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Article

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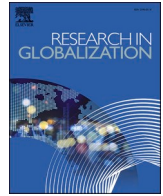
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Globalization, physical capital, and human capital nexus with economic growth: evidence from BIMSTEC

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ABSTRACT

Policymakers' main focus is economic growth, particularly in areas like BIMSTEC where structural problems and globalization's influences greatly affect paths of development. With special focus on the moderating function of globalization, this study examines the link between physical capital, human capital, and economic growth. The paper analyzes the relationships using advanced econometric methods including cross-sectional dependency, stationarity, cointegration, and fully modified ordinary least squares using panel data from 1990 to 2019. The results show a complicated link: while physical and human capital have positive direct effects on growth, globalization negatively moderates these relationships in BIMSTEC due to the region's diverse economic structures and different degrees of integration with global markets, so transforming them into stronger growth drivers in the long run. Dynamic ordinary least squares and ARDL models' robustness testing help to validate the results. Especially, although the associations maintain in the long-run, the short run shows no appreciable influence. These findings have significant consequences for policy since they encourage BIMSTEC nation officials to match globalization with capital accumulation policies in order to support sustainable economic development. This paper provides a route for creating long-term development programs that include worldwide possibilities into regional economic strategy.

1. Introduction

Physical and human capital play pivotal roles in promoting economic growth by enhancing productivity, efficiency, fostering innovation, and building a skilled workforce that supports sustainable development (Pomi et al., 2021; Rahman et al., 2024b; Saleh et al., 2020). Globalization boosts economic growth by enhancing physical capital through the transfer of advanced technologies, resources, and investments that improve productivity in areas like machinery and infrastructure (Coulbaly et al., 2018; Zaidi et al., 2019). It also strengthens human capital by enabling knowledge exchange, skill development, and access to global markets, which increases labor productivity and workforce capabilities (Asongu & Tchamyou, 2020; Stofkova & Sukalova, 2020).

Several economic theories discuss the roles of physical and human capital in economic growth. Solow (1996) underscored the importance of physical capital and technological progress in economic growth. Romer (1989) focused on human capital and innovation as important determinants for sustained growth. Mankiw et al. (1995) extended the Solow model by incorporating both physical and human capital to explain variations in economic performance. In this context,

investments in human capital, such as education and healthcare, and physical capital like infrastructure, machinery, and technology, significantly drive economic growth (Bawono, 2021; Keita, 2016; Wu & Wu, 2022).

Çepni et al. (2019) underscore a nonlinear correlation between inequality and economic growth, accentuating the importance of the human capital to physical capital ratio. Nonetheless, their approach fails to examine how globalization might affect this relationship, creating a significant void in comprehending the wider environment in which these processes function. Likewise, although Liu & Agbola (2014) illustrate a positive correlation between human capital and economic growth in China's electronics sector, their research fails to account for the potential impact of globalization on this connection within the BIMSTEC framework. This oversight is notably important, as globalization brings multiple elements—such as international trade, investment flows, and technology transfer—that can either augment or impede the efficacy of capital accumulation (Wang et al., 2023). Moreover, the prevailing research predominantly emphasizes a narrow range of economic indicators to assess globalization, neglecting its wider economic, social, and political aspects. Rao et al. (2011) contend that prior research has overlooked the extensive ramifications of

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Nomenclature		PS-LM	Pesaran Scaled LM
Acronyms		GDP	Gross domestic product
DOLS	Dynamic ordinary least square	WDI	World development indicator
ARDL	Autoregressive Distributed Lag	PPP	Purchasing power parities
ECGR	Economic growth	BoP	Balance of payment
PCAP	Physical capital	SD	Standard deviation
HCAP	Human capital	VIF	Variance Inflation Factor
GLBN	Globalization	CSD	Cross-sectional dependence
INFL	Inflation	CIPS	Cross-Sectionally Augmented IPS
FDIN	Foreign direct investment	BIMSTEC	Bangladesh, India, Myanmar, Sri Lanka, Thailand, Bhutan, and Nepal
GFDV	Global financial development	CADF	Cross-Sectionally Augmented Dickey-Fuller
PCD	Pesaran CD	FMOLS	Fully Modified Ordinary Least Squares
BP-LM	Breusch-Pagan LM	BCS-LM	Bias-Corrected Scaled LM

globalization, especially on its multifaceted effects. This limited perspective constrains the comprehension of how globalization engages with human and physical capital in affecting economic growth, particularly in areas with heterogeneous economic frameworks and differing developmental phases. Our study investigates the moderating influence of globalization on the link between physical and human capital and economic growth in BIMSTEC nations. We offer a thorough analysis of how globalization affects capital accumulation and economic growth in a region marked by considerable economic diversity, by examining the multifaceted dimensions of globalization through the framework of both types of capital. This method addresses a significant deficiency in the literature and provides innovative perspectives on the interaction between globalization, capital, and economic growth in emerging economies.

The BIMSTEC nations—Bangladesh, India, Myanmar, Sri Lanka, Thailand, Bhutan, and Nepal—form a strategically significant regional bloc, located at the intersection of South and Southeast Asia. With their diverse economic structures, abundant resources, and growing economic potential, these countries hold immense promise for regional and global economic integration. In this context, the role of globalization becomes crucial, as it influences the dynamics between physical capital, human capital, and economic growth. BIMSTEC is a region with common challenges like weak infrastructure, and differences in education and skills. They also trade, invest, and share resources, implying that their growth is interconnected. Existing studies have explored the economic growth dynamics of BIMSTEC nations, focusing on various contributing factors other than physical and human capital. [Towhid & Kiyoto \(2019\)](#) examined the effect of trade openness on economic growth within BIMSTEC countries, while [Kumar et al. \(2023\)](#) analyzed the relationship between foreign direct investment and economic growth in the region. However, this research takes a novel approach by investigating the impact of physical and human capital on the region's economic growth, with globalization serving as a moderating influence. It explores how globalization changes the impact of physical and human capital on growth in a way that past studies have not investigated. With this approach, this study seeks to explain how BIMSTEC countries, experiencing cross-border spillover effects, can work together to grow faster and benefit from their regional connections.

This research aims to investigate the relationship between physical capital, human capital, and economic growth, focusing on the moderating effects of globalization in BIMSTEC countries. The specific objectives are:

1. To find the relationship between physical capital and economic growth,
2. To examine how human capital affects economic growth, and,
3. To investigate whether globalization strengthens or weakens capital (physical and human) and economic growth relationships.

This research significantly contributes to the literature on BIMSTEC

countries by examining the intricate linkages among physical capital, human capital, and economic growth, especially within the framework of globalization. This article specifically investigates the moderating influence of globalization on economic growth, an area that has been insufficiently examined in the BIMSTEC setting, in contrast to prior studies that predominantly concentrated on the direct impacts of physical and human capital ([Iqbal et al., 2022](#)). This innovative method enhances comprehension of globalization's impact on the efficacy of both capital types in stimulating economic growth, delivering essential insights for policymakers in developing economies. Moreover, the results of this paper possess significant policy ramifications. By demonstrating that globalization diminishes the connection between physical and human capital and economic growth, we underscore the necessity for BIMSTEC nations to implement policies that enhance the synergies between globalization and capital accumulation. These measures are crucial for promoting sustainable economic development in a region characterized by different economic structures and differing developmental stages, where localized policies can profoundly influence growth trajectories ([Juknys et al., 2016](#); [Wang et al., 2023](#)).

The rest of the paper includes 'Literature review' in [section 2](#), 'Methodology' in [section 3](#), 'Results and Discussions' in [section 4](#), 'Conclusion' in [section 5](#).

2. Literature review

2.1. Physical capital and economic growth

The accumulation of physical capital is widely acknowledged as a critical driver of economic growth due to its ability to enhance productive capacity and strengthen economic infrastructure ([Sen, 2013](#)). The foundational Solow-Swan model posits that economic growth is primarily driven by capital and labor accumulation, alongside technological advancements ([Dykas et al., 2023](#)). In this model, physical capital—encompassing machinery, infrastructure, and equipment—acts as a fundamental input in the production process, facilitating efficiency and increased output ([Solow, 1956](#)).

Physical capital fosters economic growth through multiple mechanisms that enhance productivity, efficiency, and technological adoption across an economy ([Gong et al., 2012](#); [Li et al., 2015](#)). At its core, physical capital directly impacts production processes by allowing firms to produce more output with the same amount of labor, thus increasing productivity ([Solow, 1956](#)). Investments in advanced machinery or technology reduce labor requirements per unit of output, freeing up labor resources for other productive activities. This improves efficiency and productivity, increasing overall economic output and GDP growth ([Gardiner et al., 2012](#)).

Moreover, physical capital supports the development of a conducive environment for both domestic and foreign investments ([Casi &](#)

Resmini, 2017). Improved infrastructure facilitates trade by connecting markets domestically and internationally, which allows for economies of scale and better resource allocation (Bergstrand & Egger, 2007). Another crucial way physical capital drives economic growth is by enabling technology adoption and diffusion, especially in developing economies. When countries invest in modern equipment, they can more effectively implement new technologies that enhance productivity and foster innovation (Crespi & Zuniga, 2012).

For the BIMSTEC region, physical capital investment holds strategic importance in promoting economic integration and growth, as these nations work to build infrastructure that enhances connectivity and trade flows across borders (Hossain, 2023). Regional studies focusing on South and Southeast Asia underscore that existing infrastructure gaps limit growth potential; however, targeted investments in physical capital yield substantial multiplier effects on productivity and trade within the region (Wignaraja & Gatti, 2024).

Li et al. (2015) analyzed China's economic growth from 1981 to 2010 and found that physical and human capital played a key role, mainly due to capital accumulation and higher labor productivity. Loayza & Soto (2002) examined the growth experiences of developing countries and assert that strategic investment in infrastructure and productive assets can significantly bolster economic resilience and growth outcomes. Another empirical research by Ghura & Hadjimichael (1996) on African economies finds a positive correlation between capital formation in productive sectors and GDP growth rates, underscoring the impact of targeted physical capital investments on economic performance.

Thus, physical capital is essential for economic growth, as it boosts productivity and supports long-term development. Within the BIMSTEC context, where infrastructure and productive investment are prioritized to facilitate regional economic integration and cooperation, investment in physical capital represents a critical factor for fostering sustainable growth and enhancing economic stability across member nations. Given the existing studies, the following hypothesis therefore can be postulated:

H1. Physical capital positively and significantly influences economic growth in BIMSTEC regions.

2.2. Human capital and economic growth

Human capital drives economic growth, particularly through its role in enhancing productivity, innovation, and economic resilience (Ahmed et al., 2020). The theory of endogenous growth, as developed by Romer (1990) and Lucas (1988), posits that investments in human capital—such as education, health, and skill development—can lead to sustained economic growth by increasing the productivity of the workforce. Human capital enriches the capacity of individuals to generate new ideas and adapt to technological advancements, thereby fostering a self-reinforcing cycle of growth (David, 2000).

Barro (1991) and Mankiw et al. (1992) find that countries with higher levels of education and skill development tend to experience faster economic growth. These studies show that education boosts individual productivity and spreads knowledge across industries, which improves overall economic performance. The health component of human capital is also vital for economic growth, particularly in developing regions (Graff Zivin & Neidell, 2013). In a panel analysis, Pelinescu (2015) examined the role of human capital in driving economic growth, measured as gross domestic product (GDP) per capita. The model demonstrated a statistically significant and positive relationship between GDP per capita and key indicators of human capital: innovative capacity, as indicated by patent counts, and workforce qualifications, represented by secondary education levels. Mehrara & Musai (2013) explores the link between economic growth and human capital in developing countries, specifically looking at how education affects GDP from 1970 to 2010. Using panel data methods, including unit root and cointegration tests, the findings show that investment and economic

growth significantly influence education, but education does not have a notable impact on GDP or investment in the short or long term. This implies that in these nations, economic expansion and capital investment drive educational progress rather than education driving economic growth.

Moreover, human capital plays a key role in spreading technological innovation, helping developing economies modernize industries and improve competitiveness (Das & Drine, 2020). It serves as a bridge, helping countries utilize global knowledge and drive regional economic growth (Asongu & Tchamyou, 2020). In light of this, BIMSTEC nations must make strategic investments in education, health, and skill development to ensure long-term growth and economic resilience. Given the existing studies, the following hypothesis can be postulated:

H2. Human capital positively and significantly influences economic growth in BIMSTEC regions.

2.3. Moderating effects of globalization

Globalization can strengthen the relationship between physical capital and economic growth by facilitating the flow of resources, technology, and investments across borders (Coulialy et al., 2018; Grossman & Helpman, 2015). Through globalization, countries gain access to advanced technologies and capital goods that can improve the productivity of physical capital, such as machinery, infrastructure, and equipment (Sachs, 2000). This increased efficiency leads to higher output and stimulates economic growth.

Moreover, globalization opens up larger markets for goods and services and allows economies to achieve economies of scale and increase returns on physical capital (Mukherjee, 2018). Foreign direct investment (FDI), a key aspect of globalization, provides essential capital and knowledge transfer, particularly in developing countries. It leads to further enhancements in the productivity of physical capital (Latif et al., 2018). By integrating with the global economy, countries can accelerate innovation, attract investments that modernize their infrastructure, and improve the overall economic efficiency of physical capital, thereby fostering sustainable growth (Shabir, 2024).

Similarly, globalization can enhance the relationship between human capital and economic growth by facilitating knowledge transfer, technological advancements, and access to global markets (Jahanger et al., 2022). Through globalization, countries gain greater exposure to advanced technologies and innovative practices. It leads to the development of more productive and skilled workforces (Beliz et al., 2019). This exposure helps improve labor productivity, as seen in developing nations where workers adapt to the technology and skills of advanced economies, fostering productivity gains (Ra et al., 2019).

Globalization also causes increased mobility of labor and the diffusion of education and training standards across borders (Bound et al., 2021). This mobility leads individuals to acquire skills from more developed countries and bring this expertise back home, which creates a feedback loop that strengthens local human capital. Additionally, international trade and foreign direct investment (FDI) contribute to economic growth by creating more jobs and improving the demand for skilled labor (Nguyen, 2020). As human capital expands and adapts through global integration, it fosters a more competitive economy and higher GDP growth (Osiobe, 2019). Thus, the following hypothesis can be postulated:

H3. Globalization strengthens the relationship between physical capital and economic growth in BIMSTEC regions.

H4. Globalization strengthens the relationship between human capital and economic growth in BIMSTEC regions.

Based on the review of related studies, this study develops Fig. 1 as a conceptual model.

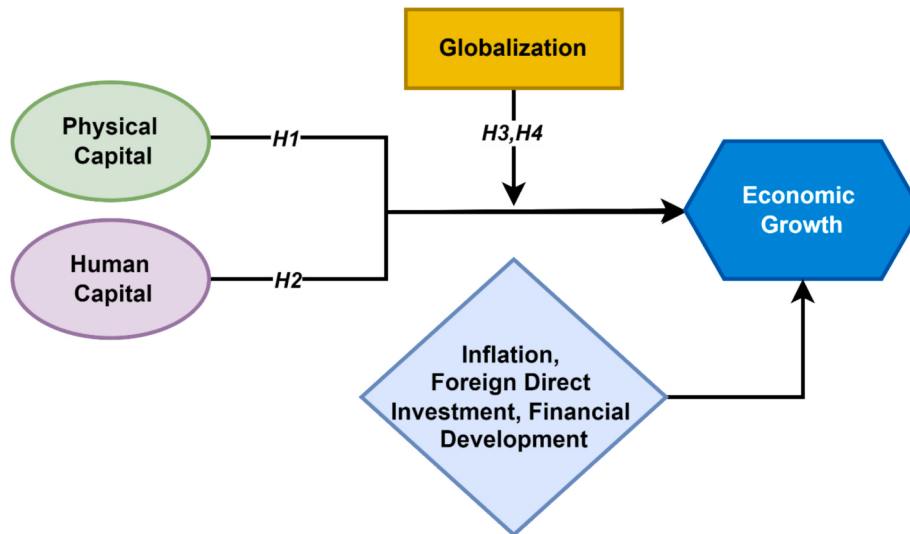


Fig. 1. Conceptual model of the study.

3. Methods

3.1. Data and variables

This study analyzes the synergy between globalization, physical capital, and human capital, and their collective influence on economic growth in BIMSTEC countries over the period 1990–2019. The dataset comprises annual panel data sourced from reputable databases, ensuring consistency and reliability. The key variables include economic growth, physical capital, human capital, and globalization, supplemented by relevant control variables such as inflation, foreign direct investment, and global financial development.

Economic growth (ECGR) is the dependent variable and is measured as annual GDP in constant 2015 US dollars, extracted from the World Development Indicators (WDI) database. It serves as the proxy for assessing economic performance across the BIMSTEC nations. Physical capital (PCAP), a critical determinant of economic output, is represented by the share of gross capital formation at current purchasing power parities (PPPs). Data for physical capital are sourced from the Penn World Table (PWT 10.01). Human capital (HCAP) reflects the role of education in fostering economic growth. This variable is measured using the gross enrollment ratio in secondary education (%) and is obtained from the WDI database. GLBN captures the multidimensional impact of globalization. The KOF Globalization Index, which incorporates economic, social, and political dimensions, is used to measure this variable. Data are accessed from the WDI database.

In addition to the key variables, the study incorporates the following control variables to address potential confounding factors: INFL is measured by the annual percentage change in consumer prices, inflation data is sourced from the WDI database. This variable accounts for macroeconomic stability in the analysis. FDIN is representing the inflow of FDI, this variable is measured in net balance of payments (BoP) terms at current US dollars, sourced from the WDI. GFDV variable, measured by liquid liabilities in millions of constant 2010 US dollars, serves as a proxy for financial market maturity. Data for this variable are extracted from the WDI. Table 1 provides a detailed overview of the variables, their definitions, measurement approaches, and data sources, ensuring transparency in the data collection process.

3.2. Theory and model specification

This study is based on the neoclassical growth model developed by Mankiw which includes human capital as a determinant of economic

Table 1

Sign, measurement, and sources of variables.

Sign	Variables	Measurement	Sources
Key variables			
ECGR	Economic growth	Annual GDP (constant 2015 US\$)	WDI
PCAP	Physical capital	Share of gross capital formation at current PPPs	PWT 10.01
HCAP	Human capital	School enrollment, secondary (% gross)	WDI
GLBN	Globalization	The KOF Globalisation Index measures the economic, social, and political dimensions of globalization.	WDI
Control variables			
INFL	Inflation	Inflation, consumer prices (annual %)	WDI
FDIN	Foreign direct investment	Foreign direct investment, net (BoP, current US\$)	WDI
GFDV	Global financial development	Liquid liabilities in millions (constant 2010 US\$)	WDI

growth. It starts from a Cobb–Douglas production function:

$$Y_{it} = K_{it}^{\alpha} H_{it}^{\beta} (A_{it} L_{it})^{1-\alpha-\beta}, \quad (1)$$

This function considers four factors of production: physical capital (K), human capital (H), labor (L), and level of technology (A).

■ Basic model:

$$ECGR = f(PCAP, HCAP, GLBN, INFL, FDIN, GFDV) \quad (2)$$

Specific models

■ Model-1:

$$ECGR_{it} = C_{it} + \beta_1 PCAP_{it} + \beta_2 GLBN_{it} + \beta_3 INFL_{it} + \beta_4 FDIN_{it} + \beta_5 GFDV_{it} + \varepsilon_{it} \quad (3)$$

■ Model-2:

$$ECGR_{it} = C_{it} + \beta_1 HCAP_{it} + \beta_2 GLBN_{it} + \beta_3 INFL_{it} + \beta_4 FDIN_{it} + \beta_5 GFDV_{it} + \varepsilon_{it} \quad (4)$$

■ Model-3:

$$ECGR_{it} = C_{it} + \beta_1 PCAP_{it} + \beta_2 PCAP_{it} \times GLBN_{it} + \beta_3 GLBN_{it} + \beta_4 INFL_{it} + \beta_5 FDIN_{it} + \beta_6 GFDV_{it} + \varepsilon_{it} \quad (5)$$

■ Model-4:

$$ECGR_{it} = C_{it} + \beta_1 HCAP_{it} + \beta_2 HCAP_{it} \times GLBN_{it} + \beta_3 GLBN_{it} + \beta_4 INFL_{it} + \beta_5 FDIN_{it} + \beta_6 GFDV_{it} + \varepsilon_{it} \quad (6)$$

■ Model-5 (final combined model):

$$ECGR_{it} = C_{it} + \beta_1 PCAP_{it} + \beta_2 HCAP_{it} + \beta_3 PCAP_{it} \times GLBN_{it} + \beta_4 HCAP_{it} \times GLBN_{it} + \beta_5 GLBN_{it} + \beta_6 INFL_{it} + \beta_7 FDIN_{it} + \beta_8 GFDV_{it} + \varepsilon_{it} \quad (7)$$

Here, the subscripts *i* and *t* represent the cross-sectional units (countries) and time periods (years), respectively. Economic growth serves as the dependent variable across equations (2) through (7). The key independent variables are physical capital (PCAP), human capital (HCAP), and Globalization (GLBN). Foreign direct investment (FDIN), inflation (INFL), and global financial development (GFDV) are the control variables. Finally, *c* is the constant, β denotes the coefficients of the explanatory variables, ' $\times$ ' indicates interaction term, and ε is the error term.

4. Results and Discussions

4.1. Descriptive statistics and correlations

Table 2 delineates the summary statistics of the examined factors for BIMSTEC nations from 1990 to 2019. The average values reflect modest levels of economic growth (24.47), physical capital (24.68), and globalization (43.86), whereas human capital (59.04) exhibits greater variability. Inflation demonstrates the greatest volatility (SD = 7.69), with a peak of 57.07 and a trough of -0.90, indicating economic instability at some intervals. The skewness and kurtosis data demonstrate that ECGR and INFL exhibit significant skewness and leptokurtosis, indicating pronounced variations. Conversely, other variables display approximately normal distributions, characterized by modest skewness and significant kurtosis. These figures underscore the varied economic realities across the BIMSTEC area.

4.2. Correlation analysis

Table 3 displays the correlation analysis of the examined variables, indicating the strength and direction of their linear correlations. The findings demonstrate that all correlation coefficients are below 0.90, indicating a lack of multicollinearity among the variables. ECGR exhibits a significant positive correlation with globalization (0.57), foreign direct investment (0.68), and global financial development (0.770), although its correlation with physical capital (-0.24) and human capital (0.28) is comparatively less. The correlations among the remaining

variables are likewise low to moderate, with no evidence of high collinearity. Moreover, the Variance Inflation Factor (VIF) values remain below 3, substantiating the assertion that multicollinearity is not an issue. The results validate the appropriateness of the variables for regression analysis, as they exhibit minimal interdependence (see Fig. 2 for scatterplot matrix).

4.3. Cross-sectional dependency, stationarity, and cointegration

Table 4 displays the outcomes of the cross-sectional dependence (CSD) tests for the examined variables, evaluating the presence of unobserved common components or interdependencies within the panel data. The assessments comprise the Breusch-Pagan LM (BP-LM), Pesaran Scaled LM (PS-LM), Bias-Corrected Scaled LM (BCS-LM), and Pesaran CD (PCD) exams.

The Breusch-Pagan LM test assesses cross-sectional dependence by aggregating the squared pairwise correlation coefficients of residuals over all cross-sectional units. The formula is:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^N T \rho_{ij}^2$$

Where, ρ_{ij} pairwise correlation coefficient of residuals between units *i* and *j*. *N* is the number of cross-sectional units, and *T* is the time periods.

The Pesaran Scaled LM test adjusts the BP-LM test by scaling it to address challenges in extensive panels. The formula is:

$$LM_{PS} = \frac{1}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \sqrt{T} \rho_{ij}^2$$

The Bias-Corrected The Scaled LM test modifies the PS-LM test to account for bias in finite samples, particularly when both *T* and *N* are substantial. The equation is as follows:

$$LM_{BCS} = \frac{1}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \sqrt{T} (\rho_{ij}^2 - \frac{1}{T})$$

The Pesaran CD test directly assesses the mean correlation of residuals, particularly useful for panels where *T* is minimal in comparison to *N*. The formula is:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \rho_{ij}$$

All variables—ECGR, PCAP, HCAP, GLBN, INFL, FDIN, and GFDV—exhibit very significant test statistics (p-value = 0.000), signifying robust cross-sectional dependence. This highlights the importance of utilizing a stationarity test for subsequent econometric models.

Table 5 displays the stationarity results derived from second-generation unit root tests, specifically the Cross-Sectionally Augmented IPS (CIPS) and Cross-Sectionally Augmented Dickey-Fuller (CADF) tests, which consider cross-sectional dependence in panel data. The CADF test utilizes cross-sectional averages of the variable and its lagged values to mitigate cross-sectional dependence. The formula for the examination is:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \gamma_i \bar{y}_{t-1} + \sum_{j=1}^{\varphi} \phi_{ij} \Delta y_{it-1} + \varepsilon_{it}$$

Where, y_{it} is the variable of interest for cross-sectional unit *i* at time *t*, $\bar{y}_{t-1}$ is the cross-sectional average of y_{it-1} , Δ is the first difference operator, φ is the optimal lag length, and ε_{it} is the error term. The null hypothesis (H_0) is that y_{it} has a unit root ($\beta_i=0$), while the alternative hypothesis (H_a) is that y_{it} is stationary ($\beta_i < 0$).

The CIPS test broadens the CADF methodology for panel data by averaging the CADF test statistics over all cross-sectional units. The CIPS statistic is calculated as follows:

Table 2

Summary statistics of the investigated variables.

	ECGR	PCAP	HCAP	GLBN	INFL	FDIN	GFDV
Mean	24.47	24.68	59.04	43.86	8.27	19.44	10.26
Maximum	28.58	51.83	130.93	73.43	57.07	24.65	14.57
Minimum	1.90	5.65	0.05	21.46	-0.90	10.82	4.45
SD	2.63	9.06	24.87	13.75	7.69	2.90	2.48
Skewness	-3.14	0.58	0.27	0.22	3.10	-0.36	-0.37
Kurtosis	27.20	3.66	2.84	2.03	16.11	2.50	2.44

Table 3
Analysis of correlation between the investigated variables.

	ECGR	PCAP	HCAP	GLBN	INFL	FDIN	GFDV	VIF
ECGR	1.00	−0.24***	0.28***	0.57***	−0.16**	0.68***	0.70***	1.112
PCAP		1.00	0.08	0.11	−0.38***	−0.10	−0.29***	1.215
HCAP			1.000	0.79***	−0.29***	0.48***	0.31***	1.267
GLBN				1.00	−0.38***	0.75***	0.61***	2.124
INFL					1.00	−0.11	0.00	1.563
FDIN						1.00	0.87***	2.334
GFDV							1.00	1.549

Note: ***= $p < 0.01$, **= $p < 0.05$, *= $0 < 0.1$.

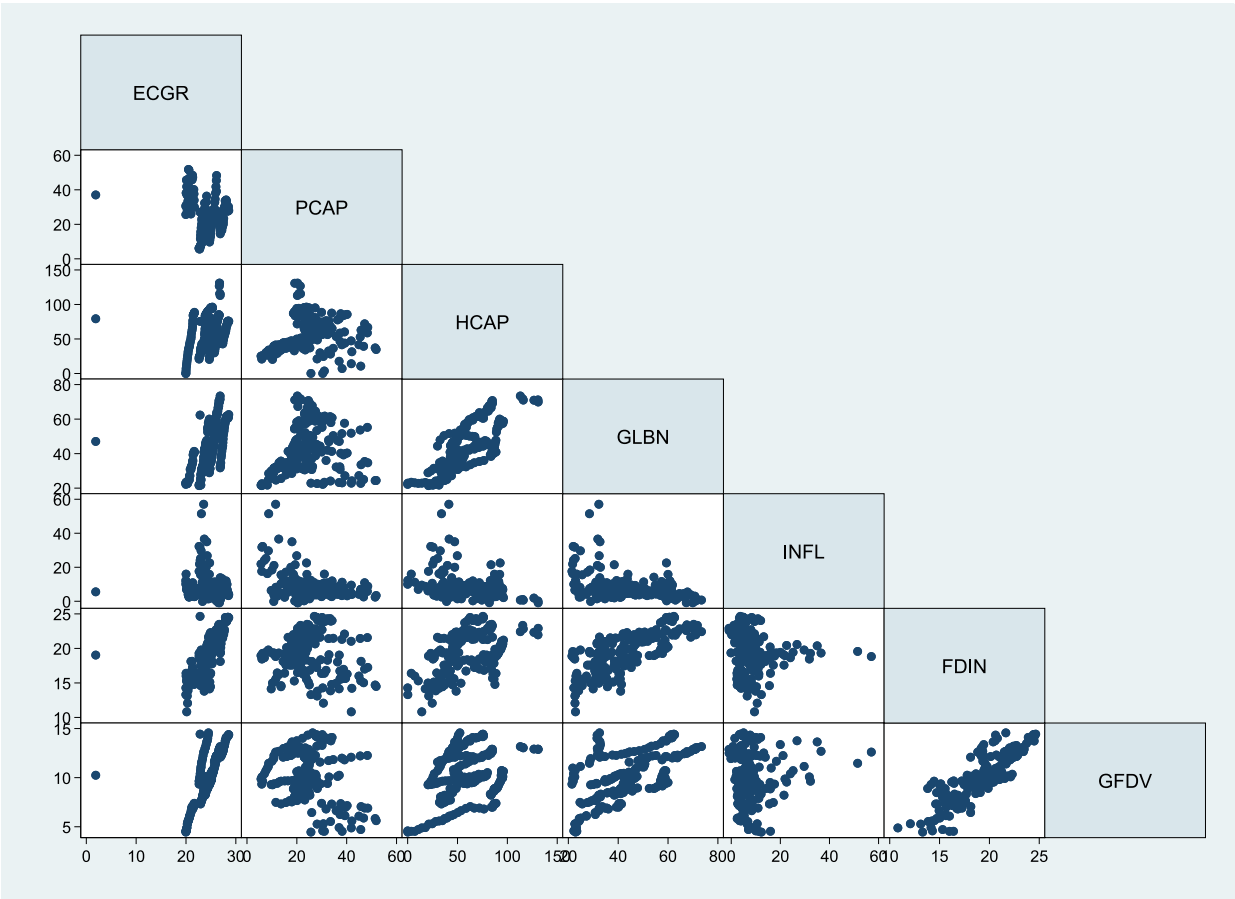


Fig. 2. Scatter matrix.

Table 4
CSD test of the investigated variables.

Variables		BP-LM	PS-LM	BCS-LM	PCD
ECGR	Stat.	333.708	48.252	48.131	13.001
	p-value	0.000	0.000	0.000	0.000
PCAP	Stat.	233.319	32.762	32.641	6.189
	p-value	0.000	0.000	0.000	0.000
HCAP	Stat.	529.106	78.402	78.282	22.977
	p-value	0.000	0.000	0.000	0.000
GLBN	Stat.	528.872	78.366	78.246	22.957
	p-value	0.000	0.000	0.000	0.000
INFL	Stat.	114.087	14.364	14.243	8.515
	p-value	0.000	0.000	0.000	0.000
FDIN	Stat.	248.910	35.167	35.047	14.679
	p-value	0.000	0.000	0.000	0.000
GFDV	Stat.	425.076	62.350	62.230	17.873
	p-value	0.000	0.000	0.000	0.000

Note: BP = Breusch Pagan LM, PS=Pesaran Scaled LM, BCS = Bias Corrected Scaled LM, PCD=Pesaran CD.

Table 5
Stationarity test using CIPS and CADF.

Variables	CIPS		CADF	
	t-value	p-value	t-value	p-value
ECGR	−1.982	≥ 0.10	−3.672	≤ 0.05
PCAP	−2.647	≤ 0.01	−3.692	≤ 0.05
HCAP	−0.150	≥ 0.10	−2.859	≥ 0.10
GLBN	−2.107	≥ 0.10	−3.439	≤ 0.05
INFL	−2.311	≤ 0.10	−4.938	≤ 0.01
FDIN	−2.351	≤ 0.10	−4.731	≤ 0.01
GFDV	−2.573	≥ 0.10	−3.959	≤ 0.05

$$CIPS = \frac{1}{N} \sum_{i=1}^N CADF_i$$

Where, N is the number of cross-sectional units, and $CADF_i$ is the test statistic from the CADF test for unit i. The null hypothesis (H_0) is that all series have a unit root, while the alternative hypothesis (H_a) is that at

least some series are stationary.

Table 5 demonstrates that all variables are stationary at level according to both tests. Both tests ascertain that ECGR, PCAP, HCAP, GLBN, INFL, FDIN, and GFDV lack unit roots. The findings indicate that the dataset is appropriate for econometric analysis without necessitating differencing or manipulation to attain stationarity.

Table 6 presents the findings of the Pedroni and Westerlund cointegration tests, which assess the existence of a long-term link among the variables. The Pedroni test, a first-generation cointegration assessment, yields significant outcomes for both the Panel v-Statistic (18.095, $p = 0.000$) and the Panel ADF-Statistic (-2.299 , $p = 0.012$), demonstrating evidence of cointegration. Likewise, the Westerlund test, a second-generation cointegration test that considers cross-sectional dependence, produces a significant test statistic (4.129, $p = 0.000$), so reinforcing the presence of a long-run link. The consistent results from both rounds of cointegration tests confirm the existence of cointegration, hence legitimizing the application of cointegrated regression models such as FMOLS or DOLS for subsequent study.

4.4. Long-run estimations

The Fully Modified Ordinary Least Squares (FMOLS) approach is employed for long-term estimations as it efficiently mitigates endogeneity and serial correlation in cointegrated panel data, hence yielding reliable and unbiased coefficient estimates (Rahman et al., 2024a). Given the long-run cointegration evidenced in Table 6, FMOLS is an appropriate technique for examining the relationships among variables. FMOLS does this by incorporating non-parametric modifications to mitigate any feedback effects between independent variables and the error term, while also rectifying serial correlation within the residuals. All models exhibit R-squared values exceeding 50%, indicating moderate to strong explanatory power.

The empirical results demonstrate that both physical and human capital positively affect economic growth across all model specifications (Model A–E), underscoring the essential role of capital accumulation and human resource development in fostering economic prosperity in the BIMSTEC area. The substantial positive influence of globalization on ECGR indicates that more integration into global markets promotes economic growth, likely via improved trade, technology transfer, and foreign investments. The interaction terms $PCAP \times GLBN$ and $HCAP \times GLBN$ demonstrate negative impacts on ECGR, suggesting that globalization diminishes the growth-promoting function of both physical and human capital. This may be ascribed to factors including heightened foreign rivalry, capital outflows, or a disparity between indigenous capabilities and global market requirements. Globalization may contribute to brain drain, weakening the domestic pool of skilled labor. Likewise, foreign direct investments and external economic dependencies may constrain the domestic use of physical capital, diminishing its impact on long-term growth. These findings underscore the intricate relationship between globalization and economic development, indicating that although globalization promotes growth, it may simultaneously impose structural limitations that hinder the efficacy of domestic capital and labor resources.

Table 6
Cointegration test of Pedroni and Westerlund.

Tests	Statistic	Prob.
Pedroni		
Panel v-Statistic	18.095	0
Panel ADF- taticistic	-2.299	0.012
Westerlund		
Test statistic	4.129	0.000

4.5. Robustness check

4.5.1. DOLS

Robustness checks are crucial in empirical analysis to confirm the dependability and consistency of results across various estimating methods, ensuring that the conclusions are not contingent upon the selected approach (Huang et al., 2024). To validate the robustness of the findings derived from FMOLS in Table 7, we utilize the Dynamic Ordinary Least Squares (DOLS) approach in Table 8, which accounts for endogeneity and serial correlation by incorporating leads and lags of the independent variables. The DOLS results corroborate the FMOLS findings, indicating persistent beneficial impacts of GLBN on ECGR and analogous moderating effects of GLBN on the interactions between PCAP, HCAP, and ECGR. The consistency among methodologies enhances the validity of the analysis, instilling higher confidence in the conclusions on the dynamics of economic growth in the examined setting.

4.5.2. ARDL

The utilization of the Autoregressive Distributed Lag (ARDL) model facilitates a comprehensive analysis of the short-run and long-run interactions among the variables (refer to Table 9). The findings demonstrate that whereas physical capital, human capital, and globalization favorably affect long-term economic growth, the interaction terms ($PCAP \times GLBN$ and $HCAP \times GLBN$) show negative impacts, aligning with prior estimates. In the short term, no significant connections were detected, indicating that the growth consequences of capital accumulation, human capital, and globalization manifest over time rather than producing instant effects. This discovery highlights the necessity of continuous investments in capital and workforce development, alongside strategic globalization policies, to attain enduring economic success in the BIMSTEC region.

4.6. Granger causality test

The Granger causality test outcomes presented in Table 10 indicate substantial causal linkages between critical variables and economic growth in the BIMSTEC region. A bi-directional causation ($\leftrightarrow$) exists

Table 7
Long-run estimations using FMOLS.

Variables	Model-A	Model-B	Model-C	Model-D	Model-E
PCAP	0.084*** [0.022]		0.035 [0.035]		0.038 [0.035]
HCAP		0.052*** [0.011]		0.010 [0.016]	0.022* [0.012]
$PCAP \times GLBN$			-0.001* [0.001]		-0.002*** [0.001]
$HCAP \times GLBN$				0.000 [0.000]	-0.001*** [0.000]
GLBN	0.011 [0.018]	-0.012 [0.019]	0.084*** [0.024]	0.075*** [0.033]	0.170*** [0.037]
INFL	-0.101*** [0.040]	-0.068 [0.053]	-0.012 [0.012]	-0.013 [0.015]	-0.012 [0.012]
FDIN	-0.093 [0.057]	0.029 [0.034]	-0.026 [0.072]	-0.066 [0.092]	-0.020 [0.071]
GFDV	-0.021* [0.013]	-0.031*** [0.013]	-0.080 [0.098]	-0.102 [0.130]	-0.089 [0.098]
Diagnostic tests					
R-squared	0.542	0.532	0.642	0.641	0.647
Adjusted R-squared	0.515	0.505	0.620	0.618	0.621
Long-run variance	2.236	2.214	0.925	1.552	0.868
Countries	7	7	7	7	7

Note: ***= $p < 0.01$, **= $p < 0.05$, *= $p < 0.1$. Standard errors in the parenthesis.

Table 8
Robustness check using DOLS.

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
PCAP	0.008 [0.007]		0.023 [0.028]		0.039 [0.055]
HCAP		0.002 [0.003]		0.013*** [0.007]	0.021 [0.019]
PCAP × GLBN			0.000 [0.001]		−0.002 [0.001]
HCAP × GLBN				0.000* [0.000]	−0.001 [0.000]
GLBN	0.034*** [0.010]	0.023*** [0.010]	0.046*** [0.018]	0.046*** [0.017]	0.150*** [0.059]
INFL	−0.016 [0.010]	−0.014* [0.009]	−0.015* [0.009]	−0.015* [0.009]	−0.014 [0.020]
FDIN	0.018 [0.049]	0.049 [0.042]	0.012 [0.055]	0.022 [0.046]	−0.019 [0.116]
GFDV	0.169** [0.085]	0.184*** [0.074]	0.111 0.077	0.089 [0.076]	−0.072 [0.162]
Diagnostic tests					
R-squared	0.637	0.639	0.638	0.641	0.655
Adjusted R-squared	0.617	0.619	0.616	0.619	0.630
Long-run variance	2.511	2.508	2.496	2.485	2.428
Countries	7	7	7	7	7

Note: ***=p < 0.01, **=p < 0.05, *=0 < 0.1. Standard errors in the parenthesis.

between physical capital and economic growth, suggesting that capital accumulation and economic expansion mutually support one another. Global financial development and ECGR demonstrate bi-directional

causality, indicating that the expansion of the financial sector both propels and is affected by economic growth. A unidirectional causality (→) exists from globalization to ECGR, indicating that globalization substantially influences economic growth, but not the other way around. Furthermore, ECGR Granger-causes human capital, inflation, and foreign direct investment; however, these variables do not significantly influence ECGR, indicating that economic growth is pivotal in determining investment, human capital advancement, and macroeconomic stability. These findings underscore the interrelatedness of capital, finance, and globalization in influencing long-term growth dynamics in the region.

4.7. Discussions

Table 11 provides a detailed discussion of the hypothesized relationships between ECGR and key variables, including their direct effects and interaction terms. The results reveal mixed support for the hypotheses, highlighting nuanced dynamics within the studied relationships.

Our research substantiates that physical capital (PCAP) exerts a positive influence on economic growth (ECGR) in BIMSTEC nations, consistent with the extensive literature highlighting capital accumulation as a crucial catalyst for economic advancement. Kumar et al. (2023) establish a robust correlation between foreign direct investment (FDI) and economic growth in BIMSTEC nations, indicating that augmented capital inflows, particularly physical capital, stimulate GDP growth. Moreover, Uneze (2013) endorses the concept of a bi-directional causal

Table 9
Robustness check using ARDL.

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
Long-run coefficients					
PCAP	0.006*** [0.002]		0.036* [0.020]		0.064*** [0.029]
HCAP		0.000 [0.001]		−0.004 [0.005]	−0.008 [0.007]
PCAP × GLBN			−0.001** [0.001]		−0.002*** [0.001]
HCAP × GLBN				0.000 [0.000]	0.000 [0.000]
GLBN	0.026*** [0.004]	0.017*** [0.003]	0.023*** [0.010]	0.015** [0.007]	−0.005 [0.020]
INFL	−0.027*** [0.004]	−0.023*** [0.004]	−0.010 [0.006]	−0.022*** [0.006]	0.011 [0.012]
FDIN	−0.007 [0.009]	0.007 [0.006]	−0.016 [0.020]	−0.003 [0.021]	0.002 [0.031]
GFDV	0.306*** [0.036]	0.364*** [0.024]	0.522*** [0.062]	0.579*** [0.042]	1.191*** [0.108]
Constant	21.087*** [0.254]	20.651*** [0.152]	18.845*** [0.646]	18.580*** [0.322]	14.438*** [0.922]
Short-run coefficients					
D(PCAP)	0.021* [0.012]		−0.111* [0.065]		0.037 [0.034]
D(HCAP)		0.061 [0.048]		−0.631 [0.552]	−0.310 [0.237]
D(PCAP) × D(GLBN)			0.003* [0.001]		0.000 [0.001]
D(HCAP) × D(GLBN)				0.019 [0.017]	0.010 [0.008]
D(GLBN)	0.257 [0.195]	0.274 [0.214]	0.177 [0.145]	−0.548 [0.541]	−0.113 [0.094]
D(INFL)	−0.011 [0.008]	−0.017 [0.014]	−0.018 [0.013]	−0.033 [0.030]	0.001 [0.002]
D(FDIN)	−0.126 [0.104]	−0.160 [0.132]	−0.070 [0.055]	−0.122 [0.100]	−0.097 [0.089]
D(GFDV)	0.006 [0.201]	0.490 [0.481]	−0.769 [0.772]	1.396 [1.470]	0.657 [1.057]
ECT	0.194 [0.286]	0.311 [0.455]	0.434 [0.467]	2.107 [2.257]	0.710 [0.686]
Log-Likelihood	263.750	241.665	278.117	235.846	285.564

Note: ***=p < 0.01, **=p < 0.05, *=0 < 0.1. Standard errors in the parenthesis.

Table 10
Causality test.

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Decision
PCAP does not homogeneously cause ECGR	4.48	2.52	0.01	PCAP ↔ ECGR
ECGR does not homogeneously cause PCAP	8.14	6.53	0.00	
HCAP does not homogeneously cause ECGR	1.37	−0.90	0.37	HCAP ↔ ECGR
ECGR does not homogeneously cause HCAP	5.64	3.79	0.00	
GLBN does not homogeneously cause ECGR	5.36	3.48	0.00	GLBN → ECGR
ECGR does not homogeneously cause GLBN	2.72	0.58	0.56	
INFL does not homogeneously cause ECGR	2.23	0.05	0.96	INFL ↔ ECGR
ECGR does not homogeneously cause INFL	7.22	5.52	0.00	
FDIN does not homogeneously cause ECGR	1.87	−0.36	0.72	FDIN ↔ ECGR
ECGR does not homogeneously cause FDIN	10.95	9.52	0.00	
GFDV does not homogeneously cause ECGR	6.60	4.84	0.00	GFDV ↔ ECGR
ECGR does not homogeneously cause GFDV	4.34	2.36	0.02	

Note: → and ↔ indicates uni-directional, and bi-directional effects, respectively.

relationship between capital formation and economic growth, substantiating the assertion that increased capital accumulation results in improved economic performance.

Our research substantiates that human capital exerts a positive influence on economic growth in BIMSTEC nations, consistent with a substantial body of literature highlighting the significance of skilled workers in economic advancement. Liu & Agbola (2014) illustrate that in China's electronics sector, human capital is a crucial catalyst for economic growth across diverse locations, underscoring the importance of a well-educated and competent workforce in enhancing economic performance. Rao & Vadlamannati (2010) demonstrate that human capital significantly influences both the level and growth effects of economic development in India, indicating that investments in education and skills are directly related to economic outcomes. Diebolt & Hippe (2018) emphasize the importance of human capital in promoting innovation and sustained economic growth in European regions, suggesting that economies with greater human capital reserves generally attain superior economic performance.

Our findings indicate that globalization adversely moderates the relationship between both capital (physical and human) and economic growth in BIMSTEC countries, aligning with research that emphasizes a diminishing return on physical capital investment as globalization elevates the significance of human capital. Çepni et al. (2019) examine a nonlinear correlation between inequality and economic growth, positing that globalization, by augmenting the ratio of human capital to physical capital, may lessen the efficacy of physical capital in stimulating growth, resulting in diminishing returns. It is crucial to acknowledge that Uddin (2020), who examines the correlation between financial development and environmental sustainability, does not endorse the assertion that globalization undermines the physical capital-growth connection and

should consequently not be referenced in this context. Conversely, certain research indicate that globalization may strengthen the correlation between physical capital and economic growth. Shahbaz et al. (2018) demonstrate that foreign capital inflows, frequently enabled by globalization, can enhance physical capital accumulation, hence promoting economic growth. Akalpler (2023) posits that globalization can enhance physical capital accumulation and stimulate economic growth under certain situations, however the exact mechanisms are not well-defined. Our findings, however, corroborate the prevailing perspective that globalization diminishes the favorable correlation between capital (physical and human) and economic growth in BIMSTEC nations, probably owing to the rising significance of human capital and the intricate dynamics engendered by global economic integration.

4.8. Policy implications

According to the findings, globalization weakens the positive impact of human and physical capital on economic growth in the BIMSTEC nations. Therefore, policymakers must take strategic steps to maximize the positive impact of capital investment while reducing negative impacts from globalization.

- **Strengthening domestic industries:** In this regard, governments should introduce tax incentives and investment-friendly regulations that would ensure companies reinvest their profits in their home countries instead of transferring them abroad. This will help strengthen domestic industries and create more job opportunities in the country.
- **Supporting SMEs:** Additionally, many small and medium-sized enterprises (SMEs) find it difficult to compete with multinational companies. Hence, providing financial support, skill development programs, and improved market access can help them expand and make greater economic impact.
- **Managing capital outflows:** Another important step is to reduce capital outflows. Foreign businesses that operate in BIMSTEC nations frequently repatriate their profits, which reduces the returns on their investments. Governments can tackle this by adopting policies that encourage reinvestment and promote partnerships between local and international firms.
- **Retaining skilled labor:** Similarly, it is crucial to retain skilled workers, as many talented professionals leave BIMSTEC countries in search of better opportunities abroad. Governments should improve wages, working conditions, and career development opportunities to prevent the brain drain in the region.
- **Improving Technology and Education:** Enhancing education and training systems should be another major focus. Education needs to adapt to the evolving nature of the labor market by emphasizing entrepreneurship, digital skills, and vocational training. This will lower unemployment and help individuals find better jobs. Furthermore, rather than largely relying on foreign technology, BIMSTEC nations need to invest in technical independence. Supporting local technological development, innovation, and research may stimulate economies and promote sustainable growth.
- **Balancing growth and globalization:** Finally, it is crucial to find a balance between domestic economic growth and globalization. Despite the fact that globalization has numerous

Table 11
Discussion of the hypothesis.

Hypothesis	Relationships	Expected direction	Result Direction	Test	Decision
H1	Physical capital → Economic growth	Positive	Positive	Significant	Supported
H2	Human capital → Economic growth	Positive	Positive	Significant	Supported
H3	Physical capital × Globalization → Economic growth	Positive	Negative	Significant	Not supported
H4	Human capital × Globalization → Economic growth	Positive	Negative	Significant	Not supported

benefits, trade agreements and foreign investments should be planned to protect domestic businesses and employees. Governments need to make sure that foreign alliances and economic policies benefit, rather than harm, local industries.

By implementing these strategies into practice, BIMSTEC nations can manage challenges brought on by globalization while optimizing the advantages of human and physical capital. These measures will help create a more resilient and sustainable economic future for the region.

5. Conclusion, Implications, and limitations

5.1. Conclusion

This study offers an exhaustive examination of the correlation among globalization, human capital, physical capital, and economic growth in BIMSTEC nations. The findings underscore the intricate, context-dependent character of these interactions, illustrating that globalization can simultaneously enhance and diminish the influence of human capital and physical capital on economic growth, contingent upon particular regional and economic circumstances. The study confirms that human capital is a crucial catalyst for economic progress, especially in a globalized environment. The effectiveness of human capital investment is determined by the broader economic context shaped by globalization, which includes market integration, technology advancement, and institutional determinants. The study emphasizes globalization's dual role in shaping the relationship between human (physical) capital and growth. Globalization can boost human capital productivity by enabling technology transfer, promoting innovation, and granting access to global markets and talent pools. Conversely, globalization may generate competitive pressures that reduce the returns on human capital investment, particularly in contexts where the economy has not adequately adapted to global trends or if institutional frameworks are deficient.

This study enhances the existing literature on economic development in emerging economies, specifically within the BIMSTEC region. The findings highlight the intricate relationship between globalization and human (physical) capital, indicating that policymakers and corporate leaders must implement more refined, context-specific strategies to utilize human and physical capital for promoting sustainable economic growth. Subsequent research ought to further investigate these links, with special emphasis on sectoral variances and the changing significance of human capital across various phases of economic development. This study offers significant insights that can guide the formulation of policies to enhance the advantages of globalization while alleviating its possible negative impacts on economic growth in BIMSTEC nations.

5.2. Managerial and theoretical implications

The theoretical significance of this study provides new insight into the growth dynamics of the BIMSTEC region. By incorporating the moderating effect of globalization in the relationship between physical capital, human capital, and economic growth, this study extends the traditional growth model. It shows that both PCAP and HCAP are positively related to ECGR but the interaction between them and globalization is negatively related. This contradicts the conventional view that globalization strengthens the effect of physical and human capital on growth in certain regional contexts. This finding emphasizes the need to consider globalization as a moderating variable in the growth model especially in regions facing structural challenges. Moreover, this study demonstrates the usefulness of advanced econometrics in understanding how interconnected economies function and how globalization shapes the growth process.

Since both physical capital and human capital positively affect economic growth within the BIMSTEC region, managers should focus on investing in equipment, infrastructure, and employee training to drive

growth. Also, companies should refrain from depending excessively on foreign markets since globalization reduces the benefit of these investments. They should instead build strong local supply chains and strengthen industries to mitigate external risks. Also, to cope with financial instability, currency fluctuations, and changes in trade policy brought about by globalization, businesses in BIMSTEC countries need to concentrate on risk management. Stability can be maintained by diversifying markets and investments. Furthermore, working with governments to formulate policies that support them will ensure that globalization supports local companies and encourages long-term development.

This study underscores the significance of incorporating both local and global components in the examination of economic growth, indicating that the influence of human capital is dynamic and dependent upon the degree of globalization. The research contests conventional theories that regard human capital as an isolated element in growth, prompting scholars to acknowledge the intermediary role of globalization in influencing the efficacy of human capital investments. The research underscores the necessity for a more comprehension of globalization's effects on developing nations, indicating that these effects may range markedly across various stages of economic growth.

Limitations

The following constraints must be recognized. The analysis utilizes secondary data from current sources, which may be prone to discrepancies or reporting biases, particularly in emerging nations where data gathering methods can differ. The investigation centers on BIMSTEC countries collectively, and although this regional emphasis provides extensive insights, it may neglect the unique dynamics and variances within individual nations that could affect the outcomes. The study used a quantitative methodology, which, although effective in discovering patterns, may inadequately account for the many social, political, and cultural aspects that influence economic growth in these nations. Finally, the study's emphasis on economic metrics may inadequately consider the potential long-term environmental or sociological repercussions of globalization, which could affect sustainable growth trajectories in BIMSTEC nations. Subsequent study may rectify these shortcomings by integrating qualitative data, examining country-specific variables, and contemplating wider aspects of globalization.

CRedit authorship contribution statement

Muhammad Raihan Uddin: Writing – original draft, Conceptualization. **Nafis Sadik:** Writing – original draft, Writing – review & editing. **Md. Mominur Rahman:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

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

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