groups of countries predominantly made up of high- and upper-middle-income nations. For instance, Adams and Akobeng, (2021) explored the immediate effects of ICT on income inequality using the dynamic two-step system GMM method and panel data covering 46 African economies from 1984 to 2018. Their findings suggest that ICT measures, such as internet usage, fixed broadband services, and mobile cellular penetration, contribute to a reduction in income inequality.

Furthermore, regional and local studies by Patria and Erumban (2020) and Ganjoei *et al.* (2021) suggest that the relationship between ICT and income disparity is influenced by the level of ICT adoption in a country. Patria and Erumban, (2020) conducted an investigation into ICT adoption across 33 Indonesian provinces between 2012 and 2016. Their analysis found that at lower levels of ICT adoption, income inequality worsens, whereas higher levels of adoption tend to reduce it. This implies an inverted U-shaped relationship between ICT adoption and income inequality. Additionally, their study identified a threshold at which the positive impact of further ICT adoption on income inequality shifts to a negative one. Figure 1 provides a summary of how the adoption of digital technologies can influence income inequality.

Figure 1 : The links between Digitalization and Income Inequality



Source: Patria & Erumban (2020)

This study contributes to existing literature by utilizing various measures of digitalization to assess their relative impact on income inequality. It broadens the scope of digitalization's effects on income inequality, incorporating a comprehensive view that spans both regional and global contexts. Unlike studies with limited time frames, this research employs a longer time span and includes a large number of countries, providing a more robust analysis. Additionally, the study rigorously evaluates the validity of conflicting theories regarding the relationship between digitalization and income disparity.

3. METHODOLOGY

This section provides the description of the theoretical model, econometric techniques, and estimation method employed for empirical analysis.

3.1. Theoretical Framework

This theoretical framework is underpinned by two key theories: the skill-biased technological change (SBTC) theory and the network effects theory, both of which provide insight into the relationship between digitalization and income inequality.

The **SBTC theory** posits that the advancement of information and communication technology (ICT) requires more skilled human capital, thus leading to an increase in the wage disparity between skilled and unskilled workers. According to this view, digitalization tends to increase income inequality by offering new opportunities to educated and skilled workers, while leaving behind those without the necessary skills.

The **network effects theory**, on the other hand, emphasizes the role of ICT in compounding network externalities and enhancing the performance of individuals and firms in the digital economy. However, this theory also suggests that ICT increases income inequality due to the dichotomy of access: those with access to technology can reap its economic benefits, while those without it are excluded, leading to disparities in economic returns.

In light of these theories, this study builds upon **the Endogenous Growth Theory**, which highlights the role of technology in economic growth. According to this theory, digitalization boosts productivity and GDP per capita. However, the benefits of digitalization may be concentrated among skilled individuals, leading to increased income inequality. **GDP growth** is commonly used in prior literature, such as in the studies by Yin and Choi, (2022) and Xu, (2023), to model the relationship between economic performance and income inequality.

Beyond GDP, this study acknowledges the complexity of income inequality and incorporates additional factors that influence income distribution. For instance, **trade openness** and **inflation** have been identified as key drivers of income inequality. Studies by Yin and Choi, (2022) and Xu (2023) suggest that trade openness can affect income distribution by exposing workers to international competition, while inflation alters the institutional structure and income patterns.

Additionally, **urbanization** plays a significant role in income inequality. The concentration of economic opportunities and resources in urban areas often leads to higher urban incomes compared to rural areas, exacerbating income inequality. Richmond and Triplett (2017) and Xu, (2023) emphasize that urbanization, as part of economic growth and structural change, has direct implications for income distribution and the evolution of societal inequality.

By incorporating these theoretical perspectives, this study aims to establish a comprehensive framework that links digitalization with income inequality while considering various economic and structural factors.

Income Inequality= f (ICT, GDP per capita, Inflation, FDI, Trade openness, Urbanizations)

3.2 Empirical Model

The empirical model can be represented by the following econometric equation:

$$(Gini)i,t = \beta o + \beta 1(ICT)i,t + \beta 2log(GDPpc)Xi,t + \beta 3(Inf)Xi,t + \beta 4(FDI)Xi,t + \beta 5(TOP)Xi,t + \beta 6(Urb)Xi,t + \mu i,t + \varepsilon i,t \quad (1)$$

where $Gini_{it}$ is the Gini index of country i in year t. ICT_{it} is the Information Communication technology of country i in year t. We used three key indicators of ICT: cell phone penetration, internet users, and broadband connection, to construct an ICT index, which we then employed to measure the implication of digitalization on income disparity. The control variables, which include openness to trade, inflation, FDI, GDP per capita, and urbanization, are represented byX_{it}. The econometric equation represents a linear regression model where $\beta_0$is representing the constant term,β_1, β_2, β_3, β_4, and $\beta_5$are the coefficients representing the effects of the explanatory variables, while the term µ denotes the influence of a particular country, andε is the error term. Similarly, terms i and t stand for the country and the corresponding time period, respectively.

Using multiple panel regression estimators, we investigate the implication of technological advancement on disparities in income. We specifically use the pooled ordinary least squares, fixed effects, random effects, and GMM. Individuals are simply grouped together in the pooled OLS model, with no consideration given to individual or time differences (Adkins & Hill, 2011). If there is unobserved heterogeneity, this method could lead to biased conclusions. This needs to be addressed, and accurate findings can be obtained by using the panel's estimations of FE or RE. The FE model accounts for variations among people, while the RE model assumes no relationship between the explanatory factors and the individual consequences.

The use of the FEM and REM estimations can potentially be verified using the Hausman test, which contrasts the coefficient estimations of the RE and FE models (Adkins & Hill, 2011). The RE model is chosen when you accept the null hypothesis, which holds that individual outcomes have no correlation with explanatory variables. The FE model is appropriate for estimation if the Hausman test rejects the null hypothesis. Additionally, we also check for autocorrelation, heteroscedasticity, and multicollinearity. To tackle the endogeneity issue, we used system GMM estimators.

4. DATA COLLECTION AND VARIABLES

To test the effects of digitalization on income inequality, we used panel data that includes 127 countries of the world over the period from 2000 to 2022. For our dependent variable, we have income inequality, and for the focus variable, we shall be considering the ICT index. The data for the dependent variable was collected from the Standardized World Income Inequality Database, while the data for the focus and control variables were collected from the World Development Indicators. Thus, because of the wide range in terms of nations and time periods, the SWIID database is ideal for cross-country analysis of income dispersion (Chen *et al.*, 2020). The study also incorporated control variables that influence income inequality depending on the prior literature. Table 1 offers a brief definition, source, and construction of the variables to be used in the analysis.

Table 1: Description of the Variables

Variables	**Symbol**	**Variable definition**	**Source**
Dependent Variable			
Gini Index	Gini	Income inequality within a population is defined by the Gini index of disposable income.	SWIID
Focused Variables			
Mobile Cellular Subscription (per 100 people)	MCS	The mobile subscription rate per 100 people reflects the level of mobile phone adoption and access to mobile communication services within a population.	World Bank, 2023
Internet Users (per 100 people)	IU	Internet users are those who have used the Internet within the last 12 months.	World Bank, 2023
Fixed Broadband Subscription (per 100 people)	FBS	Fixed broadband connections include satellite, DSL, cable modem, and other broadband services, encompassing both organizational and residential subscriptions.	World Bank, 2023
Digitalization	ICT index	Principal Component Analysis was used to generate the ICT index by combining three proxy indicators into a composite measure: internet users, mobile phone subscriptions, and fixed broadband subscribers.	World Bank, 2023
Control Variables			
Urbanization	Urb	A country's level of urbanization can be measured by looking at its	World Bank, 2023

		urban population as a percentage of its total population.	
GDP per capita	GDP pc	Measured in constant 2015 US dollars, using 2015 as the base year.	World Bank, 2023
Foreign Direct Investment	FDI	The ratio of the inflow of FDI to the GDP of a country is used to measure FDI.	World Bank, 2023
Inflation	Inf	The rate of rise in prices in the entire economy is represented by inflation, which is calculated as the annual percentage change in the GDP deflator.	World Bank, 2023
Trade Openness	TOP	The ratio of the gross domestic product of a country to the sum of its imports and exports is used to measure trade openness.	World Bank, 2023
Sensitivity Variables			
Personal remittances received	Remit	Personal remittances are measured by the personal remittances received as a percentage of the GDP.	World Bank, 2023
PopulationGrowth Annual	Pop	Population growth (annual %) is measured by the annual rate of change in a country's population over one year.	World Bank, 2023
Unemployment Total	UET	Unemployment, total (% of the total labor force, modeled ILO estimate) measured by The percentage of the labour force that is unemployed but looking for work.	World Bank, 2023
TotalNaturalResourcesRents	TNR	Total natural resources rents (% of GDP)	World Bank, 2023

5. Results & Discussion

This section demonstrates and interprets the results of the analysis. To examine the correlation of the variables, we used panel data econometric techniques, namely POLS, Fixed Effect, Random Effect, and Instrumental variables, including Systems GMM. Thus, to mitigate the issue of measurement errors, method bias, and other related sources of measurement error, various diagnostic tests were performed, such as the multicollinearity test, heteroscedasticity test, and serial correlation test. The outcomes of these diagnostic tests were utilized to address any identified econometric problems and to guide the choice of suitable estimating techniques.

Table 2: Descriptive Statistics

Variables	**Obs.**	**Mean**	**Std.dev**	**Min**	**Max**
Gini coefficient	2,921	38.22233	8.211146	22	64.9
ICT index	2,921	44.21098	28.31252	-1.238566	150.56
GDP pc	2,921	8.583658	1.399597	5.56905	11.62998
Urbanization	2,921	58.66364	22.47836	8.246	100
FDI	2,921	25.704	233.9728	-391.4367	3242.949
Inflation	2,921	7.421343	19.7108	-25.95842	604.9459
Trade Openness	2,921	23.57577	2.245535	17.05301	28.52937
Developed Countries					
Gini coefficient	805	30.33826	4.251796	22	40.2
ICT index	805	68.66947	19.76936	7.10087	150.56
GDP pc	805	10.39223	0.559059	8.767706	11.62998
Urbanization	805	78.70004	12.71113	50.754	100
FDI net inflow	805	9.117402	37.35603	-391.4367	449.0809
Inflation	805	2.346235	2.775625	-9.653676	28.0333
Trade Openness	805	25.59944	1.505104	22.1273	28.52937
Developing Countries					
Gini coefficient	2,116	41.13903	7.394046	22.5	64.9
ICT index	2,116	34.69626	25.37355	0.0003573	07.55
GDP pc	2,116	7.907049	0.9732551	5.56905	10.62525
Urbanization	2,116	51.18595	20.30042	8.246	100
FDI net inflow	2,116	31.77144	272.615	-40.08635	3242.949
Inflation	2,116	9.067825	22.70028	-25.95842	04.9459
Trade Openness	2,116	22.81425	2.008488	17.05301	27.2158

The summary statistics provide a comprehensive view of key economic indicators, highlighting significant disparities between developed and developing countries. The Gini index, which measures income inequality, shows that developing countries experience the highest levels of income inequality (41.139), compared to both global averages and developed nations. Digitalization, as indicated by its mean value of 68.669, is most prominent in developed countries, which also lead in GDP growth rates (10.393). Furthermore, urbanization is notably higher in developed countries (78.71%), while developing nations face greater inflation (9.067%). Additionally, developed countries exhibit the highest trade openness (25.59%). Overall, these findings underscore the economic inequalities between developed and developing countries through various economic measures.

Table 3: Results of Fixed Effects and Random Effects

	Global (1)		**Developed (2)**		**Developing (3)**	
Variables	**Dependent variable: Income Inequality**					
	FE	**RE**	**FE**	**RE**	**FE**	**RE**
ICT Index	-0.50509*** (.05367)	- 0.4674*** (0.05189)	0.2178** (0.0885)	0.1663** (0.0788)	-0.4858*** (.0482)	-0.5102*** (0.0484)
Urbanization	-0.04931*** (0.0106)	-0.05122*** (0.0101)	-0.0944*** (0.0289)	-0.0836*** (0.0242)	0.0966*** (0.0106)	0.0896*** (0.0104)
Log GDP pc	-0.6398*** (0 .2159)	-0.9129*** (0.2053)	-0.2349** (0.6784)	-0.6099** (0.5642)	-0.3635** (0.2382)	-0.2884** (0.2353)
FDI	-0.0089*** (.00055)	-0.0093*** (0.0006)	0.0003 (0 .0011)	0.0005 (0.0011)	-0.0108*** (0.0007)	-0.0098 *** (0.0007)
Inflation	0.00088 (0.0014)	-0.0002 (0.0013)	0.0001 (0.0147)	0.0032 (0.0146)	-0.0015 (0.0014)	-0.0014 (0.0015)
Trade Openness	-0.2177** (0.0886)	-0.3269*** (0.0843)	0.21295** (0.3989)	0.2771** (0.3069)	-0.0927* (0.0955)	-0.08509* (.0909)
Constant	39.70512*** (1.7043)	41.5228** (1.7437)	29.9923*** (6.7359)	26.3265*** (5.8407)	46.7977*** (1.6348)	46.6009*** (1.8418)
F-Statistics	117.22	-	8.55	-	132.64	-
F-probability	0.0000	-	0.0000	-	0.0000	-
Chi2(6)	-	702.22	-	53.68	-	746.12
Prob.>Chi2	-	0.0000	-	0.00	-	0.0000
Hausman Test	157.08 (0.0000)		5.99 (0.4244)		60.08 (0.0000)	
Observations	2,921	2921	805	805	2,116	2,116

The fixed-effect model (FEM) for the global level and developing countries, alongside the random-effect model (REM) for developed countries, reveals significant relationships between income inequality, the ICT index, and GDP per capita. The findings suggest a negative correlation between income inequality and the ICT index, with a 1 percent increase in the ICT index leading to a reduction in income inequality by 0.50509 units globally and 0.4858 units in developing countries. However, in developed countries, a 1 percent increase in the ICT index is associated with an increase of 0.1663 units in income inequality.

These results align with previous studies by Yin and Choi, (2022), Setyadi *et al.* (2023), Nguyen (2023), and Richmond & Triplett (2017). In developed economies, digitalization benefits skilled workers, leading to greater returns on their skills and widening the income gap between skilled and unskilled workers. In contrast, in developing countries, digital access improves information flow, telecommuting, innovation, market access, and skill development, helping reduce income inequality.

The study also incorporates GDP per capita, which demonstrates a negative relationship with income inequality across all country groups. A 1 percent increase in per capita income leads to a decrease in income disparity by 0.639% globally, 0.609% in developed countries, and 0.363% in developing countries. These findings are consistent with the work of Richmond and Triplett (2017), Zehra *et al.* (2021), Consoli *et al.* (2023), and Xu (2023), further suggesting that economic development, as measured by per capita income, mitigates income inequality.

The findings reveal that urbanization reduces income disparity by 0.04 units at the global level and 0.0834 units in developed countries, while in developing nations, urbanization leads to a 0.096 unit increase in income disparity per 0.01 rise in urbanization (Xu, 2023; Richmond & Triplett, 2017). Additionally, the study shows a reverse relationship between FDI inflows and income inequality for global and developing nations. Specifically, a 1 percent increase in FDI net inflow reduces income disparity by approximately 0.009 units globally and 0.0108 units in developing countries. This aligns with the findings of Yin and Choi (2022), who observed that digitalization and FDI together can mitigate income inequality. However, FDI's impact on income disparity in developed countries is positive and statistically insignificant. In developing nations, FDI reduces income disparity by creating job opportunities for low-skilled workers, leading to more equitable income distribution (Majeed, 2017).

Furthermore, the results indicate a statistically insignificant relationship between inflation and income inequality across all groups. Trade openness and income inequality exhibit a negative correlation globally and in developing countries, with a 1 percent increase in trade openness reducing income inequality by 0.218 units globally and 0.092 units in developing nations. Conversely, in developed countries, trade openness increases income inequality by 0.277 units. This is consistent with Majeed and Zhang (2014), who found similar effects for developing countries at higher GDP-per-person levels.

The Hausman test was employed to determine the most suitable model between the fixed-effects and random-effects approaches. Based on the results presented in Table 3, the probability value is less than 5% for both global and developing economies. This allows us to reject the null hypothesis that the random-effects model is appropriate, leading to the conclusion that the fixed-effects model is more suitable for these groups of nations. Conversely, for developed countries, the probability value exceeds 0.05, indicating that the random-effects model is the preferred technique in this case.

Table 4: Two-Step System GMM

	Global (1)	**Developed (2)**	**Developing (3)**
Variables	Income Inequality		
Lag dependent variable	0.9572*** (.00115)	0.5987*** (0.0221)	0.7704*** (0.0122)
Digitalization index	-0.1424*** (0.0044)	0 .3288*** (0.09226)	-0.4869* (0.0258)
Urbanization	-0.0206*** (0.0016)	-0.2439*** (0.0785)	-0.5886*** (0.2034)
GDP pc	-0.4298 *** (0.0129)	-1.2605** (0.5302)	-0.5886*** (0.2035)
FDI	-0.0016*** (0.00005)	-0.00009 (0.0014)	-0.0013** 0.0007
Inflation	0.0134*** (0 .0002)	0.0152*** (0.0049)	0.0021*** (0.0008)
Trade Openness	-0.6709*** (0.0074)	0 .4831** (0.2284)	-0.0765* (0.1022)
Constant	-19.94633 *** (1.151868)	(32.0821) *** 7.2963	13.4126*** (1.2768)
AR(2)p-value	0.834	0.320	0.510
Hansen p-value	0.224	0.469	0.827
No. of Instruments	70	25	19
Observation	2772	805	2024
No. of Countries	127	35	92
***p<0.01, **p<0.05, *p<0.1			

To address potential endogeneity, omitted variable bias, measurement error, and heteroscedasticity, the study utilized the system GMM approach proposed by

Arellano and Bond (1991). This approach eliminated time-invariant (country-specific) effects by including the lag of the dependent variable as an independent variable in the system GMM model. The endogenous variable, the digitalization index, was instrumented using its own lags. The validity of the instruments was assessed using the Hansen test, where a probability value greater than 0.05 confirmed the acceptance of the null hypothesis that the instruments are valid.

The system GMM estimates, as reported in Table 4, confirm that the number of instruments used was less than the number of countries, adhering to the rule of thumb recommended by Roodman (2009). Additionally, the Arellano-Bond test for AR (2) indicated no serial autocorrelation in the models, as the p-value for AR (2) exceeded 0.05, further validating the absence of serial autocorrelation.

The results reveal a negative relationship between ICT and income inequality, indicating that a 1 percent increase in the ICT index reduces income inequality by 0.1424 units globally and 0.486 units in developing countries, while it increases by 0.328 units in developed nations. These findings align with the conclusions of Xu (2023) and Yin & Choi (2022). Additionally, the analysis shows that urbanization and GDP per capita contribute to reducing income inequality across all three groups of economies.

The study also found a negative association between FDI and income disparity globally and in developing nations, whereas FDI has an insignificant effect on income disparity in developed countries. Furthermore, the findings suggest a significant and positive relationship between inflation and income disparity.

Lastly, the results indicate that trade openness decreases income inequality at the global level and in developing countries but increases it in developed nations. This variation highlights the differing impacts of trade on inequality across economic groups, consistent with Majeed (2015), who observed diverse effects of trade on income inequality in different groups of economies.

In the sensitivity analysis, additional control variables were included, such as personal remittances, population growth rate, total unemployment rate, and total natural resource rents, to assess whether the core findings regarding the influence of digitalization on income disparity remain robust. The analysis aimed to confirm that the primary results—highlighting the negative and statistically significant impact of digitalization on income inequality—are consistent and unchanged even when these additional factors are incorporated into the econometric model.

Table 6: Sensitivity Analysis of Variables

Variables	Personal remittances	Population Growth	Unemployment Total	Natural Resources Rents
Dependent Variable: Income inequality				
ICT index	-0.4669*** (0.0519)	-0.4629*** (0.0524)	-0.4649*** (0.0516)	-0.4784*** (0.0529)
Log GDP pc	-0.9088*** (0.2054)	-0.9251*** (0.2061)	-0.6339*** (0.2096)	-0.8936*** (0.2063)
Inflation	-0.0002 (0.0014)	-0.0002 (0.0014)	-0.0002 (0.0014)	5.32e-06 (0.0014)
FDI	-0.0083*** (0.0006)	-0.0083*** (0.0006)	-0.0085*** (0.0006)	-0.0083*** (0.0006)
Urbanization	-0.0509*** (0.01009)	-0.0508*** (0.0102)	-0.0609*** (0.0102)	-0.0517*** (0.0101)
TOP	0.3266*** 0.0843	0.3249*** (0.0843)	0.3395*** (0.0838)	0.3359*** (0.0847)
Constant	41.4785*** (1.7452)	41.6165*** (1.7497)	38.8901*** (1.7859)	41.2006*** (1.7717)
R-square	0.0840	0.0868	0.0763	0.0818

The estimation results, presented in Table 6, demonstrate that digitalization consistently reduces income inequality, maintaining a significant and negative impact. This finding underscores that the proliferation and adoption of digital technologies can foster a more equitable distribution of economic outcomes by enhancing participation in the digital economy, boosting productivity, and disseminating information that helps bridge income divides.

Key control variables such as GDP per capita, FDI, urbanization, and trade openness (TOP) also remain highly significant and stable in their effects. The results of the sensitivity analysis imply that the coefficients under investigation are robust and unaffected by the inclusion of additional control variables in the econometric model. This reinforces the reliability and generalizability of the findings, supporting the conclusion that ICT determinants play a significant role in influencing income disparities.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1. Conclusion

This study investigates the impact of digitalization on income inequality using panel data from 127 countries spanning 2000–2022, examining its effects at the global level and within developed and developing nations. The analysis reveals a complex relationship between digitalization and income disparity, supported by a robust theoretical framework and extensive empirical assessment across global and regional economies.

To evaluate linear relationships, the study employs standard econometric methods, including pooled OLS, fixed-effects, and random-effects models. Additionally, a two-step system GMM methodology addresses potential non-linearity and endogeneity, ensuring reliable and efficient estimates.

The findings indicate that digitalization—measured by metrics such as internet usage, broadband subscriptions, and mobile cellular penetration—negatively correlates with income inequality globally and in developing countries but positively correlates in developed nations. Urbanization and GDP per capita consistently reduce income inequality across all country groups. Foreign Direct Investment (FDI) similarly narrows the income gap globally and in developing countries but has an insignificant effect in developed regions. Inflation, on the other hand, is positively associated with income inequality at all levels. Trade openness reduces income inequality globally and in developing countries but increases it in developed regions.

At the global level, the findings highlight that digitalization plays a significant role in reducing income inequality by enhancing access to information, education, and economic opportunities. The widespread adoption of digital technologies fosters a more equitable distribution of income by bridging gaps in access to resources and enabling broader participation in economic activities.

However, the impact of digitalization shows marked differences between developed and developing countries. In developed nations, digitalization tends to widen income inequality. The benefits of technological advancements are disproportionately captured by those already economically advantaged, as high-income individuals and organizations are better equipped to leverage new technologies for greater financial gains. This amplifies the income gap, as the digital economy increasingly rewards skills and resources that are more accessible to affluent groups.

Conversely, in developing countries, digitalization has a mitigating effect on economic disparity. Digital technologies act as equalizers, expanding access to education, financial services, and employment opportunities for marginalized groups. This democratizing effect enables broader participation in the digital economy, contributing to a more level playing field. As digital infrastructure and technological adoption continue to improve, they promote inclusive growth and help narrow the income gap in these regions.

6.2. Policy Recommendations

The findings of this study have several policy implications to address the complex relationship between digitalization and income inequality. First, at the global level, the level of digitalization, especially through internet usage, significantly affects the reduction of economic inequality. To achieve a narrower income gap, governments should formulate strategies that encourage the development of digital technologies, particularly by boosting internet connectivity.

Second, because of the diffusion of digitalization, it is expected that income disparities in developed countries are likely to widen. To counter this, there is a need to improve activation frameworks that enable workers displaced by changes in demand for skills to quickly find new jobs.

Third, the increase in digitalization now supports the income gap in developing countries. This implies that poverty and income disparities in these countries can be addressed through the use of digital technologies. Since there is limited technological advancement in developing countries, their respective governments must make several efforts to enhance the use of digital technologies. This can be done through investment in technological developments, the promotion of the digital economy, and the adoption of policies regarding low-cost networks and accessible information resources.

In conclusion, the findings of this study emphasize the need to adopt context-specific measures to take advantage of the opportunities brought about by digitalization while avoiding the worsening of structural socio-economic inequalities. The analysis presented indicates that significant attention should be paid to the development of adequate policies that account for the specific features of developed and developing countries in order to maximize the positive effects of digitalization on income inequality and to address the potential challenges faced by different economic environments.

6.3. Limitations of the Study

There are certain limitations in the study that can affect the interpretation of the results presented in this paper. These limitations originate from the data used, the regression model employed, and the selection of ICT measures. Acknowledging these limitations is important when considering the findings of the study and determining potential directions for future research.

Firstly, the type of information applied in this study may not be entirely accurate due to the exclusion of missing values and some countries. The presence of missing data raises concerns about the representativeness of the sample and the potential for bias. The exclusion of many developing nations due to missing data may restrict the ability to provide a detailed picture of their situations and processes.

Secondly, another issue with this study is the regression model used, which, while providing relevant information, has certain limitations. One limitation is the choice of control variables, which are not comprehensive enough to fully explain the digitalization-income inequality nexus. Future research could consider additional and diverse control variables to address specific factors.

Finally, the measures of ICT used in this study consist of only several ICT indexes, which do not represent a broad range of technological developments. A limitation of this study is that certain more recent technologies, such as AI, were not included, despite their potential impact on income inequality. Future studies should include these dynamic ICT measures to provide a broader view of their impact and explore their interaction with traditional technologies. However, it is important to note that the required data for some emerging ICTs, like AI, across countries and for longer time periods is still limited. Therefore, more analysis can be undertaken in the future when more data becomes available.

Acknowledging these limitations provides opportunities for future research to address these constraints and further advance the understanding of the relationship between ICT and income inequality.

6.4. Future Research Directions

To gain a more detailed understanding of the relationship between digitalization and income inequality, future research could shift its focus to single-country case studies. By employing time series estimation techniques, such as Vector Autoregression (VAR) models or cointegration analysis, researchers can explore the temporal dynamics and causal relationships within specific national contexts. This approach allows for a more detailed understanding of how and to what extent income inequality increases over time, particularly in relation to digitalization, other factors, and institutional settings at the country level.

Further studies could also expand the elements of digitalization to incorporate additional factors, such as digital technology skills and the quality of digital technologies. This would provide a clearer picture of what digitalization is truly doing. Similarly, exploring income differences with different methods, such as using the Theil or Atkinson coefficients, and studying wealth indicators or patterns of social mobility, could offer more extensive and diverse analyses. By incorporating these expanded measures, researchers would gain a broader understanding of how digitalization impacts different dimensions of inequality. This would acknowledge that the digital divide extends beyond mere access to technology, encompassing the quality, usability, and required skills to effectively leverage digital technologies.

REFRENCESS

Adams, S., & Akobeng, E. (2021). ICT, governance and inequality in Africa. *Telecommunications Policy, 45* (10), 1-13. https://doi.org/10.1016/j.telpol.2021.102198

Adkins, L.C., & Hill, R. C. (2011). Using Stata for Principles of Econometrics. John Wiley & Sons.

Ashraf Ganjoei, R., Akbarifard, H., Mashinchi, M., & Jalaee Esfandabadi, S. A. (2021). Applying of Fuzzy Nonlinear Regression to Investigate the Effect of Information and Communication Technology (ICT) on Income Distribution. *Mathematical Problems in Engineering, 2021* (1), 1-11. https://doi.org/10.1155/2021/5545213

Atkinson, A. B. (1970). On the measurement of Inequality. J*ournal of Economic Theory 2, 3*(2), 244-263.

Arellano, M., & Bond, S. (1991). Some tests of Specification for Panel Data: Monte Carlo evidence and an application to employment equations. *The review of economic studies, 58*(2), 277-297. https://doi.org/10.2307/2297968

Autor, D. H., Katz, L. F., & Kreuger, A. B. (1992). Computing Inequality: Have Computers Changed the Labor Market? T*he Quarterly Journal of Economics, 113* (4), 1169-1213. https://doi.org/10.1162/003355398555874

Behar, A. (2016). The endogenous skill bias of technical change and wage inequality in developing countries. *The Journal of International Trade and Economic Development, 25* (8), 1101-1121. https://doi.org/10.1080/09638199.2016.1193887

Braun, D. (1991). The Rich get richer: The rise of income inequality in United States and the World. Chicago: Nelson- Hall .

Brynjolfsson, E., & Hitt, L. M. (2000). Beyond Computation: Information Technology, Organizational Transformation and Business Performance. *Journal of Economic Perspectives, 14* (4), 23-48. 10.1257/jep.14.4.23

Brynjolfsson, E., & McAfee, A. (2014). The Second machine age: work , progress and prosperity in the time of brilliant technologies. *WW Norton and Company .*

Canh, N. P., Schinckus, C., Su, T. D., & Ling, F.C.H. (2020). Effects of the internet, mobile, and land phones on income inequality and The Kuznets curve: Cross country analysis. *Telecommunications Policy*, *44*(10), 102041. https://doi.org/10.1016/j.telpol.2020.102041

Cioaca, S., Cristache, S. E., Vuta, M., Marin, E., & Vuta, M. (2020). Assessing the Impact of ICT Sector on Sustainable Development in the European Union: An Empirical Analysis Using Panel Data. *Sustainability*, *12*(2), 590. https://doi.org/10.3390/su12020592

Chen, J., Xian, Q., Zhou, J., & Li, D. (2020). Impact of income inequality on CO2 emissions in G20 countries. *Journal of Environmental Management, 271*, 1-8. https://doi.org/10.1016/j.jenvman.2020.110987

Consoli, D., Castellacci, F., & Santoalha, A. (2023). E-skills and income inequality within European regions. *Industry and Innovation, 30* (7), 519-946. https://doi.org/10.1080/13662716.2023.2230222

Danziger, S., & Gottschalk, P. (1986). Do Rising Tides Lift All Boats? The Impact of Secular and Cyclical Changes on Poverty. T*he American Economic Review*, *76* (2), 405-410. https://www.jstor.org/stable/1818805

de Moraes, C. O., Roquete, R. M., & Gawryszewski, G. (2023). Who needs cash? Digital finance and income inequality. *The Quarterly Review of Economics and Finance*, *91*, 84-93. https://doi.org/10.1016/j.qref.2023.07.005

Garrity, J. (2015). ICTs, Income Inequality, and Ensuring Inclusive Growth. SSRN 2588115 .

Kreuger, A. B. (1997). Labor Market Shifts and the Price Puzzle Revisited. *Quarterly Journal of Economics, 112* (4), 1469-1496. https://doi.org/10.1016/j.qref.2023.07.005

Lin, C.H.A., Lin, H.S., & Hsu,C.P. (2017). Digital divide and income inequality: A spatial analysis. Review of Economics and Finance, 8, 31-43.

Majeed, M. T. (2015). Distributional Consequences of Globalization: Is Organization of the Islamic Conference Countries Different?. *The International Trade Journal*, *29*(3), 171-190. https://doi.org/10.1080/08853908.2015.1024899

Majeed, M. T. (2017). Inequality, FDI and economic development: Evidence from developing countries. *The Singapore Economic Review*, *62*(05), 1039-1057. https://doi.org/10.1142/S0217590815500678

Majeed, M. T. (2020). Do digital governments foster economic growth in the developing world? An empirical analysis. *NETNOMICS: Economic Research and Electronic Networking*, *21*(1), 1-16. https://doi.org/10.1007/s11066-020-09138-4

Majeed, M. T., & Ayub, T. (2018). Information and communication technology (ICT) and economic growth nexus: A comparative global analysis. *Pakistan Journal of Commerce and Social Sciences), 12(*2), 443-476.

Majeed, M. T., & Zhang, G. (2014). Inequality, trade and economic development: Evidence from developing countries. *Pakistan Journal of Applied Economics*, *24*(1), 39-73.

Milanovic, B. (2005). Can We Discern the Effect of Globalization on Income Distribution? Evidence from Household Surveys. *The World Bank Economic Review*, *19* (1), 21–44. https://doi.org/10.1093/wber/lhi003

Mutiiria, O. M., Ju, Q., & Dumor, K. (2020). Infrastructure and inclusive growth in sub-Saharan Africa: An empirical analysis. *Progress in Development Studies* , *20* (3), 187-207.

Nga Ndjobo, P. M., & Ngah Otabela, N. (2023). Can Income Inequality be Affected by the Interaction Between ICTs and Human Capital?: The Evidence from Developing Countries. *Journal of Quantitative Economics, 21* (1), 235-264. https://doi.org/10.1007/s40953-022-00336-5

Noh, Y. H., & Yoo, K. (2008). Internet, inequality and growth. *Journal of Policy Modeling, 30*(6), 1005-1016.

Nguyen, V. B. (2023). The role of digitalization in the FDI – income inequality relationship in developed and developing countries. J*ournal of Economics, Finance and Administrative Science, 28* (55), 6-26. https://doi.org/10.1108/JEFAS-09-2021-0189

Patria, H., & Erumban, A. A. (2020). Impact of ICT Adoption on InequalityEvidence from Indonesian Provinces. *The Journal of Indonesia Sustainable Planning*, *1* (2), 125-139. https://doi.org/10.46456/jisdep.v1i2.58

Richmond, K., & Triplett, R. E. (2017). ICT and income inequality: a cross-national perspective. *International Review of Applied Economics, 32* (2), 195-214.

Roodman, D. (2009). A Note on the Theme of Too Many Instruments. *Oxford Bulletin of Economics and Statistics, 71* (1), 135-158. https://doi.org/10.1111/j.1468-0084.2008.00542.x

Schutz, R. R. (1951). On the Measurement of Income Inequality. *The American Economic Review, 41* (1), 107-122.

Schwab, K. (2016). The Fourth Industrial Revolution. Crown Currency .

Setyadi, S., Indriyani, L., & syaifudin, R. (2023). Digital Technology Development and Income Inequality in Indonesia: Using System GMM Model. Eko-Regional: *Journal Pembangunan Ekonomi Wilayah, 18* (1).

Shah, C. S., & Krishnan, S. (2024). ICT, Gender Inequality, and Income Inequality: A Panel Data Analysis Across Countries. *Information Systems Frontiers, 26* (2), 709-727. https://doi.org/10.1007/s10796-023-10396-4

Tachamyou, V. S., Asongu, S. A., & Odhiambo, N. M. (2019). The Role of ICT in Modulating the Effect of Education and Lifelong Learning on Income Inequality and Economic Growth in Africa. *African Development Review, 31* (3), 261-274. https://doi.org/10.1111/1467-8268.12388

Xu, X. (2023). Digital Economy, Industrial Structure and Income Inequality: Based on Cross-border Panel Data. Frontiers in Business, *Economics and Management, 10* (3), 85-94. https://doi.org/10.54097/fbem.v10i3.11313

Yao, L., & Ma, X. (2022). Has digital finance widened the income gap. *Plos One, 17* (2), e0263915.

Yin, Z. H., & Choi, C. H. (2023). Does digitalization contribute to lesser income inequality? Evidence from G20 countries. I*nformation Technology for Development, 29* (1), 61-82. https://doi.org/10.1080/02681102.2022.2123443

Zehra, S., Majeed, M. T., & Ali, A. (2021). Quality of institutional indicators and income inequality: A global panel data analysis of 114 economies. *Pakistan Journal of Economic Studies, 4*(2), 165-204.