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Revealing the Role of Technological Innovation, Institutional Quality and Foreign Direct Investment in Impacting Human Development in Developing Countries: Insights from FGLS and PCSE Models

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ABSTRACT

*The study reveals how technological innovation, institutional quality, and foreign direct investment drive sustainable human development, providing strategies for policymakers to address inequalities and enhance well-being in developing countries. For this purpose, the data from 53 developing countries from 2002 to 2021 is used in the study. 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 foreign direct investment, institutional quality, technological innovation and number of physicians are positively and significantly while total population is negatively and significantly related to the HDI in developing countries. On the other hand, educational expenditures are positively but insignificantly related to the HDI. The impact of the interaction terms IQ*TI and IQ*FDI on HDI is positive and statistically insignificant. In contrast, FDI*TI is found to be positively and significantly related to the HDI. The panel Granger causality test results show that there is a unidirectional causality between IQ and HDI, and TI and HDI. In addition, bidirectional causality is found between PHY and HDI. Lastly, no causality is observed between EDUE and HDI. Therefore, keeping in view the findings, it is concluded that FDI, technological innovation and institutional quality are imperative to improve the HDI in developing countries.*

Introduction

Developing countries still lag behind their industrialized counterparts despite substantial capital flows, including both investment and economic assistance. A few things that could be contributing to this tendency are low financial development, a lack of absorptive capacity, and poor institutional quality (IQ). Sen (1999) contends that a country's ability to extend access to basic education, maintain good health, and generate job possibilities depends critically on its social, economic, and political institutions. Institutions can be crucial to implementing the process of human development through the flow of foreign resources by improving governance and administration, enforcing law and order, controlling corruption, and designing better policies. To effectively harness the means of development, competent governance and resource allocation are essential (Wahedi, 2011; Asghar et al., 2024a; Ishfaq et al., 2024).

Similarly, foreign capital flows are essential to a nation's development. The kind and amount of foreign capital that a nation receives determines how it affects human growth. For example, FDI supports the welfare of humans via three distinct channels: governments, labor markets, and households. FDI helps the government by raising tax revenues, which can then be used to fund investments in areas such as employment opportunities, household income, health, and education (Blomstrom & Kokko, 1998). According to Globerman & Shapiro (2003), people can use the extra money they make if their household income rises to enhance their quality of life. Due to the trickle-down effects of job creation, FDI has an impact on the labor market (Jordaan, 2005; Ameer et al., 2024). In addition, talent development, managerial and organizational practices, and fostering market rivalry are further spillover effects that FDI generates (Noorbakhsh et al., 2001).

On the other hand, technology has always been a potent tool for societal and economic advancement. It can be used in many different areas, including boosting agricultural output, producing inexpensive energy, supplying clean water, and enhancing health. Information and communications technology (ICT), in particular, can help combat poverty by expanding people's access to financial, health, and educational resources. Remarkably, even basic technologies could contribute to the fight against poverty (Prodi, 2015). Technology has the power to increase or boost earnings and productivity. This can be achieved in artisanal mining by improving net benefits after improving production methods, and savings might make it viable to reinvest in mining or other economic activities (Mutagwaba et al., 1997; Ahmad et al., 2022). More time saved and put toward other endeavors is thought to occur when technology makes the production process easier (Mutagwaba et al., 1997). Similarly, technology reduces accidents and improves safety and health in the production process. Additionally, it is anticipated that the usage of devices such as water drainage facilities, air compressors, and others lessens physical discomfort and disease, improving health, lowering medical expenses, and increasing productivity (Sibt-e-Ali et al., 2024; Sibt-e-Ali et al., 2018).

Technology, institutional quality, and inflows of foreign capital are all essential factors in boosting economic development, particularly in developing nations. Poor governance is one of the leading causes of poverty in developing nations. Governance has a direct effect on the business sector. Ineffective governance has a negative impact on investments and the economy's growth. A nation's ability to develop its people is reliant on the social amenities that the government offers. In the end, poor governance results in a lack of human capital. These foreign inflows are crucial to the developing countries' ability to manage their economies. Nonetheless, the efficiency with which foreign money is employed is contingent upon the state and caliber of political and economic institutions. Therefore, this study intends to analyze the effect of foreign direct investment, institutional quality and technological innovation on human development in developing countries.

By addressing these dynamics, the study offers actionable insights for creating policies that enhance institutional capacity, attract impactful FDI, and promote innovation. Its findings will guide governments and international stakeholders in designing integrated strategies that maximize human development. This is particularly important in achieving the United Nations Sustainable Development Goals (SDGs), as it emphasizes inclusive growth and long-term well-being in developing nations. Ultimately, the study contributes to the global discourse on equitable and sustainable development by identifying pathways to improve the quality of life for millions in the developing world.

Literature Review

Foreign Direct Investment and Human Development

At the empirical level different studies analyzed the relationship between foreign direct investment (FDI) and human development (HD) such as Githaiga & Kilong'i (2023) analyzed the moderating role that IQ had in the association between FDI and human capital using data from 2009 to 2019 from a sample of 34 sub-Saharan African nations. The findings showed that FDI, human capital development, institutional quality, and remittances all had a favorable correlation. In contrast, the development of HC is adversely and significantly impacted by official development assistance (ODA). The results also showed that the quality of the institution moderates the influence of FDI and remittances on the growth of HC. However, institutional quality had little bearing on how ODA affected the growth of human capital. Similarly, Djokoto & Wongnaa (2023) used panel data from 87 developing, 13 transitional, and 34 developed nations between 1990 and 2019 to explore the effects of FDI on the phases of human development. Their findings showed that FDI positively impacted the development of people in underdeveloped nations. Nonetheless, the impact on industrialized and transitional nations was insignificant. Furthermore, Ali et al., (2022) explored the effect of foreign capital on HD using data from 65 developing nations between 1984 and 2014. It was discovered that the effect of FDI differs depending on the HD indicators and the kind of foreign capital under investigation using the two-step system GMM estimation technique. Remittances positively impact all metrics of human development except life expectancy, whereas FDI and foreign portfolio investment have a negative impact on secondary school enrollment and per capita income. The study by Nam & Ryu (2022) explored the effect of FDI on HD and demonstrated the moderating role of governance on the relationship between FDI and HD in ASEAN countries from 2001 to 2018. The study concluded that FDI hinders the host nation's human development. Governance plays a positive moderating influence on this link. FDI can stimulate economic growth, but it doesn't advance human development, as indicated by improvements in income, healthcare, and education. Furthermore, ethical FDI is regulated by strong governance, which guards against harmful FDI and promotes human development. In addition, Tsaurai (2020) examined the factors influencing the human capital in Africa using data covering the years 2001 to 2015. The estimates of GMM model showed that ICT had a considerable impact on HD across all econometric estimate methods, whereas FDI had no discernible effect. The study also showed that HC development was highly impacted by the complementarity between FDI and ICT. Therefore, keeping in view the literature review the following hypothesis is developed:

H_1: *Foreign direct investment is positively and significantly associated with the human development in developing countries*

Institutional Quality and Human Development

Different studies analyzed the relationship between institutional quality (IQ) and human development (HD) such as Li et al., (2023) analyzed the effect of financial technologies, digitalization, IQ and HC on natural resources rent from 2002 to 2020 in selected OECD economies. The findings demonstrated that at higher quantiles, the effects of digitalization and financial technologies were more pronounced. Similarly, at the greatest quantile, the impact of digitalization on the rent from natural resources was negative and significantly substantial. Similarly, Fomba et al., (2023) explored the impact of IQ on the quality of education in underdeveloped nations. The primary findings, derived from the OLS and two-stage least squares estimators, indicated that IQ had a negative impact on educational failure and a favorable influence on student accomplishment and school completion. In addition, Kamalu & Ibrahim (2022) analyzed how IQ affected HDI in 14 developing nations using data from 1991 to 2019. The results showed that IQ has a long-term, favorable, and statistically significant impact on HDI. Furthermore, it has been discovered that human growth is positively impacted by financial development, but higher military spending has a long-term detrimental impact. The findings implied that long-term human growth is supported by IQ. The study by Al-Zyoud et al., (2021) explored the factors influencing the growth of HC in the SAARC economies between 1990 and 2020. Unit root testing, slope heterogeneity, and CSD are used in this investigation. The long-run estimations in this work are computed using the CS-ARDL technique. The findings showed that the SAARC region's HC development was positively impacted by the GDP, LFPR, infrastructure, public health and education spending, and IQ. Furthermore, Aljarallah (2020) used the ARDL approach to evaluate the social dimensions of natural resource dependency and IQ in the Gulf Countries using time-series data from 1984 to 2014. The study demonstrated that human capital in Kuwait, UAE, and the Kingdom of Saudi Arabia is dampened by reliance on natural resources, and that corruption has a long-term detrimental effect on HC in both countries. Therefore, keeping in view the literature review the following hypothesis is developed:

H_2: *Institutional Quality is positively and significantly associated with the human development in developing countries*

Technological Innovation and Human Development

Few studies analyzed the relationship between technological innovation (TI) and human development (HD) such as the study by Aljazea & Belloumi (2022) explored the effects of ICT on HD in a sample of 15 MENA countries from 1995 to 2018. The findings demonstrated that only the mobile cellular subscriber's indicator is important in the short term, all three ICT indicators have a favorable and significant long-term impact on the HDI. In addition, Azuh et al. (2020) explored the impact of R&D on HD in West Africa from 2004 to 2014. The findings highlighted the potential for HD to be harnessed by consistent R&D by demonstrating that R & D in West Africa have a statistically significant positive impact on HD. In order to solve actual problems related to human development, the study suggested increasing R & D through sufficient funding and university-industry partnerships. The consistent reproduction of university-made innovations and the industry's use of these innovations are two ways that innovation may impact HD, so it is advised that West African economies work to improve the impact of innovation on HD by promoting innovation through strategies like scholarships and university-industry partnerships. The study by Ejemeyovwi et al., (2019) investigated the impact of innovation and internet usage on HD in 15 ECOWAS nations. The study discovered a strong and positive correlation between HD and Internet usage, innovation. The study also established that increase in utilization and their interactions significantly improve HD within the economic sub-regional block. Similarly, Asongu

& Le Roux (2017) evaluated the effects of ICT on HD throughout the years 2000–2012 in a sample of 49 Sub Saharan nations. According to the findings, the post-2015 sustainable development agenda's inclusive development will be enhanced by policies aimed at increasing ICT penetration. Different fundamental aspects of HD and ICT dynamics influence how positively inclusive development responds to ICT. Lastly, Gill (2013) used data from 2000 to 2009 to investigate the connection between public health and technological progress. The study's findings demonstrated a correlation between higher public health indicator scores and higher scores for TI. Therefore, keeping in view the literature review the following hypothesis is developed:

H_3: *Technological Innovation is positively and significantly associated with the human development in developing countries*

Data and Methodology

To analyze the role of foreign direct investment, technological innovation, and institutional quality in human development, data from 53 developing countries from 2002 to 2021 is used in the study. The data of human development index is taken from united nations, data of institutional quality indicators is taken from world governance indicators while the data of variables FDI, TI, EDUE, PHY and TP are taken from world development indicators, To investigate the influence of FDI, TI and IQ on HDI in developing countries, the following models are developed:

Model Functional Form

$$HDI = f(FDI, IQ, TI, EDUE, PHY, TP) \quad (1)$$

Model Econometric Form

$$HDI_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 EDUE_{ij} + \beta_5 PHY_{ij} + \beta_6 TP_{ij} + u_{ij} \quad (2)$$

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

$$HDI_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 EDUE_{ij} + \beta_5 PHY_{ij} + \beta_6 TP_{ij} + \beta_7 IQ*TI_{ij} + u_{ij} \quad (3)$$

$$HDI_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 EDUE_{ij} + \beta_5 PHY_{ij} + \beta_6 TP_{ij} + \beta_7 IQ*FDI_{ij} + u_{ij} \quad (4)$$

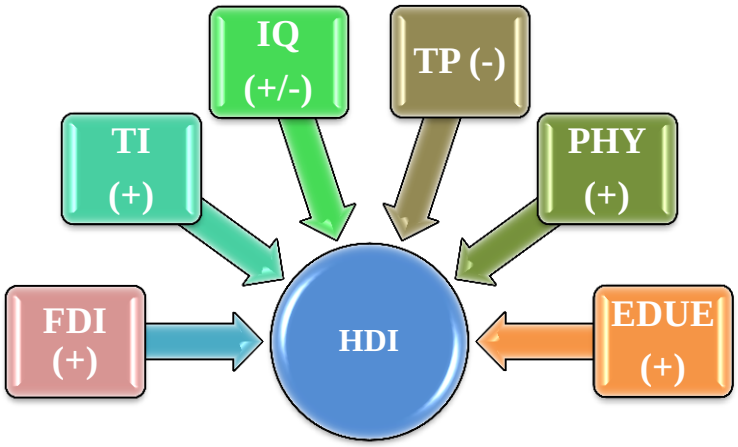
$$HDI_{it} = \beta_o + \beta_1 FDI_{ij} + \beta_2 IQ_{ij} + \beta_3 TI_{ij} + \beta_4 EDUE_{ij} + \beta_5 PHY_{ij} + \beta_6 TP_{ij} + \beta_7 FDI*TI_{ij} + u_{ij} \quad (5)$$

Where HDI indicates human development index, FDI represents foreign direct investment, IQ indicates institutional quality, TI is technological innovation, EDUE is educational expenditures, PHY represents number of physicians, TP is total population, IQ*TI is interaction term of IQ and TI, IQ*FDI is the interaction term of IQ and FDI, FDI*TI is the interaction term of FDI and TI and u_{ij} is error term.

Table 1: Description of Variables

Variables	Descriptions	
HDI	Human development index	Taken from United Nations that is based on life expectancy, per capita income and education
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
EDUE	Educational expenditures	Percentage of GDP
PHY	Number of physicians	Per 1000 people
TP	Population	Total

Figure 1: Expected Relationship between Independent Variables and HDI



Different panel data estimation techniques are employed in a study to examine the impact of FCI, TI and IQ on human development 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:

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

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

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_o: 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_o: 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 ith 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.

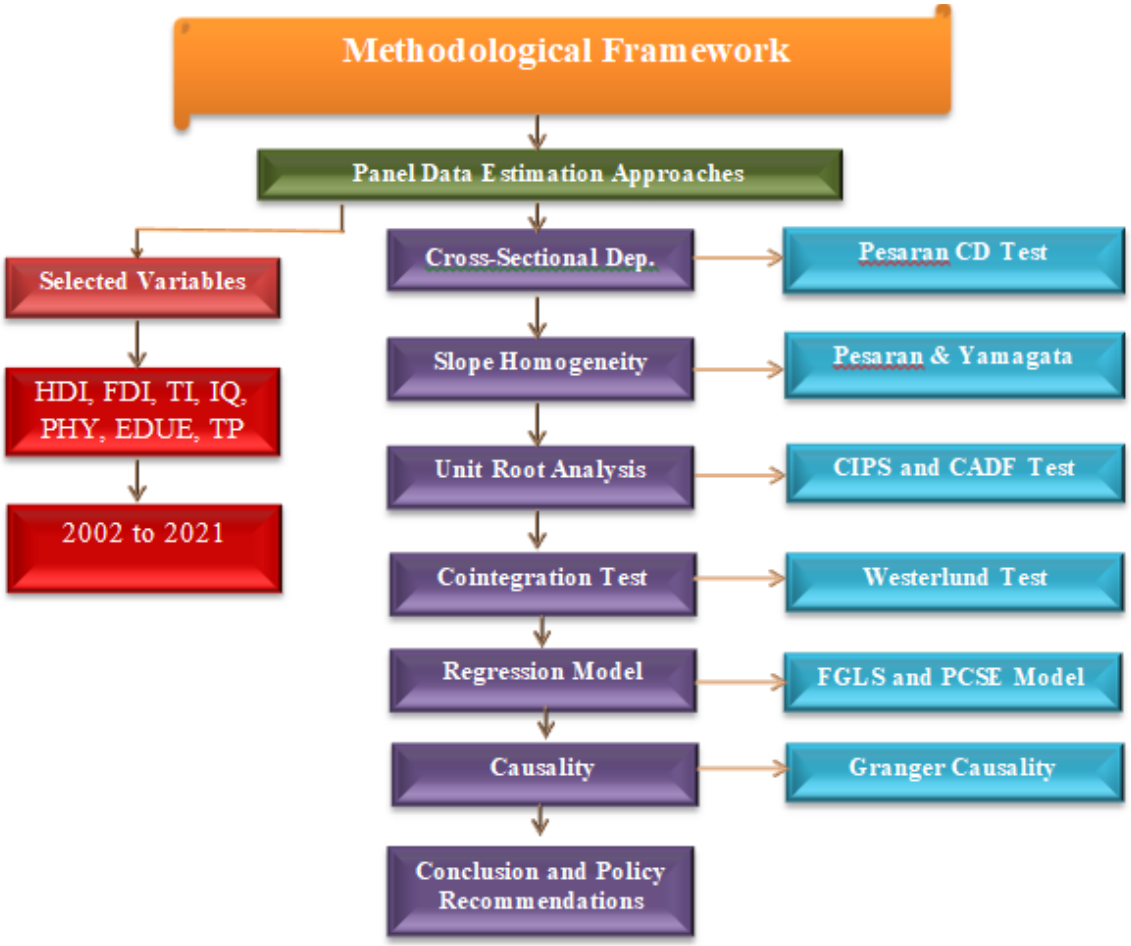
Feasible Generalized Least Square Method

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).

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 shows the descriptive estimates of the variables. Table 2 shows that the mean values of HDI, FDI, IQ, TI, EDUE, PHY and TP are 0.675, 20.871, 0.180, 5.796, 1.361, -0.272 and 16.764, respectively. Similarly, the maximum values of HDI, FDI, IQ, TI, EDUE, PHY and TP are 0.867, 26.564, 5.666, 14.277, 2.368, 1.963 and 21.069, respectively. In contrast, the minimum values of HDI, FDI, IQ, TI, EDUE, PHY and TP are 0.317, 10.361, -5.201, 0.693, -0.563, -5.915 and 14.002 respectively. The distributions of IQ, TI and TP are positively skewed while the distributions of HDI, FDI, EDUE and PHY are negatively skewed. Lastly, FDI, IQ, TI, EDUE and TP have leptokurtic distributions while HDI and PHY have a platykurtic distribution.

Table 2: Descriptive Statistics

Variables	Mean	Maximum	Minimum	S.D.	Skewness	Kurtosis
HDI	0.675	0.867	0.317	0.113	-0.782	2.874
FDI	20.871	26.564	10.361	1.971	-0.608	5.715
IQ	0.180	5.666	-5.201	1.966	0.185	3.441
TI	5.796	14.277	0.693	2.353	0.438	3.708
EDUE	1.361	2.368	-0.563	0.401	-0.408	3.637
PHY	-0.272	1.963	-5.915	1.365	-0.783	2.853
TP	16.764	21.069	14.002	1.533	0.667	3.296

Correlation Analysis

The correlation coefficient is employed to measure the extent of the relationship between two variables. Table 3 reports that HDI is positively correlated to the FDI (0.372), IQ (0.514), TI (0.417), EDUE (0.202) and PHY (0.811) while HDI is negatively correlated to the TP (-0.212) in developing countries.

Table 3: Correlation Matrix

Correlations	HDI	FDI	IQ	TI	EDUE	PHY	TP
HDI	1.000						
FDI	0.372	1.000					
IQ	0.514	0.204	1.000				
TI	0.417	0.722	0.086	1.000			
EDUE	0.202	-0.055	0.193	0.012	1.000		
PHY	0.811	0.317	0.262	0.390	0.167	1.000	
TP	-0.212	0.605	-0.266	0.661	-0.177	-0.196	1.000

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 HDI, FDI, IQ, TI, EDUE, PHY and TP 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
HDI	14115.14***	242.6232***	87.3831***
FDI	6686.681***	101.1223***	56.98329***
IQ	7626.802***	119.0302***	9.576204***
TI	7149.475***	109.9378***	4.846279***
EDUE	6351.012***	94.7283***	2.05626**
PHY	12189.14***	205.9359***	42.2498***
TP	26267.49***	474.1071***	88.7107***

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	15.143***	12.407***	12.829***	13.192***
Δ Adj Test	19.549***	16.729***	17.299***	17.789***

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 in developing countries as shown in Table 6. The results of CIPS and CADF tests show that FDI, IQ, TI, EDUE, PHY and TP are integrated at order zero I(0) while HDI is integrated at order I(1) indicating the mixed integration order of variables in a model.

Table 6: Panel Unit Root Test

Variables	CIPS		CADF		Outcomes
	I(0)	I(1)	I(0)	I(1)	
HDI	--	-2.04*	--	-2.610**	**I(1)**
FDI	-2.648***	--	-2.083***	--	**I(0)**
IQ	-2.072**	--	-2.556***	--	**I(0)**
TI	-2.710***	--	-2.572***	--	**I(0)**
EDUE	-2.019*	--	-2.549**	--	**I(0)**
PHY	-2.688***	--	-2.149***	--	**I(0)**
TP	-2.149**	--	-2.156***	--	**I(0)**

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

Cointegration, Heteroskedasticity and Autocorrelation Tests Analysis

To check the heteroskedasticity, autocorrelation and cointegration in a model, modified Wald test, 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	21775.66***	20762.28***	20350.43***	22775.37***
Wooldridge test	18.051***	17.927***	17.949***	17.830***
Westerlund test	-2.7591***	-2.1541**	-1.9922**	-2.0774**

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

FGLS Analysis

The estimates of the FGLS model to analyze the influence of foreign capital inflows, institutional quality and technological innovation on HDI 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; Asghar et al., 2024b; Yuliadi & Yudhi, 2021). Therefore, the FGLS model is adopted in a study for data estimation and outcomes are given in Table 8. Firstly, probing the relationship between FDI and HDI, the result shows that FDI is positively and significantly related to HDI in developing countries. The FDI's coefficient displays that the HDI increases by 8.12 percent as FDI inflows in developing countries increase by one percent. FDI is known for bringing additional jobs, developing local skills, and stimulating technological progress (De Mello Jr, 1997). The development of local skills and stimulation of technological progress instigates job creation. Together with autonomous or direct job creation incidental to FDI, would lead to increased income. Whilst income forms part of the HDI, some of the increased income would be spent on health and education services. Also, the government would realize tax revenue from the increased income part which would be allocated to health and education expenditures. Thus, FDI would induce positive effects on human development (Kamalu et al., 2022). Positive link between FDI and HDI was also confirmed by Gokmenoglu et al., (2018), Mbang (2022) and Tsaurai (2020). Similarly, better institutional quality is imperative to improve the wellbeing of the people. The result shows that IQ is positively and significantly related to HDI in developing countries. The IQ's coefficient displays that the HDI increases by 1.29 percent as IQ in developing countries increases by one percent. It suggests that government performs a vital role in providing a quality life for its people through a quality healthcare system. The system in each country comprises all institutions, government bodies and resources dedicated to producing healthcare. Thus, transparency in all steps of the system could promote the effectiveness of health spending to achieve better human welfare (Banik et al., 2023). The positive link between IQ and HDI was also validated by Mohammed (2022) and Dollar & Kraay (2002).

In addition, technological innovation is imperative to improve the health and educational outcomes. The findings also show that TI is positively and significantly related to HDI in developing countries. The TI's coefficient displays that the HDI increases by 1.62 percent as TI in developing countries increases by one percent. These results suggest that technological innovation could improve development by creating jobs and improving the standard of living and lead to promote HDI (Nubler, 2016). Improvement in healthcare and educational technological also improves the health and educational status of any country, therefore, helpful in augmenting the HDI. These results were also confirmed by Aljazea & Belloumi (2022), Ejemeyovwi et al., (2019). Education is imperative in improving the wellbeing of people. The study found that EDUE is positively and but insignificantly related to HDI in developing countries. The EDUE's coefficient displays that the HDI increases by 0.37 percent as EDU in developing countries increase by one percent. These results suggest that expenditure on education creates new technology, invention and innovation leading to wealth formation and human capital development. Educations enhance people's ability to contribute more to the growth process and improve their level of productivity. Education guarantees people to live longer and healthier life, because knowledgeable person improve human capital development. Fundamentally, improvement in education increase earning capacity, productivity, access to health information and enhance human capital development compare to countries with lack of investment in education (Erasmus, 2021; Shah et al., 2021). These findings were also confirmed by Sulistyowati et al., (2017) and Edeme et al., (2017). Health infrastructure plays an imperative role in improving the health status of people and HDI of the country. The result shows that PHY is positively and significantly related to HDI in developing countries. The PHY's coefficient displays that the HDI increases by 4.14 percent as PHY in developing countries increase by one percent. These outcomes infers that health services, particularly the role of doctors, encompass catering to the increasing demand for health services, augmenting the number of medical personnel, and equitably distributing hospital facilities. These efforts collectively strive to achieve an optimal level of health. Furthermore, improving health can lead to heightened productivity and labor supply, consequently fostering economic growth and HDI (Al Fian et al., 2024). The positive link between PHY and HDI was also confirmed by Fadillah & Setiartiti (2021) and Indrayana (2021).

Lastly, the result shows that TP is negatively and significantly related to HDI in developing countries. The TP's coefficient displays that the HDI decreases by 2.65 percent as TP in developing countries increase by one percent. This occurs because there is high population growth without being balanced by adequate employment opportunities, resulting in high unemployment rates and ultimately hurting the level of social welfare which decreases. Khadijah et al., (2022) state that the human development index decreases in areas with many poor people. This happens because poor people have difficulty getting what they need, such as education and medical care. To carry out development, the government needs qualified people. The negative link between TP and HDI was also validated by Zgheib et al., (2006), Furuoka & Munir (2011).

In addition, in model-II, the interaction term of IQ*TI is added to analyze the combined influence of IQ and TI on HDI. The coefficient of the interaction term of IQ*TI is found to be positive indicating a positive relationship with HDI in developing countries. However, this association is statistically insignificant. It suggests that technological innovation combined with institutional quality did not improving the HDI in developing countries. Therefore, these countries need to improve their institutional quality and technological innovation to improve the wellbeing of the people. Furthermore, in model-III, the interaction term of IQ*FDI is added to analyze the combined influence of IQ and FDI on HDI. The coefficient of the interaction term of IQ*FDI is found to be positive indicating a positive relationship with HDI in developing countries. However,

this association is statistically insignificant. It suggests that foreign capital inflows combined with institutional quality did not improving the HDI suggesting that the institutional quality in developing countries is not enough to attract more capital inflows to improve the human development in a country. Lastly, in model-IV, the interaction term of FDI*TI is added to analyze the combined influence of IQ and FDI on HDI. The coefficient of the interaction term of FDI*TI is found to be positive indicating that it is positively and significantly related to HDI in developing countries. It suggests that foreign capital inflows combined with technological innovation in a country can produce fruitful outcomes. It not only improves the GDP per capita of the country but can be supportive in eradicating poverty and improving the human development in developing countries.

Table 8: Feasible Generalized Least Square Estimates (FGLS)

Dependent Variable: HDI				
Variables	**Model-I**	**Model-II**	**Model-III**	**Model-IV**
FDI	0.0812*** [0.0130] (6.00)	0.0079*** [0.0013] (5.90)	0.0087*** [0.0014] (6.10)	0.0112*** [0.0018] (6.24)
IQ	0.0129*** [0.0009] (13.38)	0.0144*** [0.0022] (6.53)	0.0008 [0.0089] (0.09)	0.0134*** [0.0009] (13.68)
TI	0.0162*** [0.0013] (12.26)	0.0164*** [0.0013] (12.22)	0.0158*** [0.0013] (11.71)	0.0321*** [0.0061] (5.19)
EDUE	0.0037 [0.0040] (0.92)	0.0035 [0.0040] (0.87)	0.0034 [0.0040] (0.85)	0.0042 [0.0040] (1.05)
PHY	0.0414*** [0.0017] (23.71)	0.0414*** [0.0017] (23.68)	0.0415*** [0.0017] (23.77)	0.0412*** [0.0017] (23.61)
TP	-0.0265*** [0.0022] (-11.95)	-0.0264*** [0.0022] (-11.86)	-0.0268*** [0.0022] (-12.04)	-0.0249*** [0.0023] (-10.83)
IQ*TI	--	0.0002 [0.0003] (0.75)	--	--
IQ*FDI	--	--	0.0005 [0.0004] (1.36)	--
FDI*TI	--	--	--	0.0710*** [0.0264] (2.64)
C	0.8618*** [0.0294] (29.28)	0.8612*** [0.0294] (29.26)	0.8545*** [0.0298] (28.58)	0.7659*** [0.0468] (16.35)

Note: ****, **, * represents 1%, 5% & 10% significance level, respectively*
The values in [] are standard error, values in () are z-statistic values

Robustness Estimation

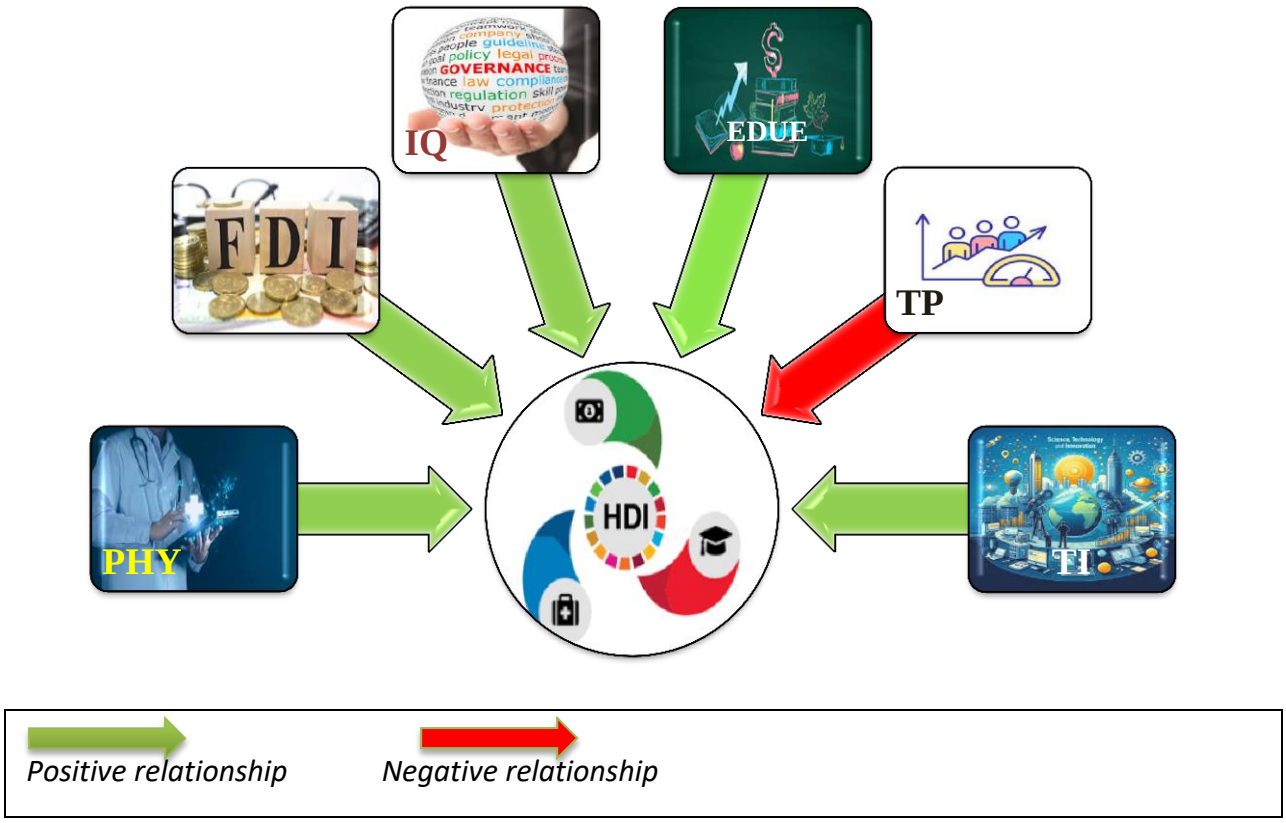
The PCSE model produces better estimates when the model faces the issues of heteroskedasticity, autocorrelation and cross-sectional dependence similar to the FGLS model (Iram et al., 2024; Asghar et al., 2024b). Therefore, PCSE model is adopted in a study for robustness estimation and outcomes are given in Table 9. The outcomes of PCSE model also confirm the outcomes of the FGLS model indicating that FDI, IQ, TI and PHY are positively and significantly related to the HDI while EDUE is positively but insignificantly related to the HDI in developing countries. In contrast, total population is negatively and significantly related to the HDI in developing countries. Similarly, the interaction terms IQ*TI and IQ*FDI impact on HDI is positive and statistically insignificant. In contrast, FDI*TI is found to be positively and significantly related to the HDI validating the estimates of the FGLS model.

Table 9: Panel Corrected Standard Error (PCSE) Estimates

Dependent Variable: HDI				
Variables	**Model-I**	**Model-II**	**Model-III**	**Model-IV**
FDI	0.0080*** [0.0011] (6.80)	0.0079*** [0.0012] (6.57)	0.0087*** [0.0014] (6.03)	0.0112*** [0.0013] (8.57)
IQ	0.0129*** [0.0004] (26.04)	0.0144*** [0.0011] (12.21)	0.0008 [0.0070] (0.12)	0.0134*** [0.0005] (25.19)
TI	0.0162*** [0.0012] (13.24)	0.0164*** [0.0012] (12.65)	0.0158*** [0.0013] (12.12)	0.0321*** [0.0066] (4.84)
EDUE	0.0037 [0.0026] (1.40)	0.0035 [0.0026] (1.32)	0.0034 [0.0026] (1.29)	0.0042 [0.0026] (1.62)
PHY	0.0414*** [0.0014] (29.07)	0.0414*** [0.0014] (28.39)	0.0415*** [0.0014] (29.00)	0.0412*** [0.0015] (27.22)
TP	-0.0265*** [0.0017] (-15.55)	-0.0264*** [0.0017] (-15.42)	-0.0268*** [0.0017] (-15.17)	-0.0249*** [0.0017] (-13.87)
IQ*TI	--	0.0002 [0.0001] (1.50)	--	--
IQ*FDI	--	--	0.0005 [0.0003] (1.77)	--
FDI*TI	--	--	--	0.0755** [0.0281] (2.70)
C	0.8618*** [0.0240] (35.83)	0.8612*** [0.0241] (35.65)	0.8545*** [0.0243] (35.03)	0.7659*** [0.0399] (19.17)

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



Panel 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 IQ and HDI, and TI and HDI. In addition, bidirectional causality is found between PHY and HDI. Lastly, no causality is observed between EDUE and HDI in developing countries.

Table 10: Panel Granger Causality Tests

Null Hypothesis:	Statistic	Prob.	Outcomes
FDI ≠ HDI	2.9077*	0.0551	Unidirectional
HDI ≠ FDI	0.4114	0.6628	
IQ ≠ HDI	1.8666	0.1552	Unidirectional
HDI ≠ IQ	3.1468**	0.0434	
TI ≠ HDI	2.2989	0.1009	Unidirectional
HDI ≠ TI	4.2875**	0.0140	
EDUE ≠ HDI	0.2965	0.7434	No-Causality
HDI ≠ EDUE	0.1003	0.9045	
PHY ≠ HDI	4.9958***	0.0069	Bidirectional
HDI ≠ PHY	4.7219***	0.0091	
TP ≠ HDI	10.0952***	0.0000	Bidirectional
HDI ≠ TP	7.9318***	0.0004	

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

Conclusions

This study analyzes the role of foreign direct investment, technological innovation, and institutional quality in human development 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. Different econometric techniques are used for data estimation such as the outcomes of CSD test shows that the variables HDI, FDI, IQ, TI, EDUE, PHY and TP 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 results point out that the delta and delta adjective values are statistically significant in four models, indicating that the H_o of no slope heterogeneity is rejected. So, it is proposed that heterogeneity is present in a model. The results of CIPS and CADF tests show that FDI, IQ, TI, EDUE, PHY and TP are integrated at order zero I(0) while HDI is at I(1) indicating the mixed integration order of variables in a model. The Modified Wald test and Wooldridge test confirms the issues of heteroskedasticity and autocorrelation in models. Long-run cointegration among variables is analyzed using the variance ratio of the Westerlund cointegration test. The outcomes suggest that all models have long-run cointegration among variables in a model. The FGLS estimates show that the variables FDI, IQ, TI and PHY are positively and significantly related to the HDI in developing countries. On the other hand, EDUE is positively but insignificantly related to the HDI. In contrast, total population is negatively and significantly related to the HDI in developing countries. On the other hand, the impact of the interaction terms IQ*TI and IQ*FDI on HDI is positive and statistically insignificant. In contrast, FDI*TI is found to be positively and significantly related to the HDI in developing countries. The outcomes of the PCSE model also validate the outcomes of the FGLS model. The panel Granger causality test results show that there is a unidirectional causality between IQ and HDI, and TI and HDI. In addition, bidirectional causality is found between PHY and HDI. Lastly, no causality is observed between EDUE and HDI in developing countries. Therefore, keeping in view the findings, it is concluded that FDI, TI and IQ are imperative to improve the HDI in developing countries.

Policy Implications

The study also has different policy implications. First, the study found that FDI inflows are imperative to enhance human development in developing countries, so these countries need to promote FDI inflows. For this purpose, policies should aim to improve the physical infrastructure of the country, enhance the human capital level, and ease of doing business in a country in order to enhance the FDI inflows. Second, technological innovation is also found to be an important factor in promoting human development; 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, t institutional quality is imperative in improving the HDI 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. Fourth, to improve the HDI, the study also suggested that the provision of health facilities should be ensured by strengthening the health infrastructure in developing countries as better health of workers can assist them in improving their productivity and income level. Lastly, to enhance the development of key skills, the government should guarantee structural reforms in the health and education sectors. Additionally, both sectors should be focused on meeting the demand for skills

and preventing a mismatch between the supply and demand for health and educational skills in the nation.

Limitations of the Study

Despite this study contributing significantly to the literature by providing evidence of the impact of FDI, institutional quality, and technological innovation on human development in developing countries, the study also has some limitations. First, the study considers FDI inflows as foreign capital inflows; however, future studies can also use remittances, foreign portfolio investment and external debt as a measure of foreign capital inflows 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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