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Poverty Mitigation, Digital Technology, and Foreign Direct Investment: ARDL Based Evidence from Pakistan

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Abstract: *This research investigates the effect of digital technology on poverty lessening in Pakistan from 1990 to 2022. The poverty headcount ratio is incorporated as the dependent variable, and the analysis integrates digital technology, GDP per capita, labor force participation, inflation, external debt, and Foreign Direct Investment (FDI) being key explanatory variables. The study uses the Autoregressive Distributed Lag (ARDL) and bounds testing approach(s) to examine long-run and short-run relationships. Long-run estimates disclose that digital technology and GDP per capita significantly decrease poverty. The findings propose that digital technology serve as an operative tool for poverty mitigation in Pakistan when supported by prudent management of debt, comprehensive growth policies, and macroeconomic stability.*

Keywords: Digitalization, Poverty, FDI, Pakistan

Introduction

Poverty is widespread socioeconomic issues of the developing nations including Pakistan. Even after the decades of policy interventions, a substantial percentage of the population is still seen having involvements in multidimensional deprivation in relative to income, education, health, and access to fundamental services (Shah et al., 2021; Sheikh et al., 2020).

According to the World Bank (2023), 39 percent of Pakistani population survives below the threshold of lower-middle-income poverty which shows the need of new ways of reducing poverty pressures. For the last decade, digital technology is viewed as potentially transformative technology in economic development and proves to address the socioeconomic issues. Digitalization is associated with productivity, costs, and access to the market, including for marginalized groups (Asghar, 2025; Qiang et al., 2009).

An example of this is mobile phones, which allow people to access labor markets, price information, and remittances, and therefore improve the welfare of the household (Aker & Mbiti, 2010). Digital technology is vital for reducing poverty in various ways. First, digital financial services enhance financial inclusion because low-income households can save, borrow, and transfer money safely. Consumption may be facilitated by mobile money and digital banking, which will make them less vulnerable to shocks and foster micro-entrepreneurship (Suri & Jack, 2016). Second, the Internet enhances human capital development by providing access to education, health information, and services offered by the government. Third, digital platforms generate jobs in formal and informal markets, such as freelancing, e-commerce, and gig-based work, especially for young people and women in third-world countries (World Bank, 2016). In Pakistan,it is vital to study how digital technology can reduce poverty. Mobile phone penetration and broadband connectivity in the country have been growing at a very high rate over the last ten years.

According to the Pakistan Telecommunication Authority (PTA, 2022), mobile teledensity is more than 85 percent, and the number of broadband subscribers has increased significantly since the introduction of 3G and 4G networks. In addition, other government programs, such as the Digital Pakistan Vision and the introduction of digital payment systems, intend to use technology to ensure inclusive development. Nevertheless, with all these developments, Pakistan still remains in a state of poverty, regional disparities,

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and a digital divide between the city and country. Current empirical data on digitalization and poverty provide uncertain yet broadly favorable results. Transnational research indicates that ICT development is linked to less poverty and income inequality, especially in low- and middle-income countries (Cheng et al., 2021).

In Pakistan, fewer empirical studies are conducted to determine if overall poverty reduction is measured at the back of digital technology. This research gap intricates the specific analyses. Thus, this study explores the association between digital technology and poverty alleviation in Pakistan. Through role analysis of ICT access and use, this study aims to add to the existing literature on digital development and offer policy-relevant knowledge. To develop effective strategies that will guarantee the benefits of digital transformation to the most vulnerable groups of society, it is necessary to understand how and whether digital technology can help decrease poverty.

Literature Review

The growing base of empirical studies appreciates the concept of digital technology as an important tool for poverty alleviation in developing economies. The background work done by Qiang et al. (2009) indicates that information and communication technologies (ICTs) can be used to improve productivity and reduce transaction costs to create inclusive economic outcomes. Aker and Mbiti (2010) also show that the diffusion of mobile phones enhances the welfare of households by enabling them to participate in the market and diversify their income and remittance. Recent research offers solid empirical data on digitalization and poverty alleviation through financial inclusion and integration into the labor market. Suri and Jack (2016) reported that the adoption of mobile money greatly alleviated poverty, manifested in the extreme levels of poverty in Kenya, by facilitating the smoothing of consumption and increasing women's labor force participation. In addition, Donou-Adonsou and Lim (2018) found that internet penetration has a statistically significant adverse impact on poverty in Sub-Saharan Africa, especially by enhancing access to financial services. Similar results have been reported by Gupta et al. (2018), who recorded that digital payment systems boost economic inclusion and decrease poverty in low-income economies.

These findings are further corroborated by cross-country analyses. According to Choi and Yi (2009) and Niebel (2018), ICT development offers higher significance to economic achievement in developing nations than in developed economies, suggesting a higher capacity to reduce poverty. Asongu and Odhiambo (2019) highlight that inclusive development is facilitated through digital connectivity, which leads to a reduction in poverty and inequality in terms of income. These conclusions are supported by evidence from developing regions. Salahuddin and Gow (2016) and Hasan et al. (2020) conclude that the growth and development of the Internet and broadband encourage employment, which, in turn, reduces poverty. Nonetheless, the World Bank (2016) warns that digital dividends cannot be automatic; a lack of sufficient human capital, infrastructure gaps, and affordability limits can mitigate the poverty-reducing effect.

Awad (2023) examined the potential ways in which ICT influences poverty eradication in Sub-Saharan African (SSA) countries using data from 2003 to 2019. Their study indicates that income and employment directly impact poverty alleviation. In Malaysia, Zainal et al. (2023) examined the determinants of poverty using data from 2009 to 2019. They showed that income inequality and the inflation rate increased the poverty headcount ratio in Malaysia. Afzal et al., (2022) investigated the effect of technological penetration on poverty and inequality of income across the globe with data on 86 countries in 2005-2020. The results indicate that the effect of technological penetration is not universal because it depends on the income levels of the countries. The correlation between technology and income inequality has profound consequences for disadvantaged nations. Rizqulloh and Firmansyah (2021) examined how the alleviation of poverty depends on ICT in 34 provinces in Indonesia. The result made it possible to conclude that ICT had a strong impact on poverty eradication across 34 regions in Indonesia. Topalli et al., (2021) conducted a study to evaluate how inflows can affect poverty levels of six Western Balkan countries over the period between 2002 and 2021. The results revealed that FDI plays a significant role in reducing poverty in Western Balkan countries. The studies also show that policies that promote economic liberty and transparency within a nation are important in reducing poverty.

Besides the digital technology, various factors also contribute to poverty like in the case of Nigeria, Omodero and Alpheaus (2019) examined the data of the period between 1997 and 2017 and discovered that the external debt had a negative impact on economic growth, whereas debt servicing had a positive impact on economic growth, which can be attributed to the presence of disciplined fiscal management. A negative but statistically insignificant effect was found for inflation. In a similar study, Okon and Monday (2017) found that foreign debt had a significant negative impact on Nigeria's economic growth, but debt servicing had a positive, albeit weak, relationship. They also found that increased per capita income leads to economic growth and alleviation of poverty. These findings are supported in Pakistan. Rauf and Khan (2017), using data from 1972 to 2013, concluded that external debt had a significant and negative impact on Pakistan's economic growth, while human and physical capital positively contributed to growth. Shahzad et al., (2014) and Ramzan and Ahmad (2014) similarly found that external debt and debt servicing negatively affected Pakistan's economic growth in both the short and long run. In contrast, foreign direct investment, exports, trade openness, and human capital were found to promote growth.

Data and Methodology

This study utilizes annual time-series data on Pakistan between 1990 and 2022. The dependent variable is the poverty headcount ratio, which is the percentage of the population below the national poverty line and is normally used as a measure of income-based poverty. The most important independent variable of interest is digital technology, which is specified by the number of persons using the Internet (percentage of the population). The measure here is the degree of digital penetration and access to information and communication technologies in the country. A few other explanatory variables are added to manipulate other macroeconomic factors that affect poverty. Economic growth and advancement in average living standards are reflected by GDP per capita (current US dollars). Foreign direct investment as a percentage of GDP indicates the inflow of external finances and future impacts on job and income creation. The consumer price index is a proxy for the inflation rate. The working-age population of a country is termed the labor force participation rate. Finally, external debt is calculated using external debt stocks as a percentage of GNI. All information was derived using credible secondary sources, such as the World Development Indicators (World Bank).

Empirical Model Specification

To examine the impact of digital technology and foreign direct investment on poverty in Pakistan, the following functional relationship is specified:

Model Functional Form

$$PHR = f(LFPR, INF, DIGT, GDPG, EXDT, FDI)$$

Model Econometric Form

$$\text{PHR} = \beta_o + \beta_1 LFPR_t + \beta_2 INF_t + \beta_3\ DIGT_t + \beta_4 GDPPC_t + \beta_5 EXDT_t + \beta_6 FDI_t + u_t$$

General Form Equation of Model

$$\Delta(PHR)_t = \alpha + \phi_1(LFPR)_{t-1} + \phi_2(INF)_{t-1} + \phi_3(DIGT)_{t-1} + \phi_4(GDPPC)_{t-1} + \beta_5(EXDT)_{t-1} + \beta_6(FDI)_{t-1}$$
$$+\sum_{i=1}^{a_1}\phi_1\Delta(PHR)_{t-i} + \sum_{i=0}^{a_2}\phi_2\Delta(LFPR)_{t-i} + \sum_{i=0}^{a_3}\phi_3\Delta(INF)_{t-i} + \sum_{i=0}^{a_4}\phi_4\Delta(DIGT)_{t-i}$$
$$+\sum_{i=0}^{a_5}\phi_5\Delta(GDPPC)_{t-i} + \sum_{i=0}^{a_6}\phi_6\Delta(EXDT)_{t-i} + \sum_{i=0}^{a_7}\phi_7\Delta(FDI)_{t-i} + \varepsilon_t$$

Long Run Equation of Model

$$\Delta(PHR)_t = \alpha + \sum_{i=1}^{a_1}\phi_1(LFPR)_{t-i} + \sum_{i=0}^{a_2}\phi_2(INF)_{t-i} + \sum_{i=0}^{a_3}\phi_3(DIGT)_{t-i} + \sum_{i=0}^{a_4}\phi_4(GDPPC)_{t-i}$$
$$+\sum_{i=0}^{a_5}\phi_5(EXDT)_{t-i} + \sum_{i=0}^{a_6}\phi_6(FDI)_{t-i} + \varepsilon_t$$

ECM Equation of Model is

$$\Delta(PHR)_t = \alpha + \sum_{i=1}^{a_1} \varphi_1 \Delta(LFPR)_{t-i} + \sum_{i=0}^{a_2} \varphi_2 \Delta(INF)_{t-i} + \sum_{i=0}^{a_3} \varphi_3 \Delta(DIGT)_{t-i} + \sum_{i=0}^{a_4} \varphi_4 \Delta(GDPPC)_{t-i}$$
$$+ \sum_{i=0}^{a_5} \varphi_5 \Delta(EXDT)_{t-i} + \sum_{i=0}^{a_6} \varphi_6 \Delta(FDI)_{t-i} + \varepsilon_t$$

Where PHR indicates poverty headcount ratio, LFPR is the labor force participation rate, INF is the inflation rate, DIGT is the digital technology, GDPPC indicates GDP per capita, FDI represents foreign direct investment, EXDT indicates the external debt, and u_t is the error term.

Table 1

Description of Variables

Variables	Description of Variables	Economic Justification
PHR	Poverty headcount ratio	
DIGT	Digital technology	Digital access improves income opportunities, financial inclusion, and information flow
LFPR	Labor force participation rate	Increase income levels and reduce poverty
GDPPC	GDP per capita (Current US dollars)	Higher income levels reduce poverty
FDI	Foreign direct investment (FDI inflows as a percent of GDP)	FDI generates employment and technology spillovers
EXDT	External debt (percentage of GNI)	Debt burden enhances poverty levels
INF	Inflation rate (Consumer price index)	Higher inflation reduces purchasing power and increase poverty levels

Econometric Methodology

This empirical research employs descriptive analysis to summarize the basic statistical properties of the variables supplemented with correlation analysis to investigate the direction and strength of relationships of the variables. on empirical front, Augmented Dickey-Fuller (ADF) test is used to determine the unit root properties of the variables. long-run relationship is confirmed via the bounds test. The ARDL model is estimated to determine long-run coefficients and short-run dynamics by an Error Correction Model (ECM). The Error Correction Term (ECT) measures the speed with which the system adjusts back to short-run shocks for the restoration of a long-run equilibrium. Furthermore, a series of diagnostic tests are run to authenticate the results.

Data Analysis

Table 2 gives the descriptive statistics of the variables. PHR shows a substantial variation, representing a persistent poverty fluctuation over time. DIGT and GDP per capita are looked for a wide dispersion. Positive skewness in PHR, inflation, digital technology, and FDI suggests right-tailed distributions, while high kurtosis in inflation and FDI indicates leptokurtic distribution.

Table 2

Descriptive Analysis

Variables	Mean	Maximum	Minimum	S. D.	Skewness	Kurtosis
PHR	35.2701	64.3	23.73	12.0893	0.93965	2.61891
LFPR	50.6364	52.11	48.36	0.89433	-0.5699	2.98653
INF	9.41354	30.7681	2.52933	5.9736	1.67463	6.63615
DIGT	8.19491	27.3759	0.00011	7.62002	0.85246	3.00504

Variables	Mean	Maximum	Minimum	S. D.	Skewness	Kurtosis
GDPPC	960.712	1569.34	399.956	401.944	-0.0458	1.57066
EXDT	38.5401	55.9009	25.7934	9.50664	0.25311	1.75603
FDI	1.1085	3.66832	0.37553	0.80574	2.09532	6.50605

Table 2 presents the correlation matrix of variables. The findings show that poverty headcount ratio is negatively correlated with the LFPR (-0.180), digital technology (-0.364), GDPPC (-0.337), FDI (-0.231) while PHR is positively correlated with the inflation (0.313) and external debt (0.154).

Table 3

Correlation Analysis

	PHR	LFPR	INF	DIGT	GDPPC	EXDT	FDI
PHR	1.000						
LFPR	-0.180	1.000					
INF	0.313	-0.047	1.000	0.444			
DIGT	-0.364	0.629	0.444	1.000	0.881		
GDPPC	-0.337	0.763	0.175	0.881	1.000		
EXDT	0.154	-0.588	0.163	-0.293	-0.634	1.000	
FDI	-0.231	-0.219	0.222	-0.087	-0.062	-0.268	1.000

Table 4 reports the Augmented Dickey–Fuller (ADF) unit root test results. The findings indicate that PHR, LFPR, and FDI are stationary at levels, as their probability values are significant, confirming integration at I(0). In contrast, inflation, digital technology, GDP per capita, and external debt are non-stationary at levels but become stationary after first differencing, indicating integration at I(1). The mixed order of integration justifies the use of the ARDL framework for cointegration analysis.

Table 4

Unit Root Test (ADF Test)

Variables	Level	Prob.	1st Diff.	Prob.	Outcome
PHR	-3.729	0.038	-2.757	0.077	I(0)
LFPR	-4.749	0.003	-9.394	0.000	I(0)
INF	-0.369	0.902	-4.323	0.002	I(1)
DIGT	-1.692	0.999	-0.605	0.855	I(1)
GDPPC	-0.881	0.779	-5.986	0.000	I(1)
EXDT	-1.380	0.579	-4.572	0.001	I(1)
FDI	-2.954	0.015	-3.577	0.013	I(0)

Table 5 reports the ARDL bounds test results for cointegration. The calculated F-statistic (7.2835) exceeds the upper bound critical values at the 1% significance level. This provides strong evidence of a long-run cointegrating relationship among the variables, confirming the existence of a stable long-run association in the estimated model.

Table 5

Bound Test

Test Statistic	Value	k
F-statistic	7.2835	6
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.12	3.23
5%	2.45	3.61
2.5%	2.75	3.99
1%	3.15	4.43

The long-run ARDL estimates shown in Table 6 contain the poverty headcount ratio (PHR) as the dependent variable, which indicates the long-term factors of poverty in Pakistan. The results show that the labor force participation rate (LFPR) has negative coefficient (-1.1890) and is significant at 10 percent level. It means that an increase in the participation in the labor force will help reduce poverty in the long-term by increasing the number of employment opportunities and generating household income. An increase in the participation of members in the labor market increases the earning potential, especially among the low-income earners (Ameer et al., 2024). The coefficient of inflation (INF) is positive and has a statistically significant value at the 5 percent level implying that increase in prices elevates poverty in the long run. Increased inflation reduces real incomes and has a larger impact among poor households which use a higher proportion of their income on necessities. This observation is in line with the traditional economic theory and empirical evidence in developing economies (Ameer et al., 2024; Paul & Sharma, 2019). The coefficient of digital technology (DIGT), which has been proxied by the internet use, is negative and statistically significant at the 5 percent level. This means that as there is more penetration on the digital, there is less poverty in the long-term due to accessibility to information, financial services, jobs and markets. The finding promotes the opinion that digitalization can be an efficient instrument of inclusive development in case of the presence of facilitating factors (Lechman & Popowska, 2022; Rizqulloh & Firmansyah, 2021). There is a negative significant association between poverty and GDP per capita (GDPPC) at the 1 percent level, which confirms the economic growth is very important in reducing poverty. An increase in income will lead to a higher standard of living and the availability of basic services, which will lower the percentage of people living below the poverty line (Hassan, 2015; Tahir et al., 2014). The effect of external debt (EXDT) on poverty is positive and significant, meaning that the higher the external debt the higher the poverty in the long-run. It implies that high dependence on foreign borrowing can crowd out social expenditures and leave debt services debt-servicing liabilities with negative implications on the welfare (Emerah&Ogege, 2013; Ashraf et al., 2020). Finally, foreign direct investment (FDI) demonstrates a negative, and statistically insignificant positive correlation with poverty, suggesting that FDI inflows have not been converted into poverty decrease directly, perhaps because there are few spillovers or investment patterns are capital-intensive (Muhammad et al., 2025).

Table 6

ARDL Long-Run Estimates

Dependent Variable: PHR				
Selected Model:ARDL(2, 1, 1, 2, 2, 0, 2)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LFPR	-1.1890	0.6285	-1.892	0.083
INF	4.097	1.546	2.649	0.021
DIGT	-0.806	0.321	2.508	0.028
GDPPC	-0.139	0.042	-3.286	0.007
EXDT	2.134	0.529	4.032	0.002
FDI	-2.390	4.746	-0.504	0.624
C	84.137	34.539	2.436	0.031

Table 7 presents the short-run ARDL error correction results. The error correction term is negative and statistically significant, confirming convergence toward long-run equilibrium, with about 36.5% of disequilibrium corrected annually. In the short run, GDP per capita, external debt, and foreign direct investment significantly reduce poverty, while labor force participation shows a marginally significant poverty-reducing effect. Inflation and digital technology do not exhibit significant short-run effects on poverty.

Table 7

ARDL Short-Run ECM Estimates

Dependent Variable: PHR				
Selected Model:ARDL(2, 1, 1, 2, 2, 0, 2)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(PHR(-1))	0.460	0.177	2.591	0.024
D(LFPR)	-2.546	1.287	-1.978	0.071
D(INF)	-0.299	0.229	-1.305	0.217
D(DIGT)	-0.299	1.815	-0.165	0.872
D(GDPPC)	-0.052	0.017	-3.120	0.009
D(EXDT)	-0.780	0.310	-2.513	0.027
D(FDI)	-5.866	2.142	-2.739	0.018
CointEq(-1)	**-0.365**	**0.135**	**-2.707**	**0.019**

Table 8 reports the diagnostic test results for the ARDL model. The Breusch–Godfrey test designates no issue of serial correlation. The Breusch–Pagan–Godfrey test confirms the homoscedasticity thus represent constant error variance. The Jarque–Bera statistic settles that residuals are normally distributed. Additionally, the Ramsey RESET test indicates no biasness of the model(s) specification. Thus, implying that the model is properly quantified and the results are reliable.

Table 8

Model Diagnostic Tests

Problem	**Test**	**Statistic**	**Prob.**	**Outcomes**
Serial Correlation	Breusch-Godfrey	2.587	0.1360	Not Found
Heteroscadasticity	Breusch-Pagan-Godfrey	0.910	0.5782	Not Found
Residuals Normality	Jarque-Bera	0.772	0.6784	Normally Distributed
Specification Bias	Ramsey RESET	3.238	0.102	Correctly Specified

Conclusions and Policy Suggestions

This research investigated relationship of digital technology and poverty in Pakistan. the outcomes confirmed the traces of poverty reduction at the back of digital technology usages. The results on the other variables also authenticated the economic relationship of the variables like that of GDP per capita, labor force participation, external debt, and FDI apart from inflation.

ECT provided evidence of a stable long-run adjustment. Finally, stability and diagnostic tests confirmed the reliability of the estimated model. The study proposes supportive policies to envisage correct use of digital technology to ensure the consistent mitigation of poverty.

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