

Eradicating Poverty in Developing Countries: The Role of Technological Innovation, Foreign Direct Investment and Institutional Quality

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ABSTRACT

This study analyzes the effect of technological innovation, institutional quality, and foreign direct investment on poverty eradication in developing countries using the data from 53 developing countries from 2002 to 2021. Different econometric techniques are used for data estimation including cross-sectional dependence test, slope homogeneity test, CIPS and CADF tests of unit root, panel cointegration test, FGLS model for parameter estimations, PCSE model for robustness estimation and Granger causality test. The findings show that FDI, institutional quality, technological innovation and education are negatively and significantly related to the poverty headcount ratio in developing countries, whereas income inequality is found to be positively and significantly linked to the poverty headcount ratio in developing countries. Lastly, the panel Granger causality test indicates a one-way causality between FDI and PHC, and TI and PHC. In addition, bidirectional causality is found between IQ and PHC. Lastly, no causality is observed between GINI and PHC, as well as between EDU and PHC, in developing countries. Therefore, it is concluded that FDI inflows, IQ and TI are imperative to reduce poverty in developing countries.



Introduction

One significant aspect influencing people's ability is poverty. People who live in poverty are unable to access better health care, education, and career prospects as well as credit. Eradicating poverty in all its forms is the first Sustainable Development Goal. It seeks to ensure that everyone, everywhere, has access to basic necessities like food, shelter, healthcare, and education. By addressing inequality, creating economic opportunities, and supporting social protection systems, this goal promotes sustainable growth and human dignity, laying the foundation for a fairer, more

resilient world (Filho et al., 2021). Poverty is a global issue, and in certain nations, poverty endures despite increasing amounts of financial prosperity. The sheer quantity of people living in poverty across all countries in the world serves as evidence of the severity and extent of this issue (Tabosa & de Carvalho, 2017). Bourguignon (2002) and Ravallion (1997) argue that reducing income disparity is a key strategy for reducing poverty.

Foreign capital inflows are important to reduce poverty as they enhance private investment, generate new job opportunities, facilitate technology transfer, and propel economic expansion in the host nations. Both Dollar & Kraay (2002) and Jalilian & Kirkpatrick (2002) demonstrate that FDI can have either a direct or indirect effect on host nations. The first effect stems from economic expansion, which raises living standards through increased GDP, enhanced productivity and technology, and economic development. The desire for work and the expansion of the labor force have a direct impact on the number of people living in poverty, as seen by the rise in employment and decline in that population (Ucal et al., 2014).

On the other hand, institutions are characterized as the laws that bind society's members together, mold the conduct of economic actors, and support a nation's economic growth. Institutions encompass not only the legal and political structure but also the cultural domain. They provided a comprehensive understanding of institutions (Chong & Calderón, 2000; Engerman & Sokoloff, 1994). Misallocation of resources and market inefficiencies are two ways that institutional quality affects the degree of poverty (Tebaldi and Mohan, 2010)). According to Keefer & Knack (1997), subpar institutions threaten the protection of property rights. Bureaucratic quality is an example and higher error rates in administrative decision-making result from both low-quality administrative professionals and a lack of institutional restraints. This makes government decision-making less predictable, which, in turn, makes property and contractual rights less secure. Property rights uncertainty can discourage foreign investment and result in slower economic growth, which can slow down the rate at which poverty is eradicated. Weak institutions can negatively impact inequality (Chong & Gradstein, 2007).

Similarly, the major objective of economic progress in developing nations is to eradicate poverty, and it is commonly recognized that technological innovation (TI) plays a critical role in achieving this aim. Technology, innovation, and R&D components should be taken into account when developing programs and strategies for the long-term eradication of poverty (Dasanayaka, 2013). Technology has long been a potent instrument for promoting progress in both society and the economy. It can be applied to several industries, including increasing agricultural productivity, generating affordable electricity, providing clean water, and improving health. Specifically, information and communications technology (ICT) can help reduce poverty by increasing people's access to resources for education, healthcare, and finance. Remarkably, even simple technology could affect the battle against poverty (Prodi, 2015).

Poverty remains a critical challenge in developing countries, hindering sustainable growth and human development. Despite various efforts, a significant portion of the population continues to live below the poverty line. This persistent issue raises concerns about the effectiveness of traditional poverty reduction strategies. Technological innovation, foreign direct investment, and institutional quality have emerged as potential drivers of economic transformation. However, their specific roles and interrelationships in eradicating poverty remain underexplored. Understanding how these factors contribute to poverty alleviation is essential for designing more effective policies. This study aims to analyze their impact and offer insights to enhance poverty reduction strategies in developing nations.

Literature Review

Studies of the Relationship between Foreign Capital Inflows and Poverty Mitigation

Different studies examine the impact of foreign capital inflows on poverty mitigation such as Bouabdallah & Baroudi (2022) investigated how FDI inflows affected Algerian poverty from 1990 to 2019. The study employed a number of criteria to determine Algeria's poverty rate, including trade openness, inflation, FDI and GDP per capita. The ARDL model was employed in the study's analysis. The study's findings indicated that trade and GDP per capita had a negative effect on poverty reduction in Algeria throughout the study period, FDI and inflation had a positive and significant impact on the country's poverty rates. Similarly, Shastri et al., (2022) explored the link between FDI and poverty reduction in major South Asian nations. The empirical findings demonstrated that inflows into portfolios of stocks have a direct impact on reducing poverty, inflows into loans and foreign direct investments had no such effect. The panel causality estimates exhibited that by promoting trade openness and economic progress, portfolio equity inflows also aid in the reduction of poverty. The study by Fahrizal et al., (2021) used a panel ARDL model to study the impact of macroeconomic variables and remittances on poverty in ASEAN-4 nations from 1991 to 2019. The analysis showed that unemployment and remittances both have a big long-term impact on reducing poverty. It was discovered that the Gini coefficient and economic growth had little effect on the decline in poverty. The long-run equilibrium returns to its original speed of adjustment after eight months, owing to short-term shocks.

The study conducted by Kayani (2021) explored the link between remittances and poverty in Kyrgyzstan by examining variables such as capital, remittances, GDPPC, savings, unemployment, and poverty size over the years 2008-2019. The results specified a weak link between remittances and poverty eradication. In addition, Shah et al., (2021) investigated the effect of migration on reducing poverty in the Multan district's rural areas. A binary logistic regression is performed on 170 rural households' worth of data. Estimates indicate that poverty is highly prevalent in Multan district's rural areas. Poverty was measured using the headcount index, poverty gap, and squared poverty gap. The results showed that physical disability and household size turn out to be encouraging aspects of poverty, while rural-to-urban migration, foreign remittances, educational attainment of the household head, age of the household head, and livestock population turn out to be discouraging aspects of poverty. The study by Topalli et al., (2021) analyzed how FDI inflows affected poverty in six Western Balkan nations while also taking into account other factors such as the HDI, corruption, trade openness, investment freedom, economic freedom, and fertility. Over panel data models with fixed effects, the paper gave estimations based on a GMM estimator over the years 2002–2021. The findings demonstrated that FDI has made a substantial contribution to the countries of the Western Balkans' efforts to reduce poverty. Reducing poverty in the Western Balkan region can also be accomplished by taking steps to enhance the HDI and fortify institutions that fight corruption. Lastly, Saleem et al., (2021) investigated the relationships between FDI and poverty in Pakistan. The ARDL method was utilized to analyze the annual data set for this study, which included the years 1987 to 2018. The results demonstrated the two-way causal link between FDI and poverty. The study's outcomes also showed that there was a greater causal link between FDI and poverty reduction. Therefore, keeping in view the literature review the following hypothesis is developed:

H₁: Foreign direct investment is negatively and significantly associated with the poverty in developing countries

Studies of the Relationship between Institutional Quality and Poverty Mitigation

Different studies examine the impact of institutional quality on poverty mitigation such as Dossou et al., (2023) analyzed how important macroeconomic factors and IQ influence the growth of the tourism industry and the fight against poverty. In order to accomplish this goal, this study used a panel of 15 Latin American nations from 2003 to 2015 using the fixed effect estimation technique to investigate the moderating effect of governance quality on the link between tourism and poverty reduction. The results demonstrated that while tourism growth worsens poverty, good governance assists to decline poverty. The outcomes showed that the effects of tourism and good governance on reducing poverty are complementary. Similarly, Kouadio & Gakpa (2022) examined the influence of IQ and economic growth on poverty alleviation and inequality in West Africa. The results showed that poverty reduction requires economic growth and that general improvements in institutional quality have a significant long-term influence on reducing poverty and income inequality. This contribution was primarily provided by strengthening democratic institutions, reducing administrative burdens, enhancing the legal and regulatory systems, combating corruption, and enhancing the stability of the administration. The study by Zhao (2021) investigated whether poverty is impacted by tourism development in relation to institutions. The study empirically demonstrated that, although at varying degrees of significance and effect magnitude, tourism and institutions have a significant and negative impact on relative poverty as measured by the FGT poverty indices as well as absolute poverty as measured by panel data for 29 Chinese provinces from 1999 to 2014. Furthermore, the relationship between poverty and tourism was favorably moderated by IQ, indicating that when IQ rises in the thin institutional framework of rural China, the pro-poor impact of tourism expansion diminishes.

In addition, Singh (2021) investigated the connection between absolute poverty reduction and governance quality in the BRICS nations between 1997 and 2011. The results of the study demonstrated that one important governance factor that directly contributes to the decrease of poverty in the BRICS countries is the rule of law. Through implications on distribution and income, other governance factors influence poverty rates. This bolsters the claim that, in the near term, only economic growth significantly contributed to absolute poverty reduction, whereas strict adherence to the rule of law was the main governance prerequisite for poverty reduction. Similarly, Fagbemi et al. (2020) examined the link between poverty and IQ in Nigeria from 1984 to 2017 using the DOLS and VECM models. The findings demonstrated the importance of the rule of law and democratic accountability for reducing poverty. Additionally, research showed that the nation's weak institutions and poverty were linked and reinforced one another. Overall, the results suggest that public institution capacity issues or fundamental governance practices were to blame for Nigeria's pervasive poverty. Lastly, Siddique et al., (2016) assessed how institutions and governance affected education and the fight against poverty in six SAARC nations between 1996 and 2012. The empirical findings showed that poverty and EG are correlated, meaning that as growth increased, poverty decreased across all nations. Nonetheless, the inverse sign of education shows that, due to lower awareness and resource availability than at a low level, education does not increase as much with expansion. The fundamental issue facing developing countries was poverty. According to the paper, effective governance will offer a framework for evaluating the numerous options for institutional adjustments and appropriate projects that are believed to be necessary for development. The following hypothesis is developed based on the literature review:

H₂: Institutional quality is significantly associated with the poverty in developing countries

Studies of the Relationship between Technological Innovation and Poverty Mitigation

Different studies examine the impact of technological innovation on poverty mitigation such as Awad (2023) explored the ways in which ICT alleviate poverty from 2003 to 2019 in Sub-Saharan African economies. The results demonstrated that rising employment and per capita income both have a favorable impact on reducing poverty. The results of the causal mediation study demonstrated that ICT amplified the detrimental effects of declining environmental quality on poverty. However, the employment and per capita income benefits of ICT were stronger and had a higher beneficial impact on poverty than the negative effects through the environmental mechanism. Similarly, Afzal et al., (2022) investigated the effects of technological adoption on global poverty rates and income inequality across various income brackets. The paper used a robust two-step Systematic GMM approach with data from 86 countries between 2005 and 2020. The findings suggested that the effects of technological penetration vary among nations. The correlation that exists between technology and income disparity is particularly detrimental to low-income nations. From the standpoint of policy, it was critical to take into account the macro- and microeconomic variables that influence how technology is embraced in low-income nations. In addition, Rizqulloh & Firmansyah (2021) scrutinized the influence of ICT on reducing poverty in 34 Indonesian provinces. The findings demonstrated that ICT had a major impact on the reduction of poverty in 34 Indonesian regions. In light of this, the government must work to raise the sub-index for the ICT index, which includes community expertise in using technology to reduce poverty in 34 Indonesian provinces and public infrastructure facilities in the ICT sector as a means of supporting community activities.

In contrast Zameer et al., (2020) explored the impact of globalization, FD and TI on China's ability to effectively reduce poverty. The research analyzed data from 2007 to 2018 and used system GMM model. The effectiveness of China's efforts to reduce poverty is positively influenced by FD and TI. Nonetheless, the outcomes regarding the influence of globalization on the effectiveness of poverty reduction were negligible. In addition, Yilmaz & Koyuncu (2018) explored the relationship between poverty and ICT. Using four ICT indicators, six poverty indicators, and a panel data set of 182 countries, the hypothesis that ICT penetration reduces poverty was evaluated for the years 2000 to 2013. Among the ICT measures, internet usage was found to have the biggest impact on all poverty indicators. The strongest correlation between internet penetration and ICT metrics indicated that increasing internet accessibility and spreading its use were critical to eradicating poverty and income disparity. The study by Muchdie (2017) studied the effects of TI on reducing poverty in Indonesia from 2004 to 2013, controlling for variables such as economic development and the unemployment rate. Total factor productivity growth was used to measure technological advancement, open unemployment rate to measure joblessness, GDP growth to measure economic growth, and poverty alleviation to estimate the proportion of the population living in poverty. SEM-Path Analysis methodologies were used to conduct the impact analysis. The findings demonstrated that technical advancement significantly reduced poverty. Lastly, Dhrifi (2014) investigated the impact of agricultural and TI on poverty in SSA countries. The study estimated a simultaneous equation model that captures the relationship between agricultural production, TI and poverty using data from 32 countries between 1990 and 2011. The finding demonstrated how much agricultural productivity influenced poverty and EG in SSA economies. Secondly, the expansion and productivity of agriculture appears to be positively and significantly impacted by TI, both directly and indirectly reducing poverty. The following hypothesis is developed based on the literature review:

H₃: Technological innovation is negatively and significantly associated with the poverty in developing countries

Data and Methodology

To analyze the role of foreign direct investment, technological innovation, and institutional quality in poverty mitigation, data from 53 developing countries from 2002 to 2021 is used in the study. The data of institutional quality indicators is taken from world governance indicators while the data of variables FDI, TI, GINI, EDU and PHC are taken from world development indicators. To investigate the influence of FDI, TI and IQ on PHC in developing countries, the following models are developed:

Model Functional Form

$$PHC = f(FDI, IQ, TI, GINI, EDU) \quad (1)$$

Model Econometric Form

$$PHC_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 GINI_{ij} + \beta_5 EDU_{ij} + u_{ij} \quad (2)$$

Similarly, the interaction terms of FDI, IQ, and TI are also added into a model to estimate the combined effect of these factors on poverty. Equation 3 added the interaction term of IQ*TI to see its influence on poverty. Similarly, equation 4 added the interaction term of IQ*FDI to see its influence on poverty. Lastly, equation 5 added the interaction term of FDI*TI to see its influence on poverty.

$$PHC_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 GINI_{ij} + \beta_5 EDU_{ij} + \beta_6 IQ * TI_{ij} + u_{ij} \quad (3)$$

$$PHC_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 GINI_{ij} + \beta_5 EDU_{ij} + \beta_6 IQ * FDI_{ij} + u_{ij} \quad (4)$$

$$PHC_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 GINI_{ij} + \beta_5 EDU_{ij} + \beta_6 FDI * TI_{ij} + u_{ij} \quad (5)$$

Where,

PHC = Poverty headcount ratio

FDI = Foreign direct investment

IQ = Institutional quality

TI = Technological innovation

GINI = Gini coefficient

EDU = Education

IQ*TI = Interaction term of IQ and TI

IQ*FDI = Interaction term of IQ and FDI

FDI*TI = Interaction term of FDI and TI

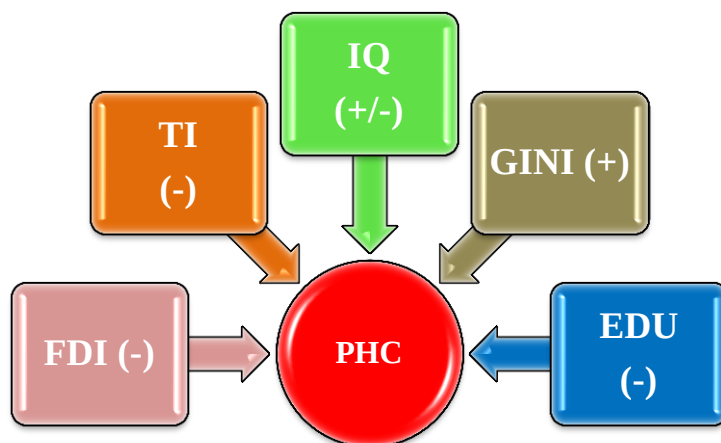
u_{ij} = Error term

Table 1: Description of Variables

Variables	Descriptions	
PHC	Poverty headcount ratio	Percentage of people below the poverty line
FDI	Foreign direct investment inflows	Current US dollars
TI	Technological innovation	Number of patent applications
IQ	Institutional quality	Index is developed using PCA analysis. Governance indicators such as rule of law, voice

		and accountability, government effectiveness, political stability, regulatory quality, and control of corruption are used for index development
GINI	Income inequality	GINI coefficient
EDU	Secondary school enrolment	Percent gross

Figure 1: Expected Relationship between Independent Variables and PHC



Different panel data estimation techniques are employed in a study to examine the impact of FCI, TI and IQ on poverty mitigation in developing countries. The discussion on the panel data techniques is as follows:

Cross-Sectional Dependence Test

In this study, the cross-sectional dependence (CSD) in panel data is assessed using the Lagrange Multiplier (LM) created by Breusch & Pagan (1980) and the CSD test published by Pesaran (2004). When countries are connected on a regional or global level, CSD is known to occur. CSD needs to be assessed in order to prevent inaccurate, biased, and inconsistent panel data analysis outcomes. The following are the LM and CSD test equations:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^N T_{ij} h_{ij}^2 \rightarrow x^2 \frac{N(N-1)}{2} \quad (6)$$

$$CSD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^N \sqrt{T_{ij} h_{ij}^2} \right) \quad (7)$$

Where h represents correlation coefficient, x^2 is asymptotic circulation for fixed, N indicates size of the cross-section, and T represents the period. For CSD, the following hypotheses are tested:

H_0 : Absence of CSD

H_1 : Presence of CSD

Slope Homogeneity Test

In econometrics, slope homogeneity is essential when using panel data. Cross-sectional units and slope homogeneity are related across national boundaries (Pesaran & Yamagata, 2008; Sadorsky, 2009). To test for slope homogeneity, the following hypotheses are put forth:

H_0 : Homogeneous slope coefficients

H_1 : Heterogeneous slope coefficients

Panel Unit Root Tests

In order to examine the integration of the variables under investigation, this study used the cross-sectional augmented Dickey-Fuller (CADF) and cross-sectional augmented Im, Pesaran, and Shin (CIPS) innovative stationarity methodologies suggested by Pesaran (2007). In order to address CSD throughout the dataset, the CADF incorporates the first difference values and the lagged cross-sectional average of the factors taken into account in ADF regression, yielding more dependable findings than traditional unit root tests. The average of the individual CADF statistics is used to estimate the CIPS test. With non-stationarity as the null hypothesis, the test statistics for CADF and CIPS regression are computed as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \chi_i \bar{y}_{it-1} + \delta_i \Delta \bar{y}_{it} + u_{it} \quad (8)$$

$$CIPS = \frac{1}{N} \sum_{i=1}^N t_i(N, T) \quad (9)$$

Where $\bar{y}_{it-1}$ and $\Delta \bar{y}_{it}$ are the cross-sectional mean estimates of the first difference and lagged variable, respectively. $t_i(N, T)$ indicates CADF, which represents the test statistic of OLS regression for i th cross-section.

Cointegration Test

In econometrics, cointegration tests are frequently employed to determine if the stationary variables in levels and first differences have a linear combination. We can also determine whether or not there is a long-term equilibrium relationship between the variables by testing cointegration. There are many different types of cointegration tests. Some are intended to test the cointegration of time series on panel data, while others are used to determine whether the variables are in a long-term equilibrium relationship. In this work, we apply the tests that Westerlund (2007) suggested about residual dynamics to determine whether there is a long-term equilibrium relationship between the variables.

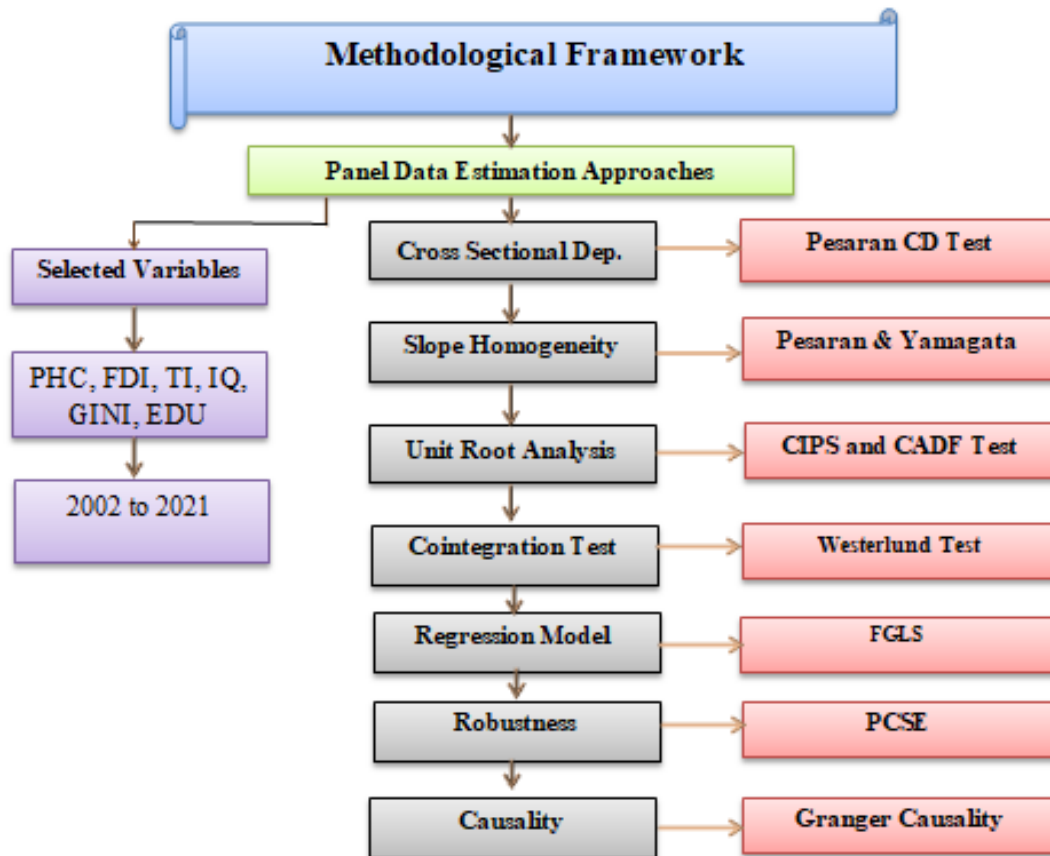
Feasible Generalized Least Square Method

In panel data analysis, the feasible generalized least square approach (FGLS) is used to find the parameters of a linear regression model. Two potential challenges in panel data analysis are heteroskedasticity and autocorrelation; FGLS performs better when these problems are present. When panel data have more time series than cross-sectional units, this technique is also helpful (Alharthi & Hanif, 2020; Asghar et al., 2024).

Panel Corrected Standard Errors Model

The study also used Beck et al., (1995)'s Panel Corrected Standard Errors (PCSEs) technique to evaluate the stability of the model's results in the inquiry. Due to problems with autocorrelation, cross-sectional dependency, and heteroskedasticity, the conventional OLS estimations are ineffective and produce biased standard errors (Adekoya, 2019). In order to increase parameter efficiency, this model is also used to correct heteroskedasticity, CSD, and autocorrelation issues (Sundjo & Aziseh, 2018).

Figure 2: Methodological Framework



Data Analysis

Descriptive Analysis

This section illustrates the descriptive estimates of the variables. Table 2 shows that the mean values of PHC, FDI, IQ, TI, GINI and EDU are 3.185, 20.871, 0.18, 5.796, 3.68 and 4.232, respectively. Similarly, the maximum values of PHC, FDI, IQ, TI, GINI and EDU are 4.302, 26.564, 5.666, 14.277, 4.189 and 4.95, respectively. In contrast, the minimum values of PHC, FDI, IQ, TI, GINI and EDU are -1.609, 10.361, -5.201, 0.693, 2.127 and 2.163 respectively. The distributions of IQ and TI are positively skewed while the distributions of PHC, FDI, GINI and EDU are negatively skewed. Lastly, all variables have leptokurtic distributions as the kurtosis value is greater than 3.

Table 2: Descriptive Statistics

Variables	Mean	Maximum	Minimum	S.D.	Skewness	Kurtosis
PHC	3.185	4.302	-1.609	0.726	-1.395	6.686
FDI	20.871	26.564	10.361	1.971	-0.608	5.715
IQ	0.18	5.666	-5.201	1.966	0.185	3.441
TI	5.796	14.277	0.693	2.353	0.438	3.708
GINI	3.68	4.189	2.127	0.237	-1.019	7.681
EDU	4.232	4.95	2.163	0.465	-1.558	5.117

Source: Author's Estimations

Correlation Analysis

The correlation coefficient is employed to measure the extent of the relationship between two variables. Table 3 reports that poverty headcount ratio is negatively correlated to the FDI (-0.352), IQ (-0.218), TI (-0.305) and education (-0.407) while poverty headcount ratio is positively correlated to the GINI coefficient (0.430).

Table 3: Correlation Matrix

Variables	PHC	FDI	IQ	TI	GINI	EDU
PHC	1.000					
FDI	-0.352	1.000				
IQ	-0.218	0.204	1.000			
TI	-0.305	0.722	0.086	1.000		
GINI	0.430	0.002	0.225	-0.002	1.000	
EDU	-0.407	0.378	0.389	0.430	-0.105	1.000

Source: Author's Estimations

Cross-Sectional Dependence and Slope Homogeneity Test Analysis

In this study, different cross-sectional dependence tests are employed and their estimates are shown in Table 4. The results show that all three tests are found to be statically significant indicating that the variables PHC, FDI, QI, TI and GINI are cross-sectional dependent in developing countries. These outcomes point out that any shock that happens in one country can influence other countries' economies.

Table 4: Cross Sectional Dependence Test

Variables	Breusch-Pagan LM	Pesaran scaled LM	Pesaran CD
PHC	16831.19***	294.3598***	52.44787***
FDI	6686.681***	101.1223***	56.98329***
IQ	7626.802***	119.0302***	9.576204***
TI	7149.475***	109.9378***	4.846279***
GINI	11662.54***	195.9049***	38.50209***
EDU	14453.10***	249.0609***	67.16254***

Source: Author's Estimations

Note: ***, **, * represents 1%, 5% & 10% significance level, respectively

The slope homogeneity test suggested by Pesaran & Yamagata (2008) is used to test the slope homogeneity in a model. The results shown in Table 5 point out that the delta and delta adjective values are statistically significant in four models, indicating that the null hypothesis of no slope heterogeneity is rejected. Therefore, it is concluded that there is a presence of heterogeneity in a model.

Table 5: Slope Homogeneity Test

Slope Homogeneity	Model-I	Model-II	Model-III	Model-IV
Δ Test	20.052***	14.620***	16.532***	14.304***
Δ Adj Test	24.871***	18.881***	21.343***	18.466***

Source: Author's Estimations

Note: ***, **, * represents 1%, 5% & 10% significance level, respectively

Panel Unit Root Test Analysis

In the presence of cross-sectional dependence and slope heterogeneity, the second-generation unit root tests can produce better results. For this purpose, CIPS and CADF tests are used to check data stationarity. The results of CIPS and CADF tests show that PHC, FDI, IQ, TI and GINI are integrated at order zero $I(0)$ while EDU is integrated at order $I(1)$. These outcomes suggest the mixed integration order of variables in a model.

Table 6: Panel Unit Root Test

	CIPS		CADF		Outcomes
	I(0)	I(1)	I(0)	I(1)	
PHC	-2.378***	--	-1.978**	--	I(0)
FDI	-2.648***	--	-2.083***	--	I(0)
IQ	-2.072**	--	-2.556***	--	I(0)
TI	-2.710***	--	-2.572***	--	I(0)
GINI	-2.820***	--	-2.112***	--	I(0)
EDU	--	-4.031***		-2.922***	I(1)

Source: Author's Estimations

Note: ***, **, * represents 1%, 5% & 10% significance level, respectively

Cointegration, Heteroskedasticity and Autocorrelation Tests Analysis

To check the heteroskedasticity, autocorrelation and cointegration in a model-modified Wald test, the Wooldridge test and Westerlund test are used respectively and the estimates of these tests are given in Table 7. The results show that Modified Wald test values of all four models are statistically significant at the one percent significance level. It points out that the null hypothesis of heteroskedasticity in a model is accepted. In addition, the Wooldridge test values of all four models are also statistically significant at the one percent significance level representing that there is an issue of autocorrelation in a model. Lastly, long-run cointegration among variables is analyzed using the variance ratio of the Westerlund cointegration test. The outcomes suggest that all four models have long-run cointegration among variables in a model.

Table 7: Heteroskedasticity, Autocorrelation and Cointegration Test Estimates

Problem	Model-I	Model-II	Model-III	Model-IV
Modified Wald test for GroupWise heteroskedasticity	66405.57***	70475.55***	68591.07***	56533.47***
Wooldridge test for autocorrelation in panel data	14.828***	15.254***	14.859***	15.077***

Westerlund test for cointegration	2.5134***	1.4673*	1.6813**	2.0110**
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Source: Author's Estimations

Note: ***, **, * represents 1%, 5% & 10% significance level, respectively

FGLS Analysis

The outcomes of the FGLS model to analyze the influence of foreign capital inflows, institutional quality and technological innovation on poverty in developing countries are discussed in this section. The FGLS model effectively addressed the issues of heteroskedasticity, autocorrelation and cross-sectional dependence. It produces reliable estimates when the model faces similar issues (Iram et al., 2024; Chatha et al., 2025; Yuliadi & Yudhi, 2021). Therefore, the FGLS model is adopted in a study for data estimation and outcomes are given in Table 8. The dependent variable used in model-I, II, III and IV is poverty headcount ratio (PHC) whereas the independent variables are foreign direct investment (FDI), institutional quality (IQ), technological innovation (TI), income inequality (GINI), and education (EDU). In addition, the interaction terms IQ*TI, IQ*FDI and FDI*TI are added in model-II, model-III and model-IV, respectively, to analyze the mutual influence of these variables on poverty headcount ratio in developing countries. The FGLS estimates show that the variables FDI, IQ, TI and EDU are negatively and significantly related to the PHC in developing countries whereas income inequality is found to be positively and significantly related to the PHC in developing countries.

Table 8: Feasible Generalized Least Square Estimates (FGLS)

Dependent Variable: Poverty Headcount Ratio				
Variables	Model-I	Model-II	Model-III	Model-IV
FDI	-0.0706*** [0.0129] (-5.46)	-0.0657*** [0.0126] (-5.18)	-0.0479*** [0.0136] (-3.50)	-0.0032 [0.0194] (-0.17)
IQ	-0.0768*** [0.0101] (-7.55)	-0.2151*** [0.0228] (-9.40)	-0.5276*** [0.0964] (-5.47)	-0.0714*** [0.0101] (-7.04)
TI	-0.0226** [0.0111] (-2.02)	-0.0421*** [0.0113] (-3.72)	-0.0406*** [0.0117] (-3.47)	-0.2821*** [0.0669] (4.22)
GINI	1.4064*** [0.0767] (18.32)	1.3618*** [0.0754] (18.04)	1.3908*** [0.0760] (18.29)	1.3948*** [0.0760] (18.34)
EDU	-0.2710*** [0.0457] (-5.92)	-0.2498*** [0.0449] (-5.56)	-0.2583*** [0.0453] (-5.69)	-0.3321*** [0.0472] (-7.03)
IQ*TI	--	-0.0287*** [0.0042] (6.71)	--	--
IQ*FDI	--	--	-0.0221*** [0.0047] (-4.70)	--
FDI*TI	--	--	--	-0.0134*** [0.0029] (-4.62)

C	0.7774* [0.4331] (1.80)	0.84558** [0.4243] (1.99)	0.3912 [0.4364] (0.90)	-0.4263 [0.5018] (-0.85)
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Source: Author's Estimations

Note: ***, **, * represents 1%, 5% & 10% significance level, respectively

The values in [] are standard error, values in () are z-statistic values

Firstly, examining the relationship between FDI and PHC, the result shows that FDI is negatively and significantly related to PHC in developing countries. The FDI's coefficient displays that the PHC declines by 7.06 percent as FDI inflows in developing countries increase by one percent. It suggests that FDI brings technology and investment into a country and helps to reduce poverty in different ways. FDI has been observed to impact poverty reduction through two primary channels positively. Firstly, FDI contributes to poverty reduction by generating employment opportunities within the private sector. Secondly, foreign investors directly invest in social welfare initiatives targeted towards poor communities. These employment opportunities directly impact poverty reduction, as the knowledge and skills acquired can empower local residents to generate further job opportunities. The indirect channel of FDI fosters the growth of the economy through promoting investments and capital accumulation and this growth further leads to alleviation of poverty in a country (Gohou & Soumaré, 2012; Anetor et al., 2020). The negative relationship between FDI and poverty was also found by Chindengwike (2022) and Tsaurai (2018). Similarly, better institutional quality is imperative to improve the welfare of the people, The result shows that IQ is negatively and significantly related to PHC in developing countries. The IQ's coefficient displays that the PHC declines by 7.68 percent as IQ in developing countries increases by one percent. It suggests that good institutions lead toward higher level of economic growth and provide a fertile ground for more equal distribution of income. On the other hand, Low quality institutions are associated with gearing wealth toward rich and have detrimental effects on income distribution. For example, corruption can switch the benefits of social spending from poor towards rich (Siddique et al., 2016). Similar outcomes were also found by Singh (2021) and Aracil et al., (2022).

Technological innovation stimulates economic progress, creates jobs, and can adversely impact poverty. The result shows that TI is negatively and significantly related to PHC in developing countries. The TI's coefficient displays that the PHC declines by 2.26 percent as TI in developing countries increases by one percent. It suggests that the utilization of technology has significantly contributed to improving living conditions for poor people. Through technological innovation, several advancements in modern medicine and public health have played a pivotal role in enhancing poor communities' nutritional status, overall health, and socio-economic well-being (Muchdie, 2017). Through the indirect channel, technological innovation improves the country's economic progress by enhancing productivity and efficiency (Mohamed et al., 2022) and leads to eradicating poverty in a country. Similar results were also confirmed by Zameer et al., (2020) and Dhrifi (2014). In contrast, the result shows that GINI is positively and significantly related to PHC in developing countries. The GINI's coefficient displays that the PHC increases by 1.4064 percent as income inequality in developing countries increases by one percent. It suggests that inequality may result in under-investment in education, health and physical capital leading to lower growth. Such under-investment seems to us to be a result of a lack of resources, rather than inequality, per se. This argues for looking at poverty as an additional channel which may hinder economic growth (Breunig & Majeed, 2020). These results were also supported by Ibrahim & Taiga (2020), and Apergis et al., (2011).

Lastly, the result shows that EDU is negatively and significantly related to PHC in developing countries. The EDU's coefficient displays that the PHC declines by 27.10 percent as EDU in developing countries increase by one percent. It advocates that acquiring a quality education plays a pivotal role in accessing employment, improving income, and improving living standards. The education plays a vital role in mitigating social and economic disparities. Education is widely recognized as a fundamental pillar of human civilization, serving as a means to foster the development and expression of individual potential, ultimately enabling individuals to attain their goals and lead productive lives (Yakunina & Bychkov). Therefore, it concluded that education is a strong pillar that eradicates poverty in developing countries. These results were also found by Ameer et al., (2024) and Sheikh et al., (2020).

In addition, in model-II, the interaction term of IQ*TI is added to analyze the combined influence of IQ and TI on PHC. The outcomes of variables FDI, TI, IQ, GINI and EDU are similar to the model-I outcomes. The coefficient of the interaction term of IQ*TI is found to be negative indicating that it is negatively and significantly related to PHC in developing countries. The IQ*TI coefficient displays that the PHC declines by 2.87 percent as IQ*TI in developing countries increases by one percent. It suggests that technological innovation with better institutional quality can be helpful in eliminating poverty in developing countries.

Furthermore, in model-III, the interaction term of IQ*FDI is added to analyze the combined influence of IQ and FDI on PHC. The outcomes of variables FDI, TI, IQ, GINI and EDU are similar to the model-I and model-II outcomes. The coefficient of the interaction term of IQ*FDI is found to be negative indicating that it is negatively and significantly related to PHC in developing countries. The IQ*FDI coefficient displays that the PHC declines by 2.21 percent as IQ*FDI in developing countries increases by one percent. It suggests that foreign capital inflows combined with better institutional quality can be helpful in eliminating poverty in developing countries.

Lastly, in model-IV, the interaction term of FDI*TI is added to analyze the combined influence of IQ and FDI on PHC. The outcomes of variables FDI, TI, IQ, GINI and EDU are similar to the model-I, model-II and model-III outcomes. The coefficient of the interaction term of FDI*TI is found to be negative indicating that it is negatively and significantly related to PHC in developing countries. The FDI*TI coefficient displays that the PHC declines by 1.34 percent as FDI*TI in developing countries increases by one percent. It suggests that foreign capital inflows combined with better technological innovation in a country can produce fruitful outcomes. It not only improves the economic growth of the country but can be supportive in eradicating poverty in developing countries.

Robustness Estimation

For robustness estimation, in this study, the PCSE model is used. The PCSE model produces better estimates when the model faces the issues of heteroskedasticity, autocorrelation and cross-sectional dependence similar to the FGLS model (Iram et al., 2024; Sundjo & Aziseh, 2018). Therefore, PCSE model is adopted in a study for robustness estimation and outcomes are given in Table 9. The dependent variable used in model-I, II, III and IV is poverty headcount ratio (PHC) whereas the independent variables are foreign direct investment (FDI), institutional quality (IQ), technological innovation (TI), income inequality (GINI), and education (EDU). In addition, the interaction terms IQ*TI, IQ*FDI and FDI*TI are added in model-II, model-III and model-IV, respectively, to analyze the mutual influence of these variables on poverty headcount ratio in developing countries. The PCSE model estimates also confirm the outcomes of the FGLS model indicating that the variables FDI, IQ, TI and EDU are negatively and significantly related to the PHC in developing countries whereas income inequality is found to be positively and significantly

related to the PHC in developing countries. Similarly, the interaction terms IQ*TI, IQ*FDI and FDI*TI are also found to be negatively and significantly related to the PHC validating the estimates of the FGLS model.

Table 9: Panel Corrected Standard Error (PCSE) Estimates

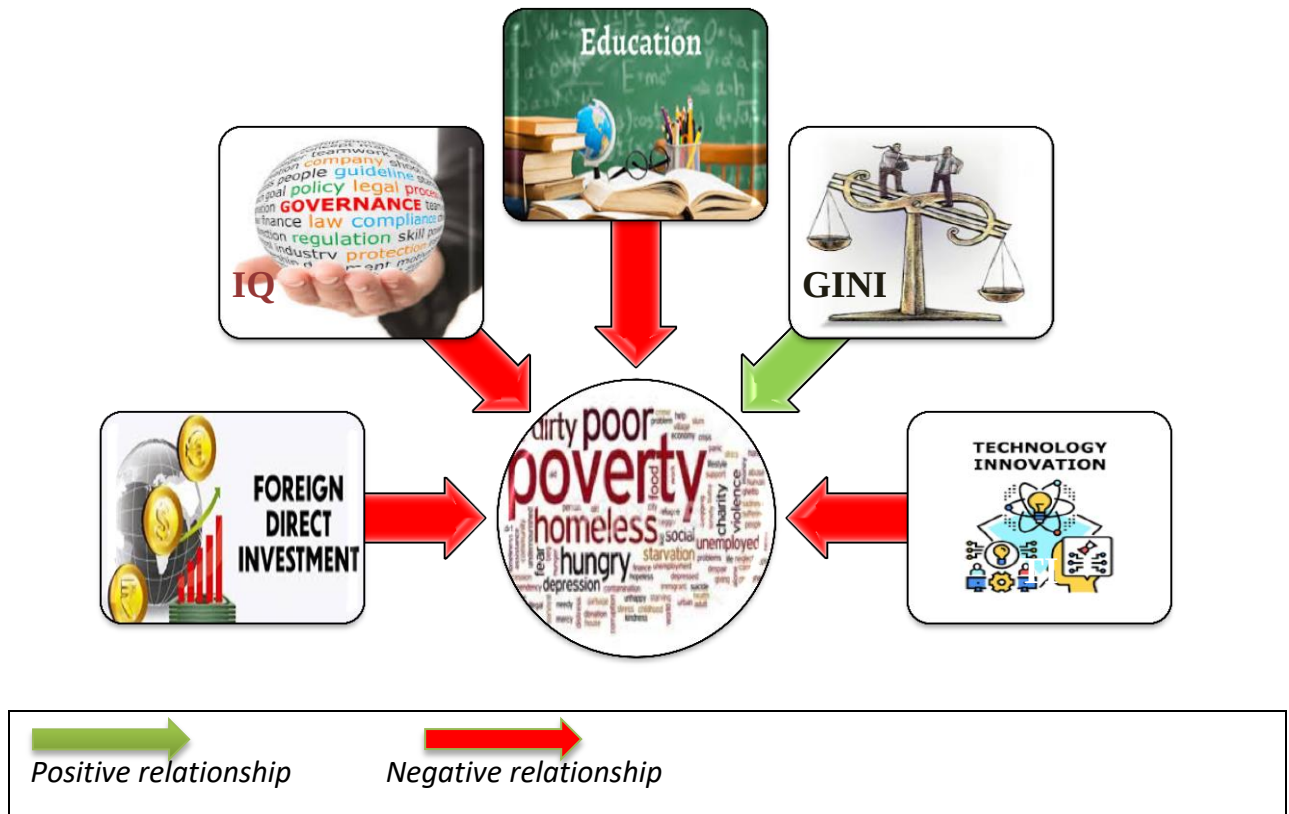
Dependent Variable: Poverty Headcount Ratio				
Variables	Model-I	Model-I	Model-II	Model-III
FDI	-0.0706*** [0.0129] (-5.46)	-0.0657*** [0.0094] (-6.98)	-0.0479*** [0.0103] (-4.65)	-0.0032 [0.0185] (-0.18)
IQ	-0.0768*** [0.0101] (-7.55)	-0.2151*** [0.0187] (-11.46)	-0.5276*** [0.0682] (-7.73)	-0.0714*** [0.0081] (-8.80)
TI	-0.0226** [0.0111] (-2.02)	-0.0421*** [0.0096] (-4.37)	-0.0406*** [0.0103] (-3.92)	0.2821*** [0.0875] (3.22)
GINI	1.4064*** [0.0767] (18.32)	1.3618*** [0.0399] (34.12)	1.3908*** [0.0443] (31.34)	1.3948*** [0.0463] (30.10)
EDU	-0.2710*** [0.0457] (-5.92)	-0.2498*** [0.0266] (-9.39)	-0.2583*** [0.0273] (-9.45)	-0.3321*** [0.0348] (-9.54)
IQ*TI	--	-0.0287*** [0.0039] (7.24)	--	--
IQ*FDI	--	--	-0.0221*** [0.0032] (-6.74)	--
FDI*TI	--	--	--	-0.01342*** [0.0040] (-3.34)
C	0.7774* [0.4331] (1.80)	0.8455*** [0.2243] (3.77)	0.39122 [0.2610] (1.50)	-0.4263 [0.3041] (-1.40)

Source: Author's Estimations

Note: ***, **, * represents 1%, 5% & 10% significance level, respectively

The values in [] are standard error, values in () are z-statistic values

Figure 3: Summary of FGLS and PCSE Outcomes in Developing Countries



Granger Causality Analysis

The panel Granger causality test is used to test the causation relationship between the variables. Table 10 reports the outcomes of the Granger causality test. The results show that there is a unidirectional causality between FDI and PHC, and TI and PHC. In addition, bidirectional causality is found between IQ and PHC. Lastly, no causality is observed between GINI and PHC, and EDU and PHC in developing countries.

Table 10: Pairwise Granger Causality Tests

Null Hypothesis	F-Statistic	Prob.	Outcomes
FDI $\neq$ PHC	4.5024	0.0113	Unidirectional
PHC $\neq$ FDI	1.4504	0.2350	
IQ $\neq$ PHC	2.6339	0.0723	Bidirectional
PHC $\neq$ IQ	6.6675	0.0013	
TI $\neq$ PHC	9.9206	0.0000	Unidirectional
PHC $\neq$ TI	0.3493	0.7053	
GINI $\neq$ PHC	1.7837	0.1686	No-Causality
PHC $\neq$ GINI	2.1961	0.1118	
EDU $\neq$ PHC	0.4493	0.6382	No-Causality
PHC $\neq$ EDU	1.9836	0.1381	

Source: Author's Estimations

Conclusions

This study analyzes the role of foreign capital inflows, technological innovation, and institutional quality in poverty mitigation in developing countries. For this purpose, the data from 53 developing countries, based on data availability, from 2002 to 2021 is used in the study. The data was collected from WDI and WGI. For data estimation, cross-section dependence test, slope homogeneity test, CIPS and CADF tests of unit root, panel cointegration test, FGLS model for parameter estimations and PCSE model for robustness estimation is used in a study. The cross-sectional dependence tests point out that the variables PHC, FDI, IQ, TI and GINI are cross-sectional dependent in developing countries. These outcomes point out that any shock that happens in one country can influence other countries' economies. The slope homogeneity test point out that the delta and delta adjective values are statistically significant in four models, indicating that the H_0 of no slope heterogeneity is rejected. Therefore, it is proposed that heterogeneity is present in a model. The results of CIPS and CADF tests show that PHC, FDI, IQ, TI and GINI are integrated at order zero $I(0)$ while EDU is at $I(1)$ suggesting the mixed integration order of variables in a model. The results show that Modified Wald test values of all four models are statistically significant at the one percent significance level. It points out that the null hypothesis of heteroskedasticity in a model is accepted. In addition, the Wooldridge test values of all four models are statistically significant at the one percent significance level, representing that there is an issue of autocorrelation in a model. Lastly, long-run cointegration among variables is analyzed using the variance ratio of the Westerlund cointegration test. The outcomes suggest that all four models have long-run cointegration among variables in a model. The FGLS estimates show that the variables FDI, IQ, TI and EDU are negatively and significantly related to the PHC in developing countries, whereas income inequality is found to be positively and significantly linked to the PHC in developing countries. Similarly, the interaction terms $IQ*TI$, $IQ*FDI$, and $FDI*TI$ have also been found to be negatively and significantly related to PHC in developing countries. The PCSE model also confirmed the findings of the FGLS model. Lastly, the panel Granger causality test indicates a one-way causality between FDI and PHC, and TI and PHC. In addition, bidirectional causality is found between IQ and PHC. Lastly, no causality is observed between GINI and PHC, as well as between EDU and PHC, in developing countries. Therefore, it is concluded that FDI inflows, IQ and TI are imperative to reduce poverty in developing countries.

Policy Implications

The study has different policy implications. First, the policies should also be aimed at promoting FDI inflows in labor-intensive industries like agriculture, services and manufacturing sectors. As developing countries are mostly labor-intensive, this incentive can increase job opportunities for the people; this may lead to a reduction in the poverty level in developing countries. Second, technological innovation is also found to be an important factor in eradicating poverty; therefore, governments of developing countries should focus on boosting technological innovation in a country. For this purpose, investment in agri-tech innovation, increased accessibility of digital infrastructure, and access to financial technology is imperative. Third, the study also shows that institutional quality is imperative in declining poverty in developing countries. Therefore, it is suggested that the institutional quality in developing countries should be strengthened by focusing on the formation of anticorruption laws, ensuring political stability, improving the law & order situation and implementing strong social protection programs. Lastly, the study also found that education is crucial in declining the poverty developing countries. Therefore, it is suggested that developing countries should invest in improving the educational infrastructure. The provision of education in rural areas should be ensured. The technical education training programs should be

designed to increase the skilled and specialized labor. All these factors are crucial to eradicating poverty in developing countries.

Limitations of the Study

Despite this study contributing significantly to the literature by providing evidence of the impact of FCI, institutional quality, and technological innovation on poverty eradication in developing countries, the study also has some limitations. First, the study considers FDI inflows as FCI; however, future studies can also use remittances, foreign portfolio investment and external debt as a measure of FCI in developing countries. Second, the study used data from developing countries from 2002 to 2021, although the panel dataset of other countries, such as developed countries, South Asian countries, and OECD countries, can be used for a given purpose. Lastly, the study relied on second-generation panel data estimation techniques, including the FGLS model and PCSE model. To better understand the short-run and long-run outcomes, future studies can also use the CS-ARDL model to analyze the results.

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