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Impact of Digitalization on Economic Growth in Developing Countries: A Panel ARDL Analysis

Hina Asma [1] Sumaira Batool [2] Basit Rehman [3]

Abstract: *The study aims to explore how digitization affects the economic growth of developing nations. It is theorized that emerging technologies are pivotal in influencing the economic landscape of developing countries. Key factors include improved communication facilitated by enhanced technology infrastructure, as well as the ability to reach a larger portion of the impoverished population previously excluded. The research employs a panel dataset spanning 24 years, from 2000 to 2023, covering 87 emerging economies. The Panel Autoregressive Distributed Lag (ARDL) methodology is utilized for the analysis. According to the research, taxes have a detrimental impact on economic expansion. At the same time, variables such as DI, GFCF, LFPR, and M2 have a positive effect on the economic growth of emerging nations. The research recommends that investments in digital infrastructure and technology utilization should be made to bolster the growth of developing countries. Increasing the Labor Force Participation Rate (LFPR) is essential for promoting job creation and entrepreneurial activities.*

Key Words: Digitalization, Economic growth, Developing countries, Digital infrastructure, ARDL

Introduction

Digitalization is considered the third industrial revolution or the digital revolution, which started in the 20th century. The introduction of computers in the 1950s marked the beginning of digitization in essence. Subsequently, the unrelenting progress of digitization has transformed nearly everything into computer-friendly binary numbers. Altering not just how we work and communicate but also how we buy, finance, and even relax and have fun.

Modern theories of economic growth are predominantly rooted in the examination of technology and research and development (R&D). These emerging paradigms also propose that the trajectory of economic growth is significantly contingent upon the processes of digitization and the level of investment in technological advancements. Nevertheless, the ultimate and most credible empirical assessment of these theories poses a notable challenge that has captured the attention of numerous policymakers in recent years. Consequently, the proliferation of novel technologies has not only facilitated the seamless integration of the knowledge economy but has also heightened its competitiveness and stimulated innovation within various sectors (World Bank, 2020).

Because digital technology advancements lower transaction costs for economic transactions and increase worker's skills and knowledge, they support economic growth in developing nations (Nguyen, 2023). In the last decade, digitalization has become more popular around the world, which helps to create more new products with easy access to world development (Lu & Zhu, 2000). As a new phase of technical and economic advancement, the digital revolution has changed the lives of many people, opened up a wealth of options, and entered a time of heightened global conflict. One important force behind development and progress is the digital economy. It may boost corporate and entrepreneurial activities, increase

[1] M.Phil. Scholar, Department of Economics, The Women University Multan, Punjab, Pakistan.
[2] Lecturer, Department of Economics, The Women University Multan, Punjab, Pakistan.
Email: sumairaimran14@gmail.com
[3] Monroe College, New Rochelle, New York, United States of America.
Email: Basitrehman42001@gmail.com

▪ **Corresponding Author:** Hina Asma (hinaasma748@gmail.com)
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competitiveness in all industries, and open up new avenues for entering foreign markets and taking part in global e-value chains (Limna, 2022). While the digitization revolution has had a transformative influence on society, the person, and the organization, it has also had unfavourable side effects that have a detrimental impact on people's well-being (Tarafdar et al. 2015b).

Literature Review

Rich research has been done regarding the impact of digitalization on the economic growth of different countries. Some authors have examined the role of digitalization on individual economies, while others have compared different economies. Afonasova and Panfilova (2019) compared the digital economy of Russia with that of other European Union nations and concluded that in terms of Internet connectivity and its effects on GDP and social processes, the cross-country examination found considerable contrasts between Russia and the other EU countries. Results indicated that Russia is ranked among the top 10 nations in terms of ICT. Habibi and Zaberdast (2020) compared the contribution of ICT to economic growth in Middle Eastern countries to that of the Organization for Economic Cooperation and Development (OECD) economies. The primary goal of comparing the most and least developed nations when it comes to measuring the effects of ICT and education is to determine whether or not these effects are influenced by the respective levels of national development. The findings demonstrate that ICT and economic growth are favourably correlated in both sets of nations. Afterwards, Myovella et al. (2020) measured the rate of digitalization on the economic growth of Sub-Saharan- Africa (SSA) and the Organization for Economic Cooperation and Development (OECD). The result of the study showed a positive impact of digitalization on the economic growth of both groups of nations included in the study.

To examine the role of digitalization, Mentsiev et al. (2020) claimed that it is almost impossible to imagine surviving in the past without access to the conveniences that modern society takes for granted. Novikova and Strogonova (2020) claimed that the digital economy is a key engine of economic growth and development in the Ural macro-region. In the context of digitalization, Nguyen (2023) stated that digital technology is an appropriate way for emerging economies to catch up with established economies. Progress in digital technology stimulates economic growth by lowering transaction costs and enhancing people's skills and knowledge. In order to promote long-term development, Liu et al. (2022) concluded that the digital economy has emerged as a critical tool for China's high-quality development, fostering technical innovation. Inna et al. (2021) looked over the impact of digital technologies on economic growth in Ukraine by focusing on areas that can accelerate digitalization to increase GDP. Stimulating IT development has significant prospects for activating digitalization processes and increasing GDP. The importance of the digital economy on Africa’s economic growth has been examined by Abendin et al. (2021) from year 2000 to 2018. The findings of the research have shown the positive effect of digitalization on trade and economic growth of African regions. In order to assess the growing trend of digitalization, Limnaat et al. (2022) found that the digital economy offers both opportunities and challenges to many countries' economic systems. Lu and Zhu (2022) executed research from 2013 to 2020 on the digital economy and high-quality development in 31 Chinese provinces. The researchers observed spatial correlation among optimal economic expansion, digital economy, and technological and scientific innovation. Moreover, the study suggested that high economic development could be sped up with digital economy development. The digital economy is growing at an exponential rate, particularly in underdeveloped countries. However, the digital economy's definitions and measures are inconsistent and constrained (Williams, 2023).

Some studies have posed a negative impact of digitalization on economic growth. For example, for 39 African nations, Solomon et al. (2020) examined how the use of digital technology affected nations. ICT usage has positive as well as negative impacts on growth. Furthermore, the study demonstrates that only individual usage has a positive influence.

Researchers have also examined the role of digitalization at various hierarchal levels. For example, Bilan et al. (2019) analyzed and evaluated the influence of information and communication technologies (ICT) on economic growth at various hierarchical levels. Based on worldwide ICT development trends and its use as a competitive advantage factor, it is demonstrated that long-term socioeconomic growth has gained characteristics of permanent digital development. For developing nations, rapid ICT development can provide a fresh impetus for economic growth, as evidenced by correlation analysis and modelling of

ICT determinants' effect on key financial outcomes. Considering current ICT development patterns in business (based on a case study of Ukraine's ICT use statistics as a developing country) and their relationships with financial outcomes, the key policy-making measures aimed at future economic growth might be defined. They should be aimed mainly at web technology use and internet access, specifically in the field of e-commerce.

Model, Data and Methodology

After the literature review now set the model, data and methodology below:

Model Specification

The link between digitization and economic growth in developing nations is a fundamental finding of this research.

GDPPCG = f (DI, GFCF, LFPR, M2, Tax)

In the above model, GDPPCG (economic growth) is the dependent variable while DI (Digital index), GFCF (gross fixed capital formation), LFPR (Labor force participant ratio), M2 (Broad Money) and Tax are independent variables. The above model shows that GDPPCG is the function of DI, GFCF, LFPR, M2 and Tax.

Where;

Digital Index

We have constructed a "Digital Index" on the basis of "Principle Component Analysis" through these four variables:

1. Fixed telephone subscription (TPHONE)
2. Fixed broadband subscription (BB)
3. Individuals using the Internet (INT)
4. Mobile cellular subscription (MOB)

Data Collection

Following the selection of variables for inquiry, the next stage involves data collecting, which is crucial for the representation of the experimental study. The following discussion centres on the techniques used for panel data collection.

Selection of Countries

We select developing countries for our research work. At the same time, looking at how digitalization has affected developing nation's economies. Developing nations are further divided into three groups: low-income countries, lower-middle-income countries, and upper-middle-income countries.

Time Span

The panel data used in this study cover the years 2000 to 2023. This is used to investigate how digitization affects economic growth. This time frame is chosen to investigate the way independent variables affect endogenous variables in the present.

Source of Data

In the process of comprehending how digitalization affects economic growth, the World Development Indicators provide the data.

Results and Discussions

Descriptive Statistics of Low-Income Countries (LIC)

The properties of the data set are summarized, and a quantitative description is presented using descriptive analysis. This study has worked on data on GDP per capita growth (GDPPCG), Digital index (DI), Labor force participant ratio (LFPR), Broad money (M2), Tax revenue (TAX), and Gross fixed capital formation (GFCF) over the period of (2000-2023) Table 1 signifies Mean, Median values, standard deviation,

skewness, kurtosis and Jarque-Bera of discussed variable values. The following data attributes, presented as descriptive statistics of lower-income countries (LIC), help to comprehend the statistical impact of digitalization on the economic growth of developing nations.

Table 1

Descriptive statistics of key variables (2000-2023)

Variables	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
GDPPCG	1.44	1.87	19.56	-36.78	5.59	-2.09	14.92	2072.93	0.00
DI	12.43	11.01	37.40	-0.18	10.40	0.49	2.17	21.40	0.00
LFPR	62.57	61.84	86.69	31.72	13.47	-0.13	2.49	4.39	0.00
M2	27.07	24.77	53.51	0.04	9.99	0.52	2.51	17.44	0.00
TAX	10.58	10.53	18.30	1.22	3.12	-0.27	3.04	3.78	0.00
GFCF	17.71	18.11	41.68	1.10	7.41	0.47	3.39	13.30	0.00

Source: Authors' computations

The descriptive results for developing nations are shown in Table 1. The above table presents the mean, median, maximum and minimum values, standard deviation, skewness, kurtosis, and probability. The gross domestic product per capita growth mean is 1.44. The median is 1.8, the maximum value is 19.56, and the minimum value is -36.7, Std. Dev. is 5.9, Skewness is -2.09, Kurtosis is 14.92, Jarque-bera ia -2072.92.

The mean of the digital index is 12.4, the Median is 11.01, the Maximum value is 37.40, the Minimum value is -0.18, Std. Dev. is 10.40. About the "LFPR" variable, the mean value is 62.57, which is the average value. Median: 61.84 is the midway number or the 50th percentile. Maximum: 86.69 is the highest recorded figure. Minimum: 31.72 is the lowest recorded figure. Std. The standard deviation is 13.47. The mean value of M2 is 27.07, the Median is 24.77, the Maximum value is 53.51, the Minimum value is 0.04, Std. Dev is 9.99. The mean value of the tax is 10.58, the Median is 10.53, the Maximum value is 18.30, the Minimum value is 1.22, Std. Dev 3.12. The mean of Gross fixed capital formation is 17.71, the Median is 18.11, the Maximum value is 41.68, the Minimum value is 1.10, and the Std. Dev is 7.41.

Correlation of Key Variables for Low-Income Countries

The link between the variables is explained by the correlation matrix. Correlation coefficients vary from -1.00 to +1.00. Relationship strength is shown by a numerical number, and relationship direction is indicated by a sign of value. The perfect positive association between the quantities of the dependent and independent variables is denoted by +1.00, while the perfect negative association between the quantities of the dependent and independent variables is denoted by -1.00. A correlation matrix is used to determine how well a link between variables works. A correlation matrix is necessary to determine the extent to which variables are connected to one another. The variables are highly correlated if the value is 0.80, and if the value is more than 0.80, there is significant multicollinearity. This is because the range of correlation is -1 to +1. The correlation matrix for the model's variable amounts is shown in the table below.

Table 2

Correlation matrix of key variables (2000-2023)

Correlation	GDPPCG	DI	LFPR	M2	TAX	GFCF2
GDPPCG	1.00					
DI	-0.19	1.00				
LFPR	0.20	-0.26	1.00			
M2	-0.08	0.49	-0.14	1.00		
TAX	-0.13	0.45	-0.13	0.18	1.00	
GFCF	0.30	0.01	0.55	0.12	-0.09	1.00

Source: Authors' computations

The correlation between the independent and dependent variables is shown in Table 2. As the diagonal number 1 illustrates, there is a perfect correlation between all variables and itself. The dependent variable, GDPPCG, has a positive correlation with both the labour force participation ratio and gross fixed capital formation. However, the digital index, broad money, primary school enrollment, secondary school enrollment, and tax are negatively related to GDPPCG. The dependent variable, GDP, has a positive correlation with both the labour force participation ratio and gross fixed capital formation at 0.20 and 0.30, respectively. Although the correlation between digital index, broad money and tax with GDPPCG -0.19, -0.08 and -0.13 correspondingly, this shows that the dependent and independent variables have a negative correlation.

Unit Root of Key Variables for Low-Income Countries

This section shows the results of unit root analysis for the key variables in the case of low-income countries. To determine whether any variable is stationary, do the panel unit root test. E-Views software is utilized in this study to verify whether or not all variables reject the null hypothesis. The level of stationarity of all the provided variable values for the model is shown in the table below. There are varying degrees of stationarity that are close to either level I (0) or first difference I (1). For example, there are variables that remain constant at the first difference and others that remain constant at the level.

Table 3

Unit roots test results for low-income countries.

Variable	Unit Root Test on Level											Result
	Intercept				Intercept and Trend				None			
	LLC Test	IPS Test	ADFFisher Chi Square	PPFisher Chi Square	LLC Test	IPS Test	ADFFisher Chi Square	PPFisher Chi	LLC Test	ADFFisher Chi Square	PPFisher Chi Square	
GDPPCG	-3.76633 (0.0001)	-5.87292 (0.0000)	84.9220 (0.0000)	167.480 (0.0000)	-3.67230 (0.0001)	-6.10279 (0.0000)	84.6987 (0.0000)	263.407 (0.0000)	-6.66556 (0.0000)	106.675 (0.0000)	176.935 (0.0000)	I(0)
DI	-3.76503 (0.0001)	-4.50914 (0.0000)	65.6079 (0.0001)	93.3511 (0.0000)	-1.93224 (0.0267)	-2.18402 (0.0145)	39.3840 (0.0448)	59.4370 (0.0002)	-5.35584 (0.0000)	58.4109 (0.0003)	91.0628 (0.0000)	I(1)
GFCF	-6.80720 (0.0000)	-9.01465 (0.0000)	127.255 (0.0000)	464.119 (0.0000)	-4.43885 (0.0000)	-6.96685 (0.0000)	93.9920 (0.0000)	440.981 (0.0000)	-12.5677 (0.0000)	174.769 (0.0000)	274.910 (0.0000)	I (1)
LFPR	-3.94897 (0.0000)	-8.14665 (0.0000)	133.338 (0.0000)	376.231 (0.0000)	-3.47564 (0.0003)	-6.64634 (0.0000)	101.993 (0.0000)	361.531 (0.0000)	-6.80850 (0.0000)	139.558 (0.0000)	177.708 (0.0000)	I(1)
M2	0.06537 (0.5261)	0.13103 (0.5521)	37.8122 (0.0630)	70.9485 (0.0000)	-2.83253 (0.0023)	-4.03610 (0.0000)	60.3557 (0.0002)	150.547 (0.0000)	-12.9871 (0.0000)	199.423 (0.0000)	268.794 (0.0000)	I (0)
TAX	-5.93671 (0.0000)	-12.5108 (0.0000)	179.026 (0.0000)	1279.49 (0.0000)	-2.26365 (0.0118)	-9.92221 (0.0000)	132.649 (0.0000)	1257.71 (0.0000)	-10.1634 (0.0000)	142.266 (0.0000)	282.725 (0.0000)	I (1)

Source: Authors' computations

From Table 3, GDPPCG, M2, PSE, and SSE are at a level I (0), and DI, GFCF, LFPR, and Tax have varying degrees of stationarity at first difference I (1). Therefore, different degrees of stationarity for certain variables are specified in the panel unit root test table. Panel autoregressive distributed lag (ARDL) model is utilized to confer such different stationarity extents.

Panel ARDL Results for Low-Income Countries

Section 4 presents the results of the study using the Panel auto-regressive distributed lag (ARDL) approach for low-income countries.

Table 4

Panel ARDL results for low-income countries

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run Equation				
DI	0.109316	0.034692	3.150995	0.0019
GFCF	0.179561	0.043320	4.144980	0.0001
LFPR	0.101592	0.028391	3.578303	0.0004
M2	0.382877	0.100373	3.814534	0.0002
TAX	-0.753783	0.140411	-5.368409	0.0000
Short Run Equation				
COINTEQ01	-0.723045	0.097933	-7.383084	0.0000
D(DI)	-0.057366	0.308978	-0.185664	0.8529
D(GFCF)	0.189185	0.215616	0.877415	0.3814
D(LFPR)	-0.062886	0.092033	-0.683301	0.4953
D(M2)	0.031197	0.205745	0.151628	0.8796
D(TAX)	0.653334	0.476526	1.371036	0.1720
C	0.548246	0.772444	0.709755	0.4787
Mean dependent var	0.009136	**S.D. dependent var**		5.333544
S.E. of regression	4.456688	**Akaike info criterion**		5.068579
Sum squared resid	3734.069	**Schwarz criterion**		6.556182
Log-likelihood	-666.6983	**Hannan-Quinn criteria.**		5.663129

**Note:* p-values and any subsequent tests do not account for model selection.
Source: Authors' computations

A 1% increase in DI is associated with a 0.1093% increase in the dependent variable. A 1% increase in GFCF is associated with a 0.1796% increase in the dependent variable. A 1% increase in LFPR is associated with a 0.1016% increase in the dependent variable. A 1% increase in M2 is associated with a 0.3829% increase in the dependent variable. A 1% increase in TAX is associated with a 0.7538% decrease in the dependent variable. The statistical significance of each coefficient is indicated by the p-values. The p-values are the probability that there is a chance explanation for the observed relationship between the independent and dependent variables. The lower the p-value, the more likely it is that the observed relationship is statistically significant.

Table 4 presents the results of a short-term study using the Panel autoregressive distributed lag (ARDL) approach. The link between digitalization and the economic development of developing countries (low-income countries) is expressed by the results of the short-run analysis. The results of the short-run analysis show general significance with a co-integration value of -0.7230 and a probability value of 0.0000. However, a short-run examination of GDP reveals that certain variables are important and some are not, indicating that these variables have little bearing on economic growth.

Descriptive Statistics of Lower Middle-Income Countries (LMIC)

The following characteristics of the data, which are shown as descriptive statistics of the lower middle-income class (LMIC), aid in understanding the statistical effects of digitalization on the advancement of some developing countries' economies.

Table 5

Descriptive statistics of key variables (2000-2023)

Variables	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Probability
GDPPCG	2.35	2.74	29.98	-21.75	4.39	-0.52	8.60	0.00
DI	23.66	23.81	73.98	-2.79	17.35	0.37	2.27	0.00
GFCF2	25.27	23.63	78.00	2.00	9.76	1.57	7.75	0.00
LFPR	59.96	60.83	88.35	36.40	11.67	-0.03	2.27	0.00
M2	48.79	41.13	151.55	4.65	28.38	1.00	3.55	0.00
TAX	242.03	14.29	2603.96	4.99	585.71	2.61	8.63	0.00

Source: Authors' computations

Table 5 presents descriptive findings for a specific lower middle-income group in developing nations. The above table displays the mean, median, maximum and minimum values, standard deviation, skewness, kurtosis, and probability. The mean of the gross domestic product per capita growth is 2.35. Median is 2.74, Maximum value is 29.98, Minimum value is -21.75, Std. Dev. is 4.39. The mean of the digital index is 23.66, the Median is 23.81, the Maximum value is 73.98, the Minimum value is -2.79, Std. Dev. is 17.35. The mean of Gross fixed capital formation is 25.27, the Median is 23.63, the Maximum value is 78.00, the Minimum value is 2.00, and the Std. Dev is 9.76. Value of LFPR variable Mean: 59.96 is the average value. Median 60.83 is the midway number or the 50th percentile. Maximum: 88.35 is the highest recorded figure. Minimum: 36.40 is the lowest recorded figure. Std. Standard Deviation is 11.67. The mean value of M2 is 48.79, the Median is 41.13, the Maximum value is 151.55, the Minimum value is 4.65, Std. Dev is 28.38. The mean value of the tax is 242.03, the Median is 14.29, the Maximum value is 2603.96, the Minimum value is 4.99, Std. Dev 5.7.

Correlation Matrix of Lower-Middle Income Countries

This section shows the correlation among the key variables for lower-middle-income countries.

Table 6

Correlation matrix of key variables (2000-2023)

Correlation	GDPPCG	DI	GFCF2	LFPR	M2	TAX
GDPPCG	1.00					
DI	-0.13	1.00				
GFCF	0.11	0.10	1.00			
LFPR	-0.02	-0.26	0.09	1.00		
M2	-0.10	0.37	0.11	-0.46	1.00	
TAX	-0.11	0.04	-0.19	0.08	0.00	1.00

Source: Authors' computations

The relationship between the quantities of independent and dependent variables is shown in Table 6. As the diagonal number 1 illustrates, there is a perfect correlation between all variables and itself. The dependent variable, GDPPCG, has a positive correlation with gross fixed capital formation. But digital index. Labour force participant ratio, broad money and tax have a negative correlation with GDPPCG. Gross fixed capital formation positively correlated with GDPPCG at 0.11. Although correlation with GDPPCG at digital index. Labour force participant ratio, broad money and tax -0.13, -0.02, -0.01 and -0.11, correspondingly, which indicates a negative correlation between dependent variables and independent variables.

Unit Roots Test for Lower-Middle Income Countries

This section shows the results of unit root tests for the lower-middle income category of developing countries. Use the panel unit root test to find out if any variable is stationary. This research uses E-Views software to confirm whether or not every variable rejects the null hypothesis.

Table 7

Unit roots test results for lower-middle-income countries

Variable	Unit Root Test on Level											Result
	Intercept				Intercept and Trend				None			
	LLC Test	IPS Test	ADFFisher Chi Square	PPFisher Chi Square	LLC Test	IPS Test	ADFFisher Chi Square	PPFisher Chi	LLC Test	ADFFisher Chi Square	PPFisher Chi Square	
GDPPCG	-13.6601 (0.0000)	-12.8828 (0.0000)	330.188 (0.0000)	819.433 (0.0000)	-14.5812 (0.0001)	-11.7520 (0.0000)	282.062 (0.0000)	949.408 (0.0000)	-10.7832 (0.0000)	345.913 (0.0000)	538.952 (0.0000)	I(0)
DI	-1.98156 (0.0238)	-7.26638 (0.0000)	195.046 (0.0001)	328.029 (0.0000)	3.47382 (0.9997)	-1.99599 (0.0230)	110.104 (0.0209)	217.103 (0.0000)	-5.80054 (0.0000)	132.422 (0.0004)	223.180 (0.0000)	I(1)
GFCF	-9.47473 (0.0000)	-13.2397 (0.0000)	331.137 (0.0000)	545.292 (0.0000)	-5.51483 (0.0000)	-8.72345 (0.0000)	223.053 (0.0000)	672.084 (0.0000)	-21.1781 (0.0000)	533.394 (0.0000)	705.680 (0.0000)	I(1)
LFPR	-11.1107 (0.0000)	-13.8007 (0.0000)	354.661 (0.0000)	753.519 (0.0000)	-9.92742 (0.0000)	-11.0353 (0.0000)	276.660 (0.0000)	983.160 (0.0000)	-17.3911 (0.0000)	534.216 (0.0000)	828.198 (0.0000)	I(1)
M2	-1.36174 (0.0866)	1.91699 (0.9728)	61.7052 (0.9540)	121.709 (0.0029)	-4.67106 (0.0000)	-4.68815 (0.0000)	143.702 (0.0000)	207.643 (0.0000)	-7.49372 (1.0000)	14.8511 (1.0000)	12.8010 (1.0000)	I(0)
TAX	-3.74982 (0.0001)	-2.65520 (0.0040)	119.060 (0.0047)	118.658 (0.0051)	-4.93802 (0.0000)	-5.77851 (0.0000)	166.840 (0.0000)	217.409 (0.0000)	-2.56479 (0.9948)	40.5338 (1.0000)	56.8073 (0.9847)	I(0)

Source: Authors' computations

Table 7 displays the degree of stationarity for each of the supplied variable values for the model. Some variables are stationary at level, whereas others are stationary at first difference. These different degrees of stationarity are in proximity to either level I (0) or first difference I (1). While DI, GFCF, LFPR and M2 have variable degrees of stationarity at the first difference I (1), GDPPCG and Tax are at level I (0). The panel unit root test, therefore, specifies various levels of stationarity for particular variables.

Panel ARDL results for Lower-Middle Income Countries.

Section 5.9 presents the results of the study using the Panel auto-regressive distributed lag (ARDL) approach for the lower-middle income category of developing countries.

Table 8

Panel ARDL results for lower-middle-income countries.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run Equation				
DI	0.329998	0.119074	2.771358	0.0061
GFCF	0.171546	0.064826	2.646238	0.0088
LFPR	0.866445	0.341183	2.539533	0.0119
M2	0.382877	0.100373	3.814534	0.0002
TAX	-0.272838	0.097017	-2.812283	0.0054
Short Run Equation				
COINTEQ01	-0.997884	0.098738	-10.10639	0.0000
D(DI)	0.260562	0.239209	1.089269	0.2774
D(GFCF)	0.211094	0.226975	0.930033	0.3535
D(LFPR)	0.480326	0.283732	1.692887	0.0921
D(M2)	-0.016244	0.030264	-0.536747	0.5921
D(TAX)	0.906218	0.061439	14.74999	0.0000
C	2.529752	1.958529	1.291659	0.1981
Mean dependent var	0.080130	**S.D.dependent Var**		6.860618
S.E. of regression	0.977942	**Akaike info criterion**		-0.321007
Sum squared resid	179.7978	**Schwarz criterion**		1.166597
Log-likelihood	174.0770	**Hannan-Quinn criteria.**		0.273543

**Note:* p-values and any subsequent tests do not account for model selection.
Source: Authors' computations

For DI, a one-unit increase in digital index is associated with a 0.329998 increase in the dependent variable, holding all other variables constant. GFCF, a one-unit increase in gross fixed capital formation, is associated with a 0.171546 increase in the dependent variable, holding all other variables constant. LFPR, a one-unit increase in the labour force participation rate, is associated with a 0.866445 increase in the dependent variable, holding all other variables constant. M2, a one-unit increase in the Broad Money is associated with a 0.382877 increase in the dependent variable, holding all other variables constant. TAX A one-unit increase in tax revenue is associated with a -0.272838 decrease in the dependent variable, holding all other variables constant. The negative coefficient for TAX suggests that higher tax revenue is associated with a decrease in the dependent variable. This may indicate that in low-income countries, higher taxes could have a dampening effect on the variable being analyzed, possibly economic growth or another outcome variable.

Table 8 presents the results of a short-term study using the ARDL approach. The link between digitalization and the economic development of developing countries is expressed by the results of the short-run analysis. The results of the short-run analysis show general significance with a co-integration value of -0.99784 and a probability value of 0.0000.

Understanding the results of digitalization on the economic growth of some developing countries is made easier by looking at the following data qualities, which are displayed as descriptive statistics of the upper middle-income class (UMIC).

Descriptive Statistics of Upper-Middle Income Countries (UMIC)

Table 9 gives descriptive results of developing countries. Mean, median, maximum and minimum values, standard deviation, skewness, kurtosis and probability are presented in the above table. The mean of gross domestic product is 2.80, the median is 2.82, the maximum value is 96.96, the minimum value is -47.90, and the Std Dev. is 6.87. The mean of the digital index is 37.61, the median is 39.69, the maximum value is 92.46, the minimum value is 0.45 and Std. Dev. is 20.52. GFCF's mean is 22.47, the median is 21.63, the maximum value is 57.71, the minimum value is 2.92 and Std. Dev. is 6.40. The mean labour force participant ratio is 9.63, and the median is 60.50, the maximum value is 79.24, the minimum value is 35.91 and Std. Dev. is 8.00.

Broad money (Broad Money)'s mean is 54.73, median is 47.19, maximum value is 220.08, minimum value is 5.74 and Std. Dev. is 34.29. The mean of tax is 15.30, the median is 14.40, the maximum value is 34.63, the minimum value is 0.52, Std. Dev. is 5.85. The normal distribution's flatness and peakness are suggested by the kurtosis value. The kurtosis value of each variable in the above table is more than 3, indicating that all variables, with the exception of the digital index, are positively skewed and leptokurtic. While most variables have a flatter distribution than GDP, the GDPPCG has a significantly peaked distribution. A platykurtic distribution is defined as one where the value of kurtosis is smaller than 3. Because the probability of every variable is "0," Table 7 shows that every variable is regularly distributed.

Table 9

Descriptive statistic of key variable (2000-2023)

Variables	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Probability
GDPPCG	2.80	2.82	96.96	-47.90	6.87	2.66	49.45	0.00
DI	37.61	39.69	92.46	0.45	20.52	-0.06	2.00	0.00
GFCF	22.47	21.63	57.71	2.92	6.40	1.28	6.42	0.00
LFPR	59.63	60.50	79.24	35.91	8.00	-0.43	3.06	0.00
M2	54.73	47.19	220.08	5.74	34.29	1.83	7.27	0.00
TAX	15.30	14.40	34.63	-0.52	5.85	0.24	3.39	0.00

Source: Authors' computations

Correlation Matrix of Upper-Middle Income Countries

This section shows the correlation among the key variables for upper-middle-income countries.

Table 10

Correlation matrix of key variables (2000-2023)

Correlation	GDPPCG	DI	GFCF2	LFPR	M2	TAX
GDPPCG	1.00					
DI	-0.12	1.00				
GFCF	0.17	-0.03	1.00			
LFPR	0.08	0.07	0.19	1.00		
M2	-0.04	0.30	0.23	0.11	1.00	
TAX	0.02	0.16	0.04	0.08	0.07	1.00

Source: Authors' computations

The relationship between the quantities of independent and dependent variables is shown in Table 10. As the diagonal number 1 illustrates, there is a perfect correlation between all variables and itself. The dependent variable, GDPPCG, has a positive correlation with gross fixed capital formation, labour force participant ratio and tax ratio. Digital index and broad money have a negative correlation with GDPPCG. Gross fixed capital formation, Labor force participant ratio and tax ratio positively correlated with GDPPCG at 0.17, 0.08 and 0.02, respectively. However, the correlation between GDPPCG at digital index and broad money is -0.12 and -0.04, correspondingly, which indicates a negative correlation between dependent variables and independent variables.

Unit Roots Test for Upper-Middle Income Countries

This section shows the results of unit root tests for the upper-middle income category of developing countries. Use the panel unit root test to find out if any variable is stationary. This research uses E-Views software to confirm whether or not every variable rejects the null hypothesis.

Table 11

Unit roots test results for upper-middle-income countries

Variable	Unit Root Test on Level											Result
	Intercept				Intercept and Trend				None			
	LLC Test	IPS Test	ADFFisher Chi Square	PPFisher Chi Square	LLC Test	IPS Test	ADFFisher Chi Square	PPFisher Chi	LLC Test	ADFFisher Chi Square	PPFisher Chi Square	
GDPPCG	-13.6601 (0.0000)	-12.8828 (0.0000)	330.188 (0.0000)	819.433 (0.0000)	-14.5812 (0.0001)	-11.7520 (0.0000)	282.062 (0.0000)	949.408 (0.0000)	-10.7832 (0.0000)	345.913 (0.0000)	538.952 (0.0000)	I(0)
DI	-1.98156 (0.0238)	- 7.26638 (0.0000)	195.046 (0.0001)	328.029 (0.0000)	3.47382 (0.9997)	-1.99599 (0.0230)	110.104 (0.0209)	217.103 (0.0000)	-5.80054 (0.0000)	132.422 (0.0004)	223.180 (0.0000)	I (1)
GFCF	-9.47473 (0.0000)	-13.2397 (0.0000)	331.137 (0.0000)	545.292 (0.0000)	-5.51483 (0.0000)	-8.72345 (0.0000)	223.053 (0.0000)	672.084 (0.0000)	-21.1781 (0.0000)	533.394 (0.0000)	705.680 (0.0000)	I (1)
LFPR	-11.1107 (0.0000)	-13.8007 (0.0000)	354.661 (0.0000)	753.519 (0.0000)	-9.92742 (0.0000)	-11.0353 (0.0000)	276.660 (0.0000)	983.160 (0.0000)	-17.3911 (0.0000)	534.216 (0.0000)	828.198 (0.0000)	I (1)
M2	-1.36174 (0.0866)	1.91699 (0.9728)	61.7052 (0.9540)	121.709 (0.0029)	-4.67106 (0.0000)	-4.68815 (0.0000)	143.702 (0.0000)	207.643 (0.0000)	-7.49372 (1.0000)	14.8511 (1.0000)	12.8010 (1.0000)	I (0)
TAX	-3.74982 (0.0001)	-2.65520 (0.0040)	119.060 (0.0047)	118.658 (0.0051)	-4.93802 (0.0000)	-5.77851 (0.0000)	166.840 (0.0000)	217.409 (0.0000)	-2.56479 (0.9948)	40.5338 (1.0000)	56.8073 (0.9847)	I (0)

Source: Author's Computation

Perform the panel unit root test to see whether any variable is stationary. In order to determine whether or not all variables reject the null hypothesis, E-Views software is used in an investigation. The table above displays each specified variable value for the model's degree of stationarity. Different levels of stationarity exist that are in close proximity to either level I (0) or first difference I (1). For instance, certain variables exhibit stationarity at level, while others exhibit it at first difference. Level I (0) is reached by GDPPCG, M2 and Tax, whereas the first difference, I (1), is reached by DI, GFCF and LFPR with varied degrees of stationarity. In the panel unit root test, several levels of stationarity for certain variables are therefore indicated.

Panel ARDL results for Upper-Middle Income Countries

Section 12 presents the results of the study using the Panel auto-regressive distributed lag (ARDL) approach for the upper-middle income category of developing countries.

Table 12

Panel ARDL results for upper middle-income countries.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run Equation				
DI	0.128535	0.036800	3.492777	0.0006
GFCF	0.073234	0.036578	2.002153	0.0467
LFPR	0.338401	0.140101	2.415408	0.0167
M2	0.086203	0.039509	2.181842	0.0304
TAX	0.521720	0.097810	5.333997	0.0000
Short Run Equation				
COINTEQ01	-0.975800	0.094406	-10.33623	0.0000
D(DI)	0.270900	0.282430	0.959177	0.3387
D(GFCF)	-1.015981	1.272125	-0.798649	0.4255
D(LFPR)	1.096864	0.985689	1.112788	0.2672
D(M2)	0.229270	0.187346	1.223779	0.2226
D(TAX)	0.365219	0.363276	1.005349	0.3160
C	-14.08633	2.679907	-5.256274	0.0000
Mean dependent var	-0.080130	**S.D. dependent Var**		6.860184
S.E. of regression	4.033322	**Akaike info criterion**		5.213013
Sum squared resid	3058.325	**Schwarz criterion**		6.700617
Log-likelihood	-689.2300	**Hannan-Quinn criteria.**		5.807563

**Note:* p-values and any subsequent tests do not account for model selection.
Source: Authors' computations

For DI (Digital index), a one-unit increase in the digital index is associated with a 0.1288535 increase in the dependent variable, holding all other variables constant. GFCF (Gross Fixed Capital Formation) A one-unit increase in gross fixed capital formation is associated with a 0.073234 increase in the dependent variable, holding all other variables constant. LFPR (Labor Force Participation Rate) A one-unit increase in the labour force participation rate is associated with a 0.338401 increase in the dependent variable, holding all other variables constant. M2 (Broad Money) A one-unit increase in the Broad Money is associated with a 0.086203 increase in the dependent variable, holding all other variables constant. TAX (Tax Revenue) A one-unit increase in tax revenue is associated with a 0.521720 decrease in the dependent variable, holding all other variables constant. The negative coefficient for TAX suggests that higher tax revenue is associated with a decrease in the dependent variable. This may indicate that in low-income countries, higher taxes could have a dampening effect on the variable being analyzed, possibly economic growth or another outcome variable.

Table 12 presents the results of a short-term study using the Panel autoregressive distributed lag (ARDL) approach. The link between digitalization and the economic development of developing countries is expressed by the consequences of the short-run analysis. According to the short-run analysis's findings, general significance with a co-integration value of -0.975800 and a probability value of 0.0000.

Conclusion and Policy Suggestions

By utilizing a comprehensive panel dataset spanning 24 years across 87 developing countries, this research focuses on the period from 2000 to 2023. The application of the Panel Auto Regressive Distributed Lag (ARDL) methodology reveals that digitalization has a substantial impact on advancing economic expansion in developing nations. In the long run, the results have shown that DI, GFCF, LFPR and M2 have a positive impact on the GDPPCG of developing economies. Conversely, there exists a relation where an escalation in

tax revenue (TAX) is connected to a reduction in the GDPPCG, thereby suggesting that within economies characterized by lower income levels, heightened taxation rates might potentially hinder the progress of economic expansion and prosperity. The results of the short-run analysis also align with these conclusions. Overall, digitalization consistently emerges as a significant catalyst for development and economic prosperity in developing countries.

The following policies are suggested to increase economic growth of developing countries:

- Promoting digitalization can lead to a notable increase in GDP per capita (GDPPC) in developing nations through increased productivity, the creation of new economic possibilities, and better service accessibility.
- Digital infrastructure, digital literacy initiatives, and capital generation should be the main policy priorities. These initiatives will raise living standards, boost productivity, and stimulate economic development.

Moreover, it is imperative and crucial that alterations and modifications in tax strategies and frameworks are carried out and implemented to guarantee a harmonious equilibrium between investments made and the overall progress and advancement of the economic landscape.

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