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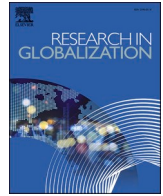
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Exploring the non-linear impact of information and communication technology, globalization, and geopolitical risks on poverty in Pakistan

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ABSTRACT

The discussion around globalization often overlooks historical context and real-world dynamics, especially in the context of global development. This study examines the relationship between information and communication technology (ICT), geopolitical risks (GPR), and globalization in Pakistan from 1980 to 2022, with a focus on their impact on poverty. Using the Non-linear Autoregressive Distributive Lag (NARDL) model, the findings reveal that improvements in ICT infrastructure (ICT_POS) significantly reduce poverty, while setbacks in ICT (ICT_NEG) have minimal impact. On the other hand, rising geopolitical risks (GPR_POS) worsen poverty by reducing economic activity, investment, and trade, with negative geopolitical events (GPR_NEG) further exacerbating the issue. Positive economic globalization (EGB_POS) also plays a key role in reducing poverty, while the effects of negative globalization (EGB_NEG) remain unclear. The study recommends enhancing ICT infrastructure and accessibility, particularly in poverty-stricken regions, and addressing geopolitical risks through political stability and conflict resolution. These measures are essential for promoting economic growth and reducing poverty.

Introduction

Poverty extends beyond mere income deficiency, encompassing the lack of financial resources and access to essential services such as housing, nutrition, and clothing. Theoretical perspectives, such as Sen's Capability Approach, emphasize that poverty is a multidimensional issue, restricting individuals from achieving their full potential (Wagle, 2002). Similarly, the structural theory of poverty highlights systemic barriers, such as unequal access to resources and opportunities, that perpetuate poverty cycles. These challenges are further exacerbated in developing countries, where, as of 2023, over 165 million additional individuals have fallen below the poverty line compared to previous years (UNDP, 2023). Despite improvements in economic performance, factors such as population growth, global changes, and natural disasters continue to sustain high poverty rates (The Global Fintech Database, 2021). Globally, approximately 700 million people live in extreme poverty, earning less than \$1.90 per day, primarily in South Asia and sub-Saharan Africa. Moderate poverty, defined by daily incomes between \$1.90 and \$3.20, affects 26 % of the global population, posing significant challenges to global poverty eradication efforts (World Poverty Statistics, 2024).

By 2030, it is projected that 67 percent of the global impoverished population will reside in hazardous areas. The COVID-19 pandemic poses a significant risk of undoing years of advancements in the fight against global poverty and economic inequalities, endangering the prospects of an entire generation of children (Suryahadi et al., 2020). The World Bank projects that between 88 million and 115 million more individuals could fall into extreme poverty by 2020 due to the COVID-19 pandemic, potentially raising the total to over 1 billion. Poverty hinders economic progress. Poverty is often viewed because of inadequate financial resources; however, it is increasingly acknowledged globally as a complex issue encompassing various socio-economic aspects of human well-being. Income by itself does not adequately measure human well-being, as it overlooks non-monetary aspects that are not captured in market transactions. The multidimensional poverty framework (Alkire & Foster, 2011) emphasizes non-income-based dimensions, such as education, health, and living standards, as crucial in assessing poverty. This approach provides a comprehensive lens to evaluate the interplay between poverty and socio-economic development. Assessing poverty through this comprehensive lens is particularly relevant considering Pakistan's historical economic and social development. From 1990 to 2003, Pakistan experienced an increase in GDP per capita from 543 USD

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to 973 USD, reflecting a growth rate of approximately 4 % (UNDP, 2015). Notwithstanding its fluctuations, Pakistan has outperformed India and Bangladesh in terms of GDP per capita. The prevalence of income-based poverty has significantly decreased, as evidenced by the reduction in the percentage of the national population living below the poverty line, which fell from 64.3 % in 2001/2002 to 29.5 % in 2013/14. Nevertheless, no notable progress has been detected regarding important social indicators. Despite significant advancements in this area, Pakistan remains behind its South Asian counterparts in vaccination coverage rates, according to the World Bank.

Poverty is a complex issue characterized by various contributing factors. Understanding these elements is essential for improving policymaking in the current context. Research (Khaliq et al., 2016; Khurshid et al., 2023a; Nguyen et al., 2023), suggests that elements such as Information and communication technology (ICT), globalization (GB), and geopolitical risks (GPR) have significantly influenced the challenging circumstances faced by individuals in Pakistan.

The ICT revolution has rapidly expanded across the globe, impacting both microeconomic and macroeconomic levels (Meijers, 2014). ICT has the potential to enhance labor and factor productivity, decrease transaction and production costs, optimize corporate operations, marketing, and pricing strategies, improve management and organizational effectiveness, and raise the quality of decision-making at the microeconomic level. Furthermore, it enables organizations to understand and leverage contemporary technology, develop innovative products, services, and business strategies, collaborate to deliver specialized expertise, improve their offerings, and promote innovation and the spread of technology (Salahuddin and Gow, 2016). The proliferation of ICT has a significant macroeconomic influence, enhancing foreign direct investments and fostering economic development (Czernich et al., 2011; Pradhan et al., 2014; Khurshid, 2023). Moreover, it promotes global trade, lowers unemployment rates, curbs inflation and corruption, and reduces the extent of the informal economy. The utilization of ICT has the potential to address societal challenges, including poverty. ICT has the potential to reduce poverty in areas such as business administration, agriculture, healthcare, and finance. ICT provides disadvantaged individuals with the means to establish ICT-focused microenterprises, educates them about job opportunities and compensation, and engages in active recruitment efforts. It enhances market transparency, reduces inefficiencies, optimizes sales, marketing, and procurement processes, decreases transaction costs, promotes efficiency, and boosts revenue for underrepresented traders and entrepreneurs. Research shows that disadvantaged entrepreneurs in Tanzania who employed ICT experienced a notable decrease in their economic poverty levels between 2008 and 2010. Bhavani et al. (2008) and Shirur et al. (2016) found that the use of mobile phones enabled low-income workers in China to save 6 % of their time by reducing commuting costs. ICT plays a crucial role in enhancing the monitoring of natural disasters and ensuring agricultural security. It helps to mitigate market price fluctuations and monopsony effects, strengthens the bargaining power of farmers and fishermen, reduces transaction and search costs, and provides education on effective agricultural practices, including the recognition and management of plant and animal diseases. This study presents a well-founded case analysis that explores these elements within the framework of a developing country, particularly Pakistan, amidst the predominantly theoretical global development dialogue.

The integration of ICT with GB presents a significant opportunity to significantly alleviate global poverty. The potential for alleviating poverty is contingent upon the growth strategies employed by both affluent and developing countries, alongside the broader global policy framework in place. Is there a connection between poverty alleviation and globalization? This subject has garnered significant attention and discussion among scholars and government officials. The current research presents conflicting findings regarding this issue. GB is viewed as a mechanism for alleviating poverty while simultaneously being a factor in its ongoing existence. Dollar and Kraay (2002), Khurshid et al.

(2024), and Bhagwati and Srinivasan (2002) demonstrated that economic openness fosters economic growth, leading to a decrease in poverty levels. Harrison and McMillan (2007) synthesized data from 15 country-specific studies to suggest that conventional understandings of the relationship between globalization and poverty may be misguided or incorrect. The findings highlight the significant disparities in the distribution of trade benefits, demonstrating that globalization does not consistently favor the disadvantaged.

The impact of geopolitical risk on poverty levels, especially in emerging nations, can be significant. Geopolitical developments are having an ever-growing impact on both global and local economic interactions. The escalation of geopolitical risks can be attributed to a variety of factors, such as terrorism, local and regional instability, political unrest, energy crises, political violence, territorial conflicts, and other significant global geopolitical events. The implications of these risks extend beyond immediate threats to human life, significantly influencing global poverty as well. Geopolitical threats can profoundly impact poverty levels through various mechanisms. The halt of economic activity may lead to unemployment, reduced income, and increased costs for vital goods and services. Geopolitical threats, such as violence and displacement, may drive individuals to leave their homes and lose their means of livelihood, thereby intensifying poverty. Geopolitical factors can significantly and enduringly influence poverty rates, particularly in emerging nations where poverty remains a pressing issue. Promoting worldwide economic development and reducing poverty relies on effectively managing these risks and creating strategies to mitigate their impacts. This paper analyzes the circumstances in Pakistan, thereby filling a gap in the existing literature and contributing to the global discussion on the interactions among globalization, information and communication technology, and geopolitical issues that influence poverty. Understanding these implications is crucial for decision-makers aiming to tackle poverty more effectively.

This study's contribution is multidimensional and grounded in the empirical examination of the relationship between globalization and poverty in a developing country context. Globalization is often discussed in broad, abstract terms in the global development debate, with cross-country analyses that obscure its true, localized impacts. By focusing on Pakistan, a lower-middle-income country where approximately 60 million people live in poverty, this study seeks to move beyond the abstract and ahistorical framing of globalization's effects. Given the wide range of theoretical predictions, the study aims to address the largely empirical question of how globalization contributes to poverty in a specific national context. While existing literature provides cross-country evidence, it often fails to capture the nuanced, nonlinear effects of globalization within a particular economy. This study fills that gap by offering a detailed case study of Pakistan, employing the NARDL cointegration approach and time series data from 1980 to 2022 to uncover these complex dynamics.

Secondly, the study breaks new ground by examining the nonlinear effects of geopolitical risks on poverty status in Pakistan. Although prior research acknowledges the negative impacts of political instability, terrorism, and corruption on poverty and economic growth, these studies often do not employ a robust measure of geopolitical risks that directly ties these factors to poverty outcomes. This research addresses this gap by using the Caldara and Iacoviello GPR index (2018), a reliable measure that captures the full range of geopolitical events—terrorism, military threats, war risks, and political tensions—relevant to both current and anticipated threats. This index allows for a more comprehensive understanding of how geopolitical risks, a factor increasingly recognized in global development discussions, shape poverty outcomes in Pakistan.

This study contributes to the broader global development debate by situating Pakistan's experience within the context of globalization and geopolitical risks, offering concrete insights that challenge the often-abstract nature of global development theories. By extending the analysis through a nonlinear lens, the study not only advances empirical

knowledge but also provides a stronger analytical framework for understanding how these global forces interact with poverty at the national level and international level.

The subsequent sections of the paper are structured as follows: Section 2 analyzes prior literature, Section 3 delineates the methodology and variables, Section 4 offers the study's findings, and the last section concludes. Section 5 delineates the policy implications of the study for the primary stakeholders.

Literature review

The intricate interplay among ICT, globalization, geopolitical risks, and poverty creates a complicated tapestry within Pakistan's socioeconomic landscape that demands more examination. As we move closer to a time when technology rules, the impact of these developments on the level of poverty around the world, particularly in Pakistan, is becoming more and more significant. By providing a scholarly viewpoint to the current conversation, this literature review aims to establish the foundation for future studies and well-informed discussions in this important area.

ICT-poverty nexus

ICTs' impact on the levels of development and poverty in developed and developing nations has been the subject of several studies. These studies have been an immense help in carrying out this research. [Rizqulloh and Firmansyah \(2021\)](#) examined the impact of ICT on poverty alleviation in 34 provinces of Indonesia using panel regression and found that technology significantly impacts poverty alleviation. The study suggests that the government should facilitate community use of technology to support community activities and reduce poverty in these provinces. By employing a panel of 123 countries consisting of 45 high-income countries, 58 middle-income countries, and 20 low-income countries from 2002 to 2017 and by constructing an ICT index from mobile, internet, and fixed broadband ([Appiah-Otoo & Song, 2021](#); [Khurshid et al., 2023b](#)), it was found that in general, ICT helps to reduce poverty, increasing economic growth in both countries; however, poor countries tend to gain more from the ICT revolution. [Israel \(2021\)](#) investigated the impact of ICT on rural development in Kogi State, Nigeria, focusing on poverty reduction. Using the neoclassical theory of poverty, the research employed a multi-stage sampling method to select 1,200 households from 120 rural communities across 21 Local Government Areas. Three regression models were estimated using the Ordinary Least Squares (OLS) technique. Results found that access, ownership, and utilization of ICT positively impacted poverty reduction in rural areas. Similarly, a comparative factor analysis by [Postula et al. \(2021\)](#) in the period 2009–2019 found that ICT usage in EU countries had significantly reduced energy poverty. [Ahsan and Afzal \(2022\)](#) examined the impact of ICT on Pakistan's poverty reduction using the Household Integrated Economic Survey 2018–19. The Probit model is used to analyze the determinants of poverty, while quantile regression is applied to assess the impact of policy interventions. Results showed that ICT alleviates poverty by providing job and entrepreneurial opportunities. [Gu et al. \(2023\)](#) used data from seven rural Chinese counties to investigate the impact of ICT on poverty reduction, finding that ICT contributed positively by increasing migration and off-farm income rather than directly enhancing agricultural production. This highlights the importance of complementary incentives alongside ICT to foster local development. In the context of analyzing poverty reduction mechanisms, four alternative estimators are employed: (1) a linear panel data model with fixed effects (FE estimator), (2) a fixed effects model with the instrumental variable method (FEIV estimator), which is preferred for addressing endogeneity, (3) the ML-SEM estimator for robustness, and (4) a fractional probit model with the generalized estimation equation (GEE estimator), used when the dependent variable is fractional and for additional robustness checks. These methodologies

ensure a comprehensive understanding of the factors influencing poverty reduction, including ICT's role. ([Awad, 2023](#)) studied the mechanisms through which ICT can reduce poverty in 37 sub-Saharan African economies from 2003 to 2019. Results of Moments Quantile methods showed that while increased per capita income and employment rate contribute to poverty reduction, environmental quality improvement increases it. The study suggests that national strategies aiming to reduce poverty in SSA must incorporate pro-poor ICT policies, as the negative impact of environmental degradation on poverty is stronger.

Globalization: Poverty Nexus

The relationship between globalisation and poverty is now being studied using a range of globalisation indicators, including openness to trade and foreign direct investment. According to much research, globalization reduces poverty. [Deyshapria \(2018\)](#) explored the impact of globalization on poverty across 119 countries using the poverty headcount and KOF globalization indexes using OLS. Results show that globalization significantly reduces poverty levels. [Khan and Majeed \(2018\)](#) examined the impact of globalization on poverty in 113 developing countries from 1980 to 2014 by applying pooled OLS, and System GMM, and found that economic and social globalisations generally reduce poverty, while political globalization does not. Using the ARDL approach ([Umair & Awan, 2019](#)), they examined the impact of globalization on poverty in Pakistan and found that trade openness, foreign direct investment, and gross domestic product negatively affect poverty, while external debt positively affects it. The study recommends using globalization as a tool for poverty elimination. Similarly, a panel data study by [Hassan et al. \(2020\)](#) shows the impact of globalization on poverty in 73 developing countries from 2005 to 2016 by using feasible generalized least square and finds that globalization contributes to poverty alleviation. [Salahuddin et al. \(2020\)](#) analyze the impact of globalization and corruption on poverty in South Africa from 1991 to 2016 utilizing second-generation panel regression techniques. It found that globalization reduces poverty, while corruption intensifies it. [Kiani et al. \(2021\)](#) examined the impact of poverty, globalization, and environmental degradation on economic growth in selected SAARC countries from 1980 to 2018. Using the panel ARDL, it found a positive relationship between globalization and economic growth. Furthermore, [Majeed and Farooq \(2021\)](#) examined the impact of globalization on poverty in Pakistan from 1975 to 2018. ARDL results showed that despite progress towards the Millennium goals, over one billion people still live on less than USD 1.25 per day. The empirical analysis shows that globalization significantly adversely affects Pakistan's annual poverty, leaving the poor behind and marginalizing them. [Osinubi et al., \(2022\)](#) examine the relationship between poverty and globalization dimensions in MINT countries (Mexico, Indonesia, Nigeria, and Turkey) from 1980 to 2018. Key findings ARDL and NARDL show that income inequality influences the relationship between globalization and poverty in Mexico and Indonesia, and social globalization and poverty in Turkey, and does not affect all dimensions of globalization and poverty in Nigeria. [Khan et al. \(2023\)](#) evaluated the impact of financial inclusion on energy poverty in six emerging economies from 2004 to 2019. The research uses a multidimensional index, a novel index for financial inclusion, and panel data approaches to show that globalization and energy investment are key determinants of energy poverty in emerging economies. [Pal \(2024\)](#) investigated the impact of economic globalization on poverty levels in Europe, Central Asia (ECA), and South Asia (SA) from 1991 to 2020 and suggested that economic globalization has a negative (positive) effect on poverty in the top (bottom) globalized region.

Geopolitical Risk: The Poverty Nexus

With increasing global economic dependence, geopolitical risk has

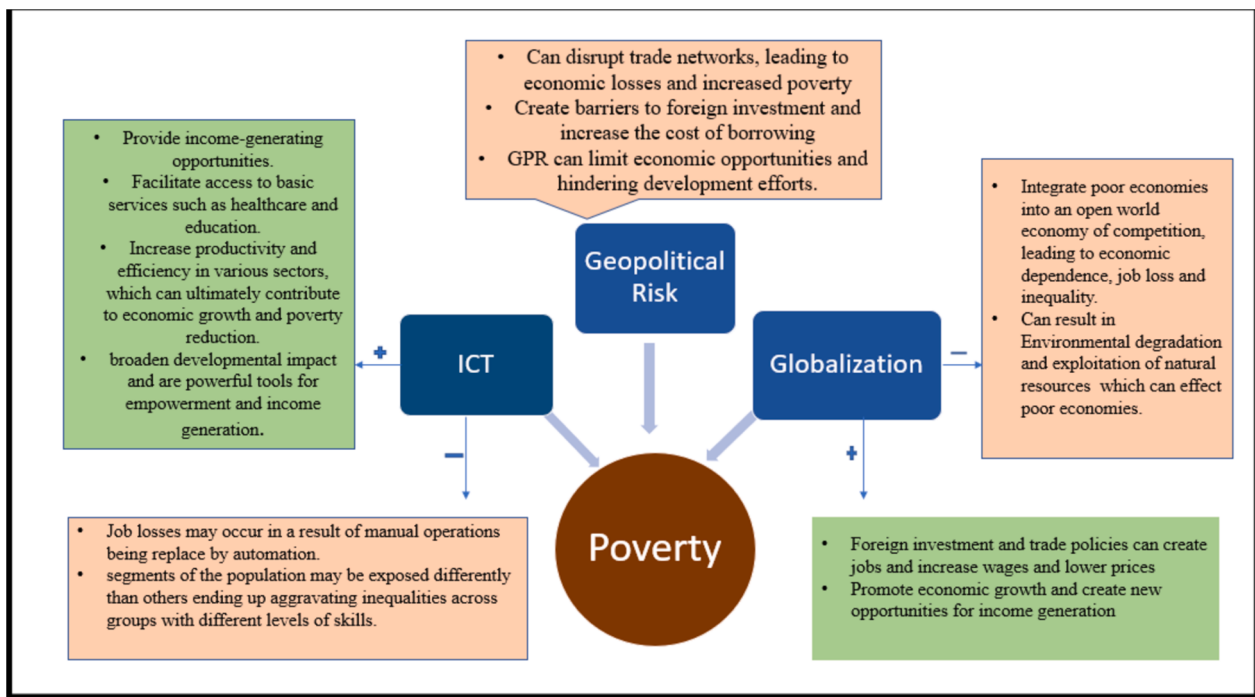


Fig. 1. Transmission mechanism of variables.

become one of the primary determinants of economic decision-making across countries. It is reasonable to predict that geopolitical risk and unfavorable geopolitical events will have a considerable impact on a country's growth rate since these are among the major factors influencing economic decision-making processes (IMF, 2017). The literature is replete with studies that do a comparative assessment of the economic development of nations that have been through wars, acts of terrorism, revolutions, coups, or changes in political rule. However, Soybilgen et al. (2019) built a parallel assessed regulator (IMPI), which covered 18 emerging economies over 31 years from 1986 to 2016. Their results indicate that the effect of geopolitical risks on growth rates is negative and statistically significant. Specifically, a 10-point increase in the geopolitical risk index leads to a 0.2 % to 0.4 % decline in GDP growth. The study by Lu et al. (2020) examines the impact of geopolitical risks on financial development in 18 emerging markets from 1985 to 2018. Results of fixed effects show that increased risks lead to lower domestic credit to the private sector. Controls like per capita income and broad money positively affect domestic lending. External imbalances suppress domestic credit in emerging markets. The study provides evidence for the negative impact of geopolitical risks on financial development, suggesting that economic performance can slow down due to concomitant threats. In a study analysis by Soltani et al. (2021), however, they pointed out that the political conflicts in MENA are among some of the most critical factors in the region's economic growth slowdown. With the help of the fixed index variation, the panel vector autocorrelation portrayal via the units stays dangerous and creates a permanent economic threat within MENA countries. Moreover, Ja et al. (2022) argue that GPR leads to an upgrade in living standards evident in the advanced states and calibration aftershocks. In their piece of the year, "The effect of geopolitical risks on the foreign direct investment from 2003 to 2020 in the 41 countries," Yu and Wang (2023) reveal the strong negative impact of geopolitical risks declining foreign direct investments into these countries, which affects local economic growth negatively in turn. In addition, Bajaj et al. (2023) have conducted a research paper that focuses on geopolitical risk contributions to the economies of emerging countries from 1999 to 2016. It was established that geopolitical risk has a strong negative correlation with financial situations triggered by risk appetite by investors as well as market performance. The study by Jha

et al. (2024) examines the impact of geopolitical risk on economic growth across 41 countries from 2000 to 2020. Results of feasible generalized least squares show a positive relationship, with a 1 % increase in risk resulting in a 3.3 % increase in economic growth. Advanced economies can mitigate geopolitical shocks while emerging economies experience adverse effects. Institutional factors like democracy and economic freedom enhance this relationship.

Concluding remarks from the literature review:

The literature review highlights the multifaceted dynamics shaping the ICT-poverty nexus, the complex relationship between globalisation and poverty, and the significant impact of geopolitical risks on economic development and poverty outcomes. While existing studies provide valuable insights, there are evident gaps that underscore the need for further research. A notable corpus of studies has been conducted on the effects of globalization, GPR, and ICT on Pakistan's poverty status, yet there is a significant lack of comprehensive non-linear analysis in the literature. Although several studies have studied linear relationships using techniques like regression analysis, there aren't many that make use of non-linear analytical frameworks. The complex and possibly nonlinear nature of the linkages between ICT, globalization, geopolitical hazards, and poverty may be better captured by a non-linear technique like threshold models or non-linear regression. Eliminating this disparity would greatly enhance the comprehensive and precise depiction of the intricate connections between ICT, globalization, geopolitical risks, and poverty in Pakistan.

Research methodology

Conceptual framework

In Fig. 1, the transmission mechanism of study variables has been given. The linkage of transmissions demonstrates how ICT, globalization, and political risk interlink with poverty. ICT plays a positive role in poverty reduction and facilitates labor market expansion, education opportunities, and health care delivery. ICTs stand for the creation of new opportunities for economic growth that significantly contribute to

Table 1
Description of variables.

Abbreviations	Explanation	Data Source
Dependent Variable		
POV (Poverty Status)	Head count ratio is used as proxy of poverty status	Economic Survey of Pakistan
Independent Variables		
GPR (Geopolitical Risks)	Geopolitical Risks index is used for GPR	Matteoiacoviello.com
ICT (Information and Communication Technology)	No. of fixed telephone subscriptions are used as proxy of ICT	WDI
GLB (Globalization)	Globalization Index	Kof Globalization Index
GDP (Economic Growth)	GDP per capita ((current US \$))	WDI
LBR (Employment level)	Labour force participation rate (% of total population)	SBP
FDI (Foreign Direct Investment)	Net Inflows (% of GDP)	WDI

the development of human capital, setting an economic environment that offers better economic opportunities, and finally, a good quality of life. On the contrary, if the phenomenon is the result of the disparity in income between people with different sources of income and those with access to technical resources, the poverty gap could get wider. Political geographies like conflicts and competition can be responsible for the unsteady situation of the economy, which, in turn, can influence poverty through obstacles such as the loss of jobs and revenue. Besides, geopolitical risks can often result in the displacement of people, which will worsen the deplorable situation of poverty. The population segments with smaller incomes and communities that are located most in proximity to global events possess the highest level of risk from geopolitical interplay. As the term ‘globalization’ describes the rapid integration of economies and trading activities across different borders, it has in many cases been identified as a major factor that tackles the issue of poverty. A surge in international trade and the inflow of foreign investment creates more jobs and makes people richer, which consequently leads to higher wages and better standards of living for the citizens. Worldwide markets allow developing countries to escape, when necessary, thereby increasing poverty. Others are concerned that globalization is a poverty-increasing phenomenon, specifically in underdeveloped countries, because as the operations of companies move to countries with cheaper labor costs, it follows that people will lose their jobs. Consequently, this may lead to a drop in the wage, as many of those who remain in the occupation will have less ability to negotiate higher wages. Furthermore, slightly higher income inequality may be caused by the wave of globalization, with the high consumption of goods by wealthy people making poor people poorer.

Variable setting and model Specification

This study explores the interplay of geopolitics, ICT, and globalization and their effects on poverty in Pakistan from 1980 to 2022. Given Pakistan’s strategic location and exposure to political risks, the research highlights the significance of aligning its policies with global standards

while addressing regional challenges. Data on poverty, measured using the headcount ratio, were sourced from various economic surveys. Missing data were addressed using a simple interpolation method (Jamal, 2006; Khurshid et al., 2023c). The study examines how factors like digital skills, ICT evolution, and governance measures influence poverty, emphasizing the need to bridge the digital divide and promote equitable technological access for marginalized communities. To search for the link between target variables, the current paper proposes the succeeding equation:

$$POV = F(GPR, ICT, GLB, GDP, LBR, FDI) \quad (1)$$

The current study species the association among GPR, ICT, GLB, GDP, LBR, and FDI in a single multivariate structure, accordingly our econometric model is stated as follows:

$$POV_t = \beta_0 + \beta_1 GPR_t + \beta_2 ICT_t + \beta_3 GLB_t + \beta_4 GDP_t + \beta_5 LBR_t + \beta_6 FDI_t + \mu_t \quad (2)$$

The following Table 1 shows the detail regarding to study variables:

Estimation technique

Unit root testing

This study employs a novel econometric approach using the nonlinear ARDL (NARDL) framework to analyze long-term impacts and causal relationships. The methodology begins with the BDS test to identify nonlinear features, ensuring the appropriateness of nonlinear modeling. The BDS test, widely used in prior research, evaluates the linearity or non-linearity of data patterns. Unit root tests, including the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, were then applied to assess the stationarity of the series while addressing potential structural issues. This approach ensures robustness in capturing both linear and nonlinear dynamics and the structural properties of the data.

Nonlinear ARDL

The current study seeks to investigate the asymmetries between our research variables. We explore whether positive (negative) shocks in GPR, ICT, and GLB impact POV in the short- and long-term using Shin et al.’s (2014) non-linear ARDL Model.

$$POV_t = \beta_0 + \beta_1^+ GPR_t^+ + \beta_1^- GPR_t^- + \beta_2^+ ICT_t^+ + \beta_2^- ICT_t^- + \beta_3^+ GLB_t^+ + \beta_3^- GLB_t^- + \beta_4^+ GDP_t^+ + \beta_4^- GDP_t^- + \beta_5^+ LBR_t^+ + \beta_5^- LBR_t^- + \beta_6^+ FDI_t^+ + \beta_6^- FDI_t^- + \mu_t \quad (3)$$

where β^+ and β^- are the asymmetric parameters and GPR_t^+ , GLB_t^+ , ICT_t^+ and μ_t are the partial sum process of positive changes in education expenditure, knowledge spillover, and energy consumption: i.e.,

$$POS = GPR_t^+ = \sum_{k=1}^t \Delta GPR_k^+ = \sum_{k=1}^t \max(GPR_k, 0); \sum_{k=1}^t \Delta ICT_k^+ = \sum_{k=1}^t \max(ICT_k, 0); \sum_{k=1}^t \Delta GLB_k^+ = \sum_{k=1}^t \max(GLB_k, 0) \quad (4)$$

Table 2
Descriptive Statistics.

	POV	ICT	LBR	GDP	FDI	GLB	GPR
Mean	27.501	1.867	49.937	10.916	0.799	45.543	8.342
Median	27.185	2.010	49.705	10.340	0.675	46.545	8.395
Maximum	36.800	3.230	52.730	15.070	2.410	54.670	13.530
Minimum	20.710	0.380	42.200	6.930	0.100	33.100	3.970
Std. Dev.	5.072	0.988	1.504	2.304	0.518	8.022	2.057
Jarque-Bera	3.753	4.356	461.082	1.815	17.974	4.351	0.520
Probability	0.153	0.113	0.000	0.403	0.000	0.114	0.771

Table 3
Correlation Matrix.

Probability	POV	ICT	LBR	GDP	FDI	GLOB	GPR
POV	1						
ICT	0.691 (0.000)	1					
LBR	0.359 (0.020)	0.396 (0.009)	1				
GDP	0.474 (0.002)	0.891 (0.000)	0.381 (0.013)	1			
FDI	0.308 (0.047)	0.534 (0.000)	0.064 (0.686)	0.375 (0.014)	1		
GLOB	0.675 (0.000)	0.984 (0.000)	0.385 (0.012)	0.928 (0.000)	0.522 (0.000)	1	
GPR	0.085 (0.594)	-0.315 (0.042)	-0.054 (0.734)	-0.371 (0.016)	-0.251 (0.109)	-0.321 (0.038)	1

Note. Figures in parentheses are p-values.

Table 4
Augmented Dickey-Fuller (ADF) and Zivot Andrews Unit Root Test Results.

	At Level t-Statistic	1st Difference t-Statistic	At Level t-Statistic	Break	1st Difference t-Statistic	Break	Cointegration
POV	-	-6.862***	-1.345	2017	-9.170***	2019	I(1)
FDI	-	-5.844***	-3.480	2004	-7.536**	2009	I(1)
GDP	-	-5.009***	-3.476	2010	-5.648***	2014	I(1)
GLOB	-	-4.835***	-3.003	2013	-7.189**	1989	I(1)
GPR	-2.872**	-	-5.402***	2001	-7.431**	2004	I(0)
ICT	-	-7.569***	-4.637	2004	-7.459**	2007	I(1)
LBR	-4.969***	-	-5.484***	2001	-7.179***	1990	I(0)

(*) Significant at the 10 %; (**) Significant at the 5 %; (***) Significant at the 1 %

While GPR_t^- , $\beta_t ICT_t^-$, and $\beta_t GLB_t^-$ are the partial sum process of negative changes in education expenditure, knowledge spillover, and trade liberalization: i.e.,

$$NEG = GPR_t^- = \sum_{k=1}^t \Delta GPR_k^- = \sum_{k=1}^t \min(GPR_k, 0); \sum_{k=1}^t \Delta ICT_t^- = \sum_{k=1}^t \min(ICT_k, 0); \sum_{k=1}^t \Delta GLB_t^- = \sum_{k=1}^t \min(GLB_k, 0) \quad (5)$$

Nonetheless, Eq. (4) and Eq. (5) mentioned earlier can be revamped into the following NARDL model, correspondingly.

$$POV_t = \delta_0 + \sum_{i=1}^p \delta_1 POV_{t-i} + \sum_{i=0}^q \delta_2 GPR_{t-i}^+ + \sum_{i=0}^q \delta_2 GPR_{t-i}^- + \sum_{i=0}^q \delta_3 ICT_{t-i}^+ + \sum_{i=0}^q \delta_4 ICT_{t-i}^- + \sum_{i=0}^q \delta_5 GLB_{t-i}^+ + \sum_{i=0}^q \delta_6 GLB_{t-i}^- + \sum_{i=0}^q \delta_7 GDP_t + \sum_{i=0}^q \delta_8 LBR_t + \sum_{i=0}^q \delta_9 FDI_t + \gamma_1 (POV)_t + \gamma_2 GPR_t^+ + \gamma_3 GPR_t^- + \gamma_4 ICT_t^+ + \gamma_5 ICT_t^- + \gamma_6 GLB_t^+ + \gamma_7 GLB_t^- + \gamma_8 (GDP)_t + \gamma_9 (LBR)_t + \gamma_{10} (FDR)_t + \varepsilon_t \quad (6)$$

Result and discussion

Descriptive statistics and correlation matrix

The descriptives of the study's variables are shown in Table 2. Here, we can see that the mean value for every variable is higher than the standard deviation, indicating that they are all dispersed. This characteristic implies that the data exhibits a pattern and implies that the mean value is better representative than a dispersed variable. According to our data, GLB has the largest standard deviation (8.022), which reflects its high fluctuation during the previous 40 years. Contrarily, FDI has the lowest standard deviation (0.518), which demonstrates its stagnation

Table 5
Results of BDS test of non-linearity.

Dimension	BDS Stat.	Std. Err	z-Stat.	Prob.
2	0.011	0.012	3.070	0.002
3	0.005	0.004	2.154	0.031
4	0.046	0.006	5.669	0.000
5	0.028	0.009	7.486	0.000
6	0.099	0.002	8.201	0.000

and rather stable performance throughout the study. The Jacque-Bera test was performed to determine the normality of each variable, and it was discovered that GDP and GPR were normally distributed, whereas POV, ICT, LBR, FDI, and GLB were non-normal at a 95 % confidence level.

As seen in Table 3, POV is positively and significantly correlated with ICT, LBR, GDP, FDI, GLOB, and GPR but the correlation is quite weak, indicating that the variables can be used in the same model.

Stationarity test

Results of the Augmented Dicky Fuller (ADF) unit root test and Zivot Andrews unit root results in Table 4 confirm that variables of research have mixed levels of stationarity. GPR and LBR are stationary at level I (0) while POV, FDI, GDPC¹, GDPC², GLOB, and ICT became stationary at first difference I (1). Since the unit root test indicates that the results are

Table 6
Bound test results.

Value	Signif.	I (0)	I (1)
6.72	10 %	2.16	3.24
9	5 %	2.43	3.56
	2.50 %	2.67	3.87
	1 %	2.97	4.24

Table 7
Short-run Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.261	0.363	6.223	0.000
POV (-1)	-1.594	0.241	-6.627	0.000
ICT_POS (-1)	5.096	3.260	1.563	0.144
ICT_NEG (-1)	-11.426	4.398	-2.598	0.023
LBR (-1)	-2.635	0.612	-4.302	0.001
GDP(-1)	-6.807	1.709	-3.982	0.002
FDI (-1)	-3.026	1.730	-1.749	0.106
GLB_POS (-1)	1.827	0.584	3.128	0.009
GLB_NEG (-1)	4.433	3.043	1.457	0.171
GPR_POS (-1)	1.547	0.303	5.113	0.000
GPR_NEG	-1.464	0.473	-3.095	0.009
D(ICT_POS)	-6.110	3.011	-2.029	0.065
D (ICT_POS (-1))	-9.438	2.844	-3.318	0.006
D(ICT_NEG)	1.907	3.126	0.610	0.553
D (ICT_NEG (-1))	7.684	4.021	1.911	0.080
D (LBR)	-0.972	0.305	-3.189	0.008
D (LBR (-1))	0.433	0.225	1.929	0.078
D(GDP)	0.218	1.596	0.136	0.894
D(GDP(-1))	2.870	2.049	1.401	0.187
D(FDI)	-2.456	1.249	-1.967	0.073
D (FDI (-1))	1.799	1.383	1.301	0.218
D(GLB_POS)	0.422	0.748	0.564	0.583
D (GLB_POS (-1))	-1.633	0.912	-1.791	0.099
D(GLB_NEG)	-2.818	2.233	-1.262	0.231
D (GLB_NEG (-1))	-5.841	2.394	-2.440	0.031
D(GPR_POS)	0.755	0.283	2.666	0.021
CointEq (-1)	-0.771	0.079	-9.728	0.000

a combination of I (0) and I (1) variables, we have applied (the ARDL) model for the linear relationship among variables and NARDL for the nonlinear relationship.

In this study, the BDS test was applied to evaluate the linearity of the parameters. Originally developed by Broock et al. (1996) to identify non-linear patterns, the test results, as outlined in Table 5, provide substantial evidence of non-linear features within the variables. These findings highlight the necessity of employing non-linear methods to explore the relationships among the variables in question.

Bound test

The findings from the bound test are detailed in Table 6. The analysis shows that the estimated F-statistics exceed the upper bound critical values at all significance levels: 10 % (3.24), 5 % (3.56), 2.5 % (3.87), and 1 % (4.24). This suggests a persistent relationship among the variables.

Empirical results

This study's results in Table 7 offer significant insights into the dynamics of the short-run NARDL framework. The constant term is statistically significant, indicating that when all independent variables are zero, there is a positive impact on the dependent variable. The lagged dependent variable has a robust negative association, indicating that prior poverty levels substantially affect current poverty owing to temporal variations. The research indicates that positive ICT shocks have little immediate consequences, but negative ICT shocks result in a substantial rise in poverty. The results indicate that positive ICT shocks have a detrimental influence on poverty, exhibiting a delayed effect. The dynamics of the labor force demonstrate a significant negative link with poverty in both present and previous periods, suggesting that fluctuations in the labor force facilitate short-term poverty alleviation. Nevertheless, variations in GDP have minimal immediate impacts on poverty, and the same outcomes are seen for FDI, with no substantial short-term influence.

The study indicates that positive globalization shocks decrease poverty in the short run, but negative globalization shocks have no

Table 8
Long run Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ICT_POS	3.197	1.997	1.601	0.135
ICT_NEG	-7.168	2.376	-3.017	0.011
LBR	-1.653	0.393	-4.209	0.001
GDP	-4.271	1.152	-3.708	0.003
FDI	-1.898	0.976	-1.944	0.076
GLB_POS	1.146	0.328	3.494	0.004
GLB_NEG	2.781	1.695	1.641	0.127
GPR_POS	0.971	0.190	5.113	0.000
GPR_NEG	-0.919	0.308	-2.987	0.011

substantial initial impact. Nonetheless, the detrimental consequences of negative globalization shocks manifest over time, intensifying poverty. Geopolitical risks significantly impact poverty levels, since positive geopolitical risks exacerbate poverty in the short term, whilst negative geopolitical risks mitigate poverty. The transient variations in poverty due to geopolitical concerns underscore the considerable impact of these dangers. The error correction term is significant, indicating a long-term equilibrium connection between the variables, with around 77.1 % of the short-run disequilibrium rectified in each period. The findings underscore the significance of negative shocks in ICT, globalization, and geopolitical concerns in the near term, while also illustrating the steady adjustment process towards long-term equilibrium.

One of the key concerns all over the world has been the reduction of poverty. In Pakistan, several initiatives have been implemented to raise the nation's economic capability and provide social safety nets for the poor. The long-term estimations of the NARDL model are summarised in Table 8. The findings reveal that a one percent increase in ICT_NEG hurts poverty (POV), reducing it by 7.168 percent. Additionally, the results indicate that an increase in ICT_POS has a positive but insignificant effect on poverty status in Pakistan, with a one percent increase causing poverty status to increase by 3.197 percent. These empirical results align with those of Alimi and Okunade (2020), who examined ICT diffusion's impact on poverty reduction in 27 sub-Saharan African countries from 2004 to 2017. They found that while ICT diffusion, based on internet penetration, reduces poverty in the short run, it has no long-term impact. Our findings are analogous to those of Rizqulloh and Firman-syah (2021), Appiah-Otoo and Song (2021), Khurshid et al. (2023c, 2023d), and Ahsan and Afzal (2022), who discovered that higher values of ICT indicators correlate with lower poverty indices.

Furthermore, GLB_POS has a positive and significant impact on POV, while the impact of GLB_NEG is positive but insignificant. A one percent increase in GLB_POS increases POV by 1.146 percent. The results of our study are comparable to those of Aisbett et al. (2007), who suggested that globalization produces both winners and losers among the poor, with some individuals experiencing worsened poverty due to trade or financial integration. Therefore, there is a need for carefully targeted safety nets for the poor. Similarly, Harrison (2007) found that globalization negatively impacts poor countries, particularly in import-competing sectors and during financial crises. However, our empirical findings differ from those of Deyshappria (2018) and Khan and Majeed (2018), who found that globalization significantly reduces poverty.

Moreover, our results show that GPR_POS significantly contributes to POV, with a one percent increase causing POV to increase by 9.71 percent, whereas a one percent increase in GPR_NEG leads to a decrease in POV by 9.19 percent. Altiner and Bozkurt (2023) arrived at a similar conclusion regarding GPR's significant positive impact on poverty in Turkey, as it negatively affects foreign direct investment. Similarly, Lu et al. (2020) found that in 18 emerging markets from 1985 to 2018, financial development decreased due to GPR, potentially slowing economic performance due to concurrent threats. However, Jha et al. (2024) examined 41 countries from 2000 to 2020 and found that an increase in GPR boosts economic growth in advanced economies while emerging economies face detrimental effects.

Table 9
Results of Diagnostics Tests.

Test Statistics	F-statistics	p-value
Lagrange multiplier test for serial correlation	1.264	0.304
White test for heteroscedasticity	2.015	0.109
Ramsey's RESET for functional form	1.925	0.180
Jarque-Bera test for normality	0.175	0.916

To ensure the accuracy of the results, additional control variables (LBR, GDP, and FDI) are included. These variables exhibit negative and significant impacts on POV, with coefficients of (-1.653) , (-4.271) , and (-1.898) , respectively. This suggests that in the long run, increases in the labour force, GDP, and FDI can contribute to poverty reduction. Increasing the labour force can alleviate poverty by creating job opportunities and increasing household income, consistent with the findings of Faridi et al. (2016). Similarly, Mulugeta (2021) found that increased women's labour force participation can reduce household poverty.

Our findings indicate that the primary issue between an increase in GDP and poverty is the negative impact. Amar and Pratama (2020), who used dynamic panel data methodologies and discovered that because of economic expansion, poverty disappears in developing nations, validate this. Furthermore, Adams and Akobeng (2021) argue that economic growth is one of the most effective techniques for poverty reduction in developing nations, using 51 intervals and 50 developing countries as examples.

Our findings underscore the pivotal role of FDI in poverty

eradication. Specifically, our analysis reveals that a mere one percent increase in FDI can lead to a significant decrease in the POV by 1.898 percent. This indicates that FDI inflows play a crucial role in lifting individuals and communities out of poverty and fostering overall economic growth. The beneficial effect of FDI on reducing poverty is consistent with earlier research by Shamim et al. (2014), who discovered that FDI contributes to poverty alleviation, particularly when combined with other important control variables. By attracting foreign investment, countries can benefit from increased capital inflows, technology transfer, job creation, and enhanced productivity, all of which can help alleviate poverty and improve living standards for the population. Furthermore, the findings of Topalli et al. (2021) further corroborate the significant role of FDI in poverty reduction. The Generalised Method of Moments (GMM) estimator was used on panel data to show that FDI has a big positive effect on reducing poverty in Western Balkan countries. This suggests that FDI not only stimulates economic growth but also contributes to poverty reduction by creating employment opportunities, fostering entrepreneurship, and promoting economic diversification.

Table 9 demonstrates that our estimated model satisfies the various diagnostic tests. According to the LM test, serial correlation does not affect our empirical results. The white test is applied for detecting heteroscedasticity, proving that heteroscedasticity exhibits no impact upon the outcomes we obtained. The Ramsay RESET test has been employed for validating the functional form, and the results demonstrate that our model is well-specified. Finally, the Jarque Bera test assesses residual normality, demonstrating the fact that residuals have a normal distribution.

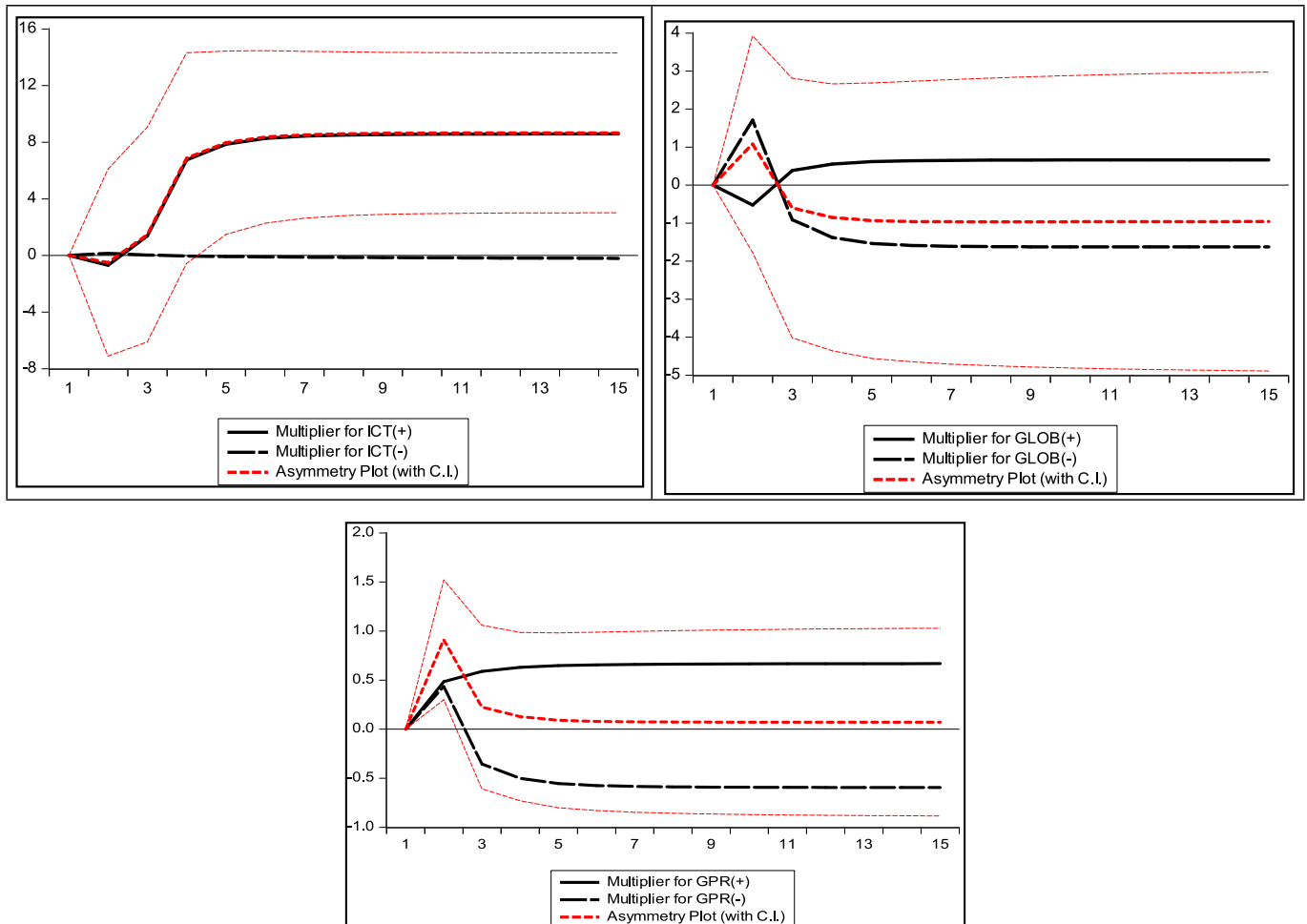


Fig. 2. A: multiple dynamic adjustment of ict and poverty. b: multiple dynamic adjustment of glob and poverty. c: multiple dynamic adjustment of gpr and poverty.

Table 10
Pairwise Granger Causality Test Results.

Null Hypothesis:	F-Statistic	Prob.
ICT $\neq$ POV	1.797	0.181
POV $\neq$ ICT	2.780	0.076
LBR $\neq$ POV	0.128	0.880
POV $\neq$ LBR	3.126	0.056
GDP $\neq$ POV	1.933	0.160
POV $\neq$ GDP	3.505	0.041
LBR $\neq$ ICT	0.129	0.879
ICT $\neq$ LBR	3.893	0.030
GLB $\neq$ ICT	2.311	0.114
ICT $\neq$ GLB	3.849	0.031
GDP $\neq$ LBR	3.772	0.033
LBR $\neq$ GDP	0.163	0.851
GLB $\neq$ LBR	4.533	0.018
LBR $\neq$ GLB	0.252	0.779
GPR $\neq$ GDP	4.684	0.016
GDP $\neq$ GPR	1.061	0.357

All authors declare that they have no conflict of interest in this paper.

Note: Fig. 2 separate figs a,b,c is all merged in caption kindly check.

The figures (Fig. 2a, 2b, and 2c) illustrate the multipliers for the two independent parameters, revealing a pattern of moving towards equilibrium following initial positive and negative shocks. They demonstrate the nonlinear changes in POV in response to these shocks. A black dotted line specifically denotes the adaptation of POV to negative shocks, whereas a solid black line illustrates the adaptation to positive shocks. The difference in reactions to positive and negative shocks is depicted by an asymmetric pattern, which is indicated by the red dotted line. The black line in Fig. 2a clearly shows that a rise in the ICT has a positive effect on the POV. The black dotted line illustrates that a drop in ICT has a minimal effect on POV. Additionally, Fig. 2b shows that an early increase in GLOB is linked to a negative impact on POV but after three periods its effects become positive. Fig. 2c reflects that positive shock in GPR affects POV positively throughout the period and negative shock in GPR initially increases POV but after 3rd period its effects become negative.

Additionally, the outcomes of Granger causality tests are presented in Table 10. Unidirectional causality was confirmed from result outcomes. We also dismiss the null hypothesis that ICT does not Granger-cause POV, as POV Granger-causes ICT with a near-significance level of 0.076. Thus, we found no evidence that LBR Granger causes POV or is influenced by it. The findings indicate that POV Granger causes GDP with a significance level of ($p = 0.041$). ICT significantly influences LBR, whereas GLB Granger causes ICT with a significance level of 0.031, indicating a reciprocal relationship between ICT and GLB. Empirical

data indicate that GDP Granger causes LBR ($p = 0.033$), as does GLB ($p = 0.018$). Ultimately, the GPR was a crucial factor influencing GDP, indicating its impact on the economy ($p = 0.016$). The results indicate that the relationships among the variables, particularly ICT, GDP, globalization, and labor, are complex and critically important.

We used Brown et al.'s (1975) cumulative sum of recursive residual squares (CUSUMSQ) methods to assess the model's stability. Figs. 3a and 3b show the graphical results for CUSUM and CUSUMSQ which reflect the model's dynamic stability.

Conclusion

The enduring existence of poverty continues to be a crucial obstacle for economies around the globe, representing one of the most urgent global concerns. Notwithstanding diligent endeavors, the worldwide prevalence of extreme poverty increased to 9.3 % in 2023, highlighting the imperative need to tackle this matter. The United Nations Millennium Development Goals emphasize that to effectively eradicate poverty, a thorough understanding of its fundamental causes is necessary. This article examines the effects of ICT, globalization, and geopolitical threats on poverty in Pakistan. It utilizes the NARDL model and analyses yearly data from 1980 to 2021. The results of our study highlight the possibility of investing in ICT and reducing geopolitical risks to reduce poverty. We discovered a negative effect of ICT_POS, whereas ICT_NEG had no significant influence. ICT solutions that are improved and have subtle distinctions may effectively contribute to the elimination of poverty and the promotion of sustainable development. Furthermore, the worsening of poverty in developing countries such as Pakistan is demonstrated by the increase in GPR_POS, which hampers economic activity, investment, and trade, whereas GPR_NEG indicates the possibility of reducing poverty. The establishment of geopolitical stability is crucial for promoting development and enabling the availability of education, healthcare, and resources, thereby enhancing living conditions and economic prospects. The positive benefits of globalization (GLB_POS) have a substantial influence on reducing poverty, whereas the negative effects of globalization (GLB_NEG) are not significant. Neglecting the importance of addressing poverty in global economic strategies increases the likelihood of making it worse. Regional integration has the potential to encourage economic growth and reduce poverty, particularly in emerging nations, when supported by equitable trade and capital movements and improved social safeguards. The report emphasizes the importance of focused policies and comprehensive strategies to reduce poverty in the changing context of globalization.

Poverty reduction is one of the most important issues on the public policy agenda of almost every country in the world. By successfully

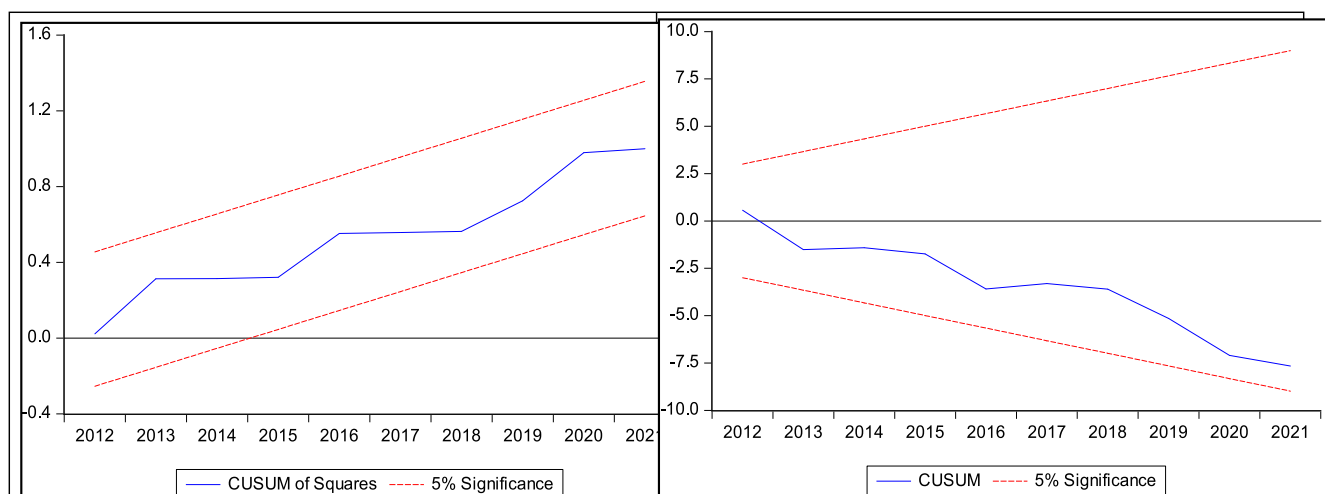


Fig. 3a and 3b. . CUSUM and CUSUMQ graphs

utilizing the capabilities of ICT and reducing geopolitical risks, Pakistan may provide a favorable atmosphere for achieving sustainable development, eliminating poverty, and fostering inclusive economic growth. These policies can enhance the capabilities of individuals and communities by providing them the means to get education, healthcare, and economic opportunities, therefore enhancing their overall quality of life and promoting economic resilience. Poverty can be reduced if factors linked to poverty are dealt with judiciously. This analysis proposes the following policy implications:

Pakistan should focus on developing and implementing smarter and more comprehensive ICT strategies that prioritize accessibility, affordability, and relevance to the needs of diverse communities, especially in rural and underserved areas. Efforts should be made to reduce geopolitical risks through diplomatic initiatives, conflict resolution, and fostering stability. This involves strengthening institutions, promoting dialogue, and fostering cooperation among neighboring countries to mitigate the adverse effects of geopolitical instability on economic development and poverty reduction efforts.

Suggestions for future studies

Future studies could explore the dynamic relationships among ICT, globalization, and poverty using advanced econometric models or machine learning techniques to capture complex interactions. Additionally, incorporating environmental and social factors could provide a more holistic understanding of poverty reduction strategies.

CRediT authorship contribution statement

Nabila Khurshid: Writing – review & editing, Methodology, Investigation, Data curation. **Nabila Akram:** Writing – review & editing, Methodology, Investigation, Data curation. **Mudassar Rashid:** Writing – original draft, Validation, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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