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Revealing major macroeconomic growth factors for an emerging economy: evidence from half-century of economic resilience

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Abstract

Bangladesh's economic transformation over the past 50 years, from one of the world's poorest nations to an emerging middle-income economy, provides a compelling context for analysing macroeconomic growth factors. This study aims to identify key determinants of Bangladesh's economic growth, examining how variables such as foreign direct investment (FDI), government expenditure, trade openness, inflation, exchange rates, and official aid have influenced growth over the long and short term. Using an autoregressive distributed lag (ARDL) bounds testing approach, the study leverages 50 years of time-series data to explore the dynamic relationships between these macroeconomic factors and economic growth. The findings reveal that FDI, government consumption, and trade openness significantly boost economic growth, while inflation and exchange rate appreciation exert negative effects. Diagnostic tests confirm the model's robustness, with stability tests indicating consistent parameter reliability across the sample period. However, this research is limited by the use of secondary data and potential measurement biases, suggesting the need for primary data in future studies. The study holds practical implications for policymakers, offering evidence-based recommendations to attract sustained FDI, manage inflation and exchange rate stability, and optimise aid utilisation. By comprehensively examining Bangladesh's macroeconomic landscape, this research adds original insights into the resilience factors underpinning emerging economies, contributing valuable guidance for policy initiatives to foster sustainable growth.

Keywords Macroeconomic growth factors, Economic growth, Time-series analysis, ARDL model, Bangladesh

1 Introduction

In 2021, Bangladesh marked its 50th year of independence, celebrating a journey from one of the poorest nations to a dynamic, emerging economy in South Asia. Initially regarded as a "test case of development" following the devastation of its 1971 liberation war, Bangladesh has since been celebrated as a "development miracle" and a model for other developing nations [1]. Over the past five decades, the country has achieved

substantial progress in poverty reduction, with recent data showing poverty rates now at 18.7% (upper) and 5.6% (lower) from the previous 80% [2].

Today, Bangladesh ranks as the 35th largest economy globally by nominal GDP, with a per capita income of $2793 as of 2022 [1]. Key socio-economic indicators reflect this growth, as life expectancy has increased from 47 years in 1971 to over 73 years while the literacy rate has similarly risen to 74.0% for those aged seven and above [2], demonstrating how strategic investments in human capital have compounded the benefits of economic growth. The availability of electricity has become nearly universal [3]. Sanitation and access to safe drinking water have also experienced a considerable enhancement, with 92.3% and 96.1% of the population, respectively, now enjoying improved facilities [2]. These developments have played a crucial role in ensuring health and well-being.

Moreover, crucial demographic indicators tell a tale of significant transformation. The birth rate per 1000 has plummeted from 46.9 to 17.4, while the death rate per 1000 has declined to 5.5 from 19.0. The infant mortality rate per 1000 live births has seen an extraordinary reduction from 160.6 to a mere 23.7 [2]. These trends illuminate the success in improving healthcare maternal and child well-being. The fertility rate has also significantly declined, dropping from 6.914 to a more sustainable 1.979. This change is a testament to the evolving socio-economic landscape and reflects the conscious choices and family planning initiatives contributing to a more balanced demographic profile [2].

These socio-demographic gains were underpinned by sustained macroeconomic stability and strategic policy interventions. Central to this progress were key macroeconomic indicators—including gross domestic product, foreign direct investment, exchange rate, trade expansion, official aid received, general government final consumption expenditure along with inflation management collectively fueled Bangladesh's structural transformation.

The country's GDP surged from $6.29 billion in 1972 to $460.20 billion in 2021, driven by structural reforms, increased trade, and rising foreign investment [4]. This expansion was supported by foreign direct investment (FDI), which, though negligible in the early years at $0.090 million [5], gained momentum in the 1990s, particularly in energy and manufacturing, reaching $3.6 billion in 2021 [4]. FDI inflows have been influenced by exchange rate policies, which transitioned from a fixed system pegged to the British pound (1972–1979) to a managed float (1980–2003) and eventually to a freely floating regime in 2003, allowing greater currency flexibility [6]

Government intervention has played a crucial role in maintaining economic stability. Official development assistance (ODA) supported the early years of growth, addressing poverty and disaster response through programs like Food-for-Work [7]. Alongside this, government expenditure steadily increased from 15% of GDP in 1971 to 21% in 2021, reflecting enhanced public sector investments [4]. However, inflationary pressures have remained a challenge. Initially it was 10% in post-independence period, then inflation declined to 2.8% in 1998 [8] but spiked to 10.7% in 2007 due to global commodity price shocks [9]. More recently, external disruptions such as COVID-19 have intensified inflationary pressures [10]. Trade expansion has been another key driver of growth, particularly in the textile sector, which propelled exports from $144 million in 1971 to $62.25 billion in 2022 [9].

While Bangladesh's economic growth has been notable, the underlying macroeconomic determinants of this growth remain underexplored in a comprehensive,

longitudinal context. While prior studies have examined factors such as foreign direct investment, government expenditure, inflation, and trade openness in isolation rather than investigating their combined and dynamic effects on Bangladesh's economy [11–14]. Additionally, there is a lack of studies exploring these variables' short-term and long-term impacts within a single econometric framework [15].

Consequently, the absence of an integrated analysis impedes efforts to design policies that sustain and enhance economic stability amid global uncertainties and internal economic fluctuations [16]. This study seeks to address this gap by comprehensively analysing macroeconomic growth factors in Bangladesh.

Understanding the macroeconomic drivers of growth in emerging economies is critical for fostering sustainable development. Bangladesh presents a compelling case study, having transitioned from low-income to middle-income status within five decades—a trajectory marked by both remarkable resilience and unique challenges [17]. While its success in poverty reduction, human development, and export-led growth (notably RMG) exemplifies a "development miracle," the economy remains vulnerable to external shocks due to reliance on remittances and volatile FDI inflows [18]. This duality, progress alongside persistent risks like inflation volatility and exchange rate instability makes Bangladesh an ideal laboratory for investigating macroeconomic dynamics. Its experience offers actionable insights for similarly positioned economies, particularly in balancing structural transformation with resilience. By analyzing Bangladesh's distinctive pathway, this study aims to identify replicable policy frameworks that can sustain growth amid global disruptions.

This study is guided by several critical questions to illuminate the macroeconomic dynamics underlying Bangladesh's economic growth. Primarily, the research seeks to determine the short-term and long-term impacts of selected macroeconomic variables such as FDI, government expenditure, inflation, and trade openness—on Bangladesh's economic growth. It also examines how external factors like exchange rate fluctuations and official aid influence Bangladesh's growth trajectory. Finally, by examining these variables in an integrated framework, this research fills a critical gap, offering novel insights into these factors' cumulative and interactive effects in an emerging economy context. This approach provides a more comprehensive understanding of how macroeconomic policies can shape growth trajectories in Bangladesh and similar economies.

This paper has practical implications for policymakers, economists, and stakeholders seeking to enhance Bangladesh's economic resilience, reflecting this study's significance.

The paper is structured as follows: The Sect. 1 outlines the research context and objectives. Followed by a Sect. 2 that positions the study within existing research on macroeconomic growth factors. The Sect. 3 section details the ARDL model and data sources used for analysis. Sects. 4 and 5 interpret the findings within the context of Bangladesh's economy, while the Sec. 6 summarises key insights, policy implications, and directions for future research.

2 Literature review

Economic growth is influenced by various international and domestic factors, including Foreign Direct Investment (FDI), exchange rates, official aid, government consumption expenditure, inflation, and trade openness. A critical assessment of the literature reveals both theoretical perspectives and empirical findings on how these factors interact with

economic growth. This review synthesizes key studies, identifies gaps, and discusses policy implications.

2.1 Foreign direct investment and economic growth

Foreign Direct Investment (FDI) is widely regarded as a catalyst for economic growth, contributing to capital accumulation, technology transfer, and human capital development. Theoretical frameworks such as the neoclassical growth model [19] and endogenous growth models [20] emphasize FDI's role in enhancing productivity. The neoclassical theory, as discussed by Helpman and Krugman [21], posits that FDI fosters productivity by facilitating technology transfer, thereby enhancing local firms' capacity to compete in the global market, particularly in economies transitioning to market-based systems [22]. Similarly, Berthélemy and Démurger [23] assert that foreign technology transfer is a crucial driver of economic growth, but its effectiveness depends on country-specific factors such as trade regime, education levels, and macroeconomic stability [24]. Furthermore, Baldi and Miethe [25] highlight that FDI is more effective in economies with robust education systems, quality infrastructure, and well-developed financial sectors.

Empirical research strongly supports the notion that FDI contributes positively to economic growth. Borensztein et al. [26] find that FDI enhances economic performance, particularly in countries with high levels of human capital. Similarly, Reza et al. [13] and Kabir Sumon [27] establish a significant positive impact of FDI on Bangladesh's GDP, with Reza emphasizing FDI's role in technological advancement. Tabassum and Ahmed [28] acknowledge FDI's beneficial influence but argue that domestic investment plays an even more critical role. Noor et al. [29] reinforce the importance of FDI by highlighting its role in technology dissemination and human capital enhancement [30]. Other studies further validate these findings, including [11, 12] and Jannat et al. [31] for Bangladesh, Havi et al. [32] for Cameroon, Sharma et al. [33] and Biswas and Saha [34] for India, and Bakari and Tiba [35] for Gabon. Thaddeus et al. [36] also confirm a strong correlation between FDI and economic growth across multiple contexts.

However, contrasting evidence indicates that FDI may have adverse effects, particularly in weak institutional environments. Rodrik et al. [37] caution that FDI can crowd out domestic investment, particularly in economies with inefficient financial systems. In the case of Bangladesh, Mamun and Kabir [38] reveal a long-term inverse relationship between FDI and GDP, indicating that FDI may not always lead to economic expansion. Similarly, Rahman et al. [16] investigate the symmetrical and non-symmetrical effects of FDI on GDP and find evidence of a long-term negative impact. Dunning and Lundan [39] argue that FDI may sometimes lead to a decline in domestic investment, thereby negatively influencing GDP growth. These mixed findings suggest that the impact of FDI on economic development is highly dependent on contextual factors, including institutional quality, financial systems, and absorptive capacity. While FDI is generally perceived as a driver of economic growth, its effectiveness varies across economies, reinforcing the need for policy interventions to optimize its benefits. Policymakers must focus on enhancing absorptive capacity, strengthening institutions, and ensuring that FDI complements rather than substitutes domestic investment. Future research should further explore sectoral differences and the role of institutional frameworks in shaping FDI's contribution to economic development.

2.2 Exchange rates and economic growth

The relationship between exchange rates and economic growth is theoretically complex, with competing hypotheses emerging from different economic schools. The positive impact hypothesis, rooted in export-led growth theories [40], suggests that competitive exchange rates stimulate export performance and domestic production. Conversely, the adverse impact hypothesis [41] emphasizes how excessive volatility can disrupt trade and investment flows. Modern synthesis models [42] propose that managed flexibility optimally balances these effects by maintaining competitiveness while mitigating instability.

Fiaz et al. [43] establish a positive GDP-exchange rate relationship in Pakistan, while Morina et al. [44] document substantial inverse correlations between REER fluctuations and growth in CEE nations. Fiaz et al. [45] employ Markov regime-switching models to demonstrate how terms of trade, net foreign assets, and interest differentials shape exchange rate behavior across economic regimes in Pakistan.

In Bangladesh, the relationship between exchange rates and economic growth is multifaceted, with evidence suggesting both positive and negative impacts depending on the context of exchange rate movements. Studies indicate that exchange rate misalignment can significantly influence economic growth dynamics, with undervaluation promoting growth while overvaluation tends to hinder it [46]. Additionally, a positive correlation exists between exchange rates and economic growth, with bi-directional causality indicating that changes in exchange rates can affect GDP and vice versa [47]. Razzaque et al. [48] demonstrate that real depreciations positively correlate with aggregate output, validating export-led growth channels.

Overall, while some studies support the positive role of exchange rate adjustments in fostering economic growth, others highlight the risks of excessive volatility and misalignment.

2.3 Official aid and economic growth

The impact of foreign aid on economic growth remains a subject of debate. Four primary hypotheses define this relationship: firstly, the growth hypothesis, which suggests that foreign aid fosters economic development [49]. Secondly, the conservative hypothesis, which argues that economic expansion leads to increased foreign aid. Thirdly, the neutrality hypothesis, which states that no direct connection exists between foreign aid and economic growth [50]. Fourthly, the feedback hypothesis, which proposes a bidirectional causality between the two, meaning that both factors influence each other [49]. Empirical evidence provides mixed findings across different economies. Burnside and Dollar [51] assert that aid fosters growth in well-governed economies, while Easterly [52] argues that aid dependence discourages necessary structural reforms. Rajan and Subramanian [53] highlight potential adverse effects, such as currency appreciation and reduced competitiveness. For Africa, Oyebowale and Algarhi [54] reveal a unidirectional causal relationship between GDP and foreign aid. Similarly, in Ghana, Havi et al. [32] found that GDP growth is positively impacted through both unilateral and bidirectional causality. In Cameroon, Charles [55] identified a negative association between foreign aid and economic growth, as the country became increasingly reliant on external assistance despite having natural resources. Findings from India also suggest a short-term adverse impact of foreign aid on GDP [33]. Meanwhile, Sothan [56], using the ARDL

method, reported that aid accelerates short-term economic development but with varied long-term effects.

In Bangladesh, evidence suggests that foreign aid plays a significant role in economic growth, particularly when allocated to infrastructure and human capital development [38]. Studies by Golder et al. [57] highlight the positive short- and long-term effects of aid on GDP, although governance issues and inconsistent allocation pose challenges that necessitate policy reforms. These diverse findings underscore the context-dependent nature of foreign aid's effectiveness, emphasizing the role of institutional quality, policy consistency, and economic structure in shaping aid's impact on growth.

2.4 Government consumption expenditure and economic growth

Government spending influences economic activity through public investments and social programs. Keynesian theory supports countercyclical spending to boost demand, while neoclassical perspectives [58] argue that excessive spending may crowd out private investment. Landau [59] and Devarajan et al. [60] stress the composition of government expenditure, with productive investments yielding better growth outcomes than recurrent costs. Empirical research provides mixed evidence on the relationship between government final consumption expenditure and GDP growth. Sharma et al. [33] provide insights from their study on India, indicating the positive short- and long-term effects of government investment on GDP growth, suggesting a temporary boost in economic growth due to government expenditure. Similarly, Ismaila and Lawrence [61] for Nigeria suggest that overall government spending, particularly final consumption expenditure, significantly influences economic growth, indicating a long-term positive impact. Oyebowale and Algarhi [54] highlight a strong association between GDP growth and general government final consumption expenditure in Africa, showcasing long-term, statistically significant positive correlations. Additionally, Sendi and Nyorekwa [62] underscore the substantial short- and long-term impacts of government consumption expenditure and investments on Uganda's GDP growth, emphasizing the role of government spending in fostering economic growth.

In case of Bangladesh, government consumption expenditure significantly influences economic growth, with evidence supporting a long-term positive relationship. Studies show that increased spending can boost GDP by stimulating investment and domestic demand, consistent with Keynesian theory [63, 64]. Panel cointegration analysis across SAARC countries also confirms a long-run equilibrium between government spending and growth, highlighting a bidirectional link [65].

2.5 Inflation and economic growth

The relationship between inflation and economic growth has been extensively studied in economic literature, with four primary theoretical perspectives emerging to explain this complex interaction. The growth theory posits that moderate inflation can stimulate economic activity through several channels, including reduced real wages that boost corporate profits and subsequent investment, as well as mechanisms that encourage productive capital allocation. This perspective finds empirical support in studies like those of Sumon and Miyan [66] in Bangladesh and Ume et al. [67] in Nigeria, which demonstrate beneficial connections between controlled inflation and GDP expansion. The traditional theory, conversely, argues that economic growth itself can generate inflationary

pressures through capacity constraints and demand-pull factors, a relationship observed in research from Bangladesh by Chowdhury et al. [68] and in cross-country studies like Biswas and Saha's [34] analysis of India.

International evidence presents a nuanced picture of this relationship. In developed economies like the United States, Lio and Abou-Zaid [69] identified threshold effects, where inflation's impact on growth turns negative above certain levels. Developing country studies reveal even greater complexity—while some like Ume et al. [67] found low inflation beneficial in Nigeria, others such as Mbulawa [70] documented purely detrimental effects in Zimbabwe's hyperinflationary context. The feedback hypothesis, exemplified by Saungweme's [71] Kenyan study, suggests bidirectional causality where inflation and growth influence each other in self-reinforcing cycles, particularly in economies with weak policy frameworks.

Bangladesh's experience provides critical insights into inflation-growth dynamics for emerging economies. Research reveals a dual nature of this relationship: while moderate inflation can support growth, excessive price rises become detrimental. Sumon and Miyan [66] found a statistically significant positive relationship (1986–2016), showing mild inflation's growth-supportive effects.

However, studies also identify concerning thresholds. Hossin [72] revealed a long-run negative relationship (1961–2013), particularly when inflation exceeds optimal levels. Rahman [73] confirmed this, finding significant negative effects of high inflation on growth (1976–2011). Chowdhury et al. [68] further identified transmission mechanisms where inflation constrains economic activity.

2.6 Trade openness and economic growth

The relationship between trade openness and economic growth has been extensively studied through multiple theoretical lenses. Classical theories like the Heckscher-Ohlin model and Ricardian comparative advantage [74] establish trade liberalization's growth benefits through specialization. The New Trade Theory [75] and Gravity Model further explain how economies of scale and geographic factors shape trade impacts. While trade liberalization generally promotes growth, developing countries may experience trade balance deterioration [76]. The debate continues between protectionism's short-term benefits versus liberalization's long-term gains [74], with imports presenting both challenges [77] and opportunities [78, 79] for domestic economies.

Empirical evidence overwhelmingly supports trade openness' growth-enhancing effects. Exports drive growth through foreign exchange, technology transfer, and innovation [80, 81], particularly in manufacturing [82]. Regional studies reveal diverse patterns: reciprocal relationships in India [83], unidirectional links in transition economies [84], and bidirectional causality in Africa [35, 54]. Methodological advances continue to refine our understanding, from asymmetric impacts [85] to causal testing [86].

Bangladesh's experience exemplifies these dynamics. The garment sector has been pivotal to its export-led growth [87], with studies confirming long-term trade openness benefits [88, 89] and short-term linkages [90]. Manufacturing exports particularly demonstrate strong growth impacts [91]. However, successful trade policies must account for Bangladesh's unique economic structure and institutional context to ensure sustainable development.

3 Methodology

3.1 Data source and variable description

This study employs a comprehensive secondary dataset spanning 1972–2021 from the World Bank's World Development Indicators (WDI), providing standardized macroeconomic data for Bangladesh's entire post-independence period. The 50-year timeframe enables robust analysis of both short-term fluctuations and long-term trends through the ARDL framework. Table 1 summarizes the seven key variables analyzed, all transformed into natural logarithmic form to normalize distributions and enable elasticity interpretations.

The selected variables represent fundamental drivers of economic growth in emerging economies, each carefully chosen for its theoretical and empirical relevance to Bangladesh's development trajectory. As the dependent variable, GDP per capita serves as the primary indicator of economic performance [22]. Foreign direct investment (FDI) captures critical capital inflows and technology transfer effects [16, 24], while the exchange rate reflects export competitiveness crucial for Bangladesh's trade-dependent economy [48]. Domestic policy variables include inflation—a key stability indicator [34]—and government consumption expenditure measuring public sector influence [33]. Trade openness quantifies Bangladesh's global integration [84], and official development assistance accounts for external support mechanisms [57].

These variables collectively provide a comprehensive framework for analysing Bangladesh's economic growth, encompassing internal dynamics and external influences. Each factor has been strategically selected to capture the multifaceted nature of growth drivers, offering insights into how domestic policies and global integration shape Bangladesh's economic trajectory.

Table 1 Data information and sources

Variables	Unit	Definition	Source
LNGDP	U.S. dollars	Real GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It represent economic growth.	WDI
LNFDI	U.S. dollars	Foreign direct investment refers to direct investment equity flows in the reporting economy. It is the sum of equity capital, reinvestment of earnings, and other capital.	
LNEXC	Percentage	Official exchange rate refers to the exchange rate determined by national authorities or to the rate determined in the legally sanctioned exchange market. It is calculated as an annual average based on monthly averages (local currency units relative to the U.S. dollar).	
LNAID	U.S. dollars	Net official development assistance (ODA) includes loans (net of repayments) and grants from Development Assistance Committee (DAC) members, multilateral institutions, and non-DAC countries to promote economic development and welfare in ODA recipient countries.	
LNGFC	U.S. dollars	General government final consumption expenditure (formerly general government consumption) includes all government current expenditures for purchases of goods and services (including compensation of employees).	
LNINF	Percentage	Inflation is calculated by the GDP deflator (%).The average yearly consumer price index is used to calculate the average rise or reduction in general prices.	
LNTOP	Percentage	Total goods and services exports and imports expressed as a % of GDP	

All variables are in Natural log form where "LN" for log

3.2 Model selection

The Autoregressive Distributed Lag (ARDL) model was selected for this study due to its distinct advantages, making it particularly suitable for analysing Bangladesh's economic data spanning the last 50 years. Unlike traditional cointegration methods, the ARDL approach allows for mixed integration orders, accommodating variables integrated at both I(0) and I(1) levels. This flexibility is essential for emerging economies like Bangladesh, where macroeconomic indicators frequently show varying integration levels [92]. Additionally, the ARDL model is robust with smaller sample sizes, offering reliable estimates even with the study's annual data over five decades [93]. The model's ability to capture both short-term dynamics and long-run equilibrium within a single framework provides a comprehensive view of the immediate and sustained effects of key variables, such as FDI, inflation, and trade openness, on economic growth. Finally, the model's Error Correction Term (ECT) is particularly valuable in assessing the speed of adjustment back to equilibrium, providing insights into the stability of economic relationships in Bangladesh's dynamic macroeconomic environment. Together, these features make the ARDL model an ideal choice for understanding the nuanced impacts of macroeconomic variables on Bangladesh's growth trajectory.

Here, Gross Domestic Product is the dependent variable, with other variables employed to explain it.

$$GDP_t = f(FDI_t, EXC_t, AID_t, GFC_t, INF_t, TOP_t). \tag{1}$$

GDP stands for Gross Domestic Product (Economic growth), FDI for foreign direct investment, EXC for official exchange rate, AID for official aid received, GFC for government final consumption expenditure, INF for inflation, and TOP for trade openness.

After considering the linear association among the variables, the expected model is given as follows.

$$GDP_t = \alpha_0 + \alpha_1 FDI_t + \alpha_2 EXC_t + \alpha_3 AID_t + \alpha_4 GFC_t + \alpha_5 INF_t + \alpha_6 TOP_t + \varepsilon_t. \tag{2}$$

By transforming the variable into the natural logarithm, the log–log form model can be represented as follows in Eq. (3):

$$\begin{aligned} LNGDP_t =& \alpha_0 + \alpha_1 LNFDI_t + \alpha_2 LNEXC_t + \alpha_3 LNAID_t \\ &+ \alpha_4 LNGFC_t + \alpha_5 LNINF_t + \alpha_6 LNTOP_t + \varepsilon_t. \end{aligned} \tag{3}$$

Here, LN stands for logarithmic form, ε stands for error term, and t represents the time.

3.3 Stationary test

The stationary properties of the time-series data for the chosen study variables were evaluated using the Phillips-Perron (PP) and ADF tests, which were introduced by Phillips and Perron (1988) and Dickey and Fuller (1979). This analysis aimed to ascertain whether the variables demonstrate stationarity at the level, first difference, or both. According to the PP and ADF unit root tests, the null hypothesis asserts the existence of a unit root, showing non-stationarity at the level. The alternative hypothesis argues for the deficiency of a unit root, demonstrating stationarity. The equations of ADF and PP tests are given as follows in Eqs. (4) and (5):

$$\Delta yt = \rho_0 + \rho_1 y_{t-1} + \delta_i \sum_{i=j}^{k} \Delta y_{t-i} + u_l. \tag{4}$$

where Δy_t denotes the differenced time series data, y_{t-1} is the lagged value of the time series, t denotes the time, and u_l is white noise error; on the other hand PP unit root is expressed by the following Eq. (5):

$$\Delta y_t = \sigma + \rho y_{t-1} + \sigma_t. \tag{5}$$

We employed the Zivot-Andrews [107] unit root test to evaluate the variables' stationarity and address possible structural breaks in the data. Conventional unit root tests, like the Augmented Dickey-Fuller (ADF) test, may erroneously classify a series as non-stationary in the presence of structural breaks—abrupt alterations in the mean or trend of the series. Structural breaks frequently result from substantial, infrequent economic shocks, policy alterations, or other notable occurrences, potentially modifying the fundamental data creation process. The Zivot-Andrews test identifies unit root characteristics and endogenous breakpoints in the series, enhancing the robustness of our stationarity study. The Zivot-Andrews model's general form, with a break in the intercept, is as follows in Eq. (6):

$$\Delta y_t = \alpha + \beta_t + \gamma y_{t-1} + \delta D_t + \sum_{j=1}^{k} \theta_j \Delta y_t + \varepsilon_t. \tag{6}$$

3.4 ARDL approach: long and short-run estimates

The ARDL framework was developed by [92, 93, 97]. The ARDL model is used to examine dynamic connections within data. The model distinguishes between long-term and short-term impacts through its equilibrium correction form.

In Eq. (7), the ARDL model is represented as follows.

$$\begin{aligned}\Delta LNGDP_t =& \alpha_0 + \alpha_1 LNFDI_t + \alpha_2 LNEXC_t + \alpha_3 LNAID_t + \alpha_4 LNGFC_t \\ &+ \alpha_5 LNINF_t + \alpha_6 LNTOP_t + \sum_{i=1}^{n} \beta_1 \Delta LNFDI_{t-i} + \sum_{i=1}^{n} \beta_2 \Delta LNEXC_{t-i} \\ &+ \sum_{i=1}^{n} \beta_3 \Delta LNAID_{t-i} + \sum_{i=1}^{n} \beta_4 \Delta LNGFC_{t-i} + \sum_{i=1}^{n} \beta_5 \Delta LNINF_t + \sum_{i=1}^{n} \beta_6 \Delta LNTOP_{t-i} + \varepsilon_t\end{aligned} \tag{7}$$

where ϵ is the error term and Δ represents the variable difference, the SC, HQC, and AIC were used to verify the correct lag of each series and model. The bound test can identify the long-term relationship among the variables. The following equation of the long-run estimation model can be expressed as follows in Eq. (8):

$$LNGDP_t = \delta_0 + \delta_1 LNFDI_t + \delta_2 LNEXC_t + \delta_3 LNAID_t + \delta_4 LNGFC_t + \delta_5 LNINF_t + \delta_6 LNTOP_t + \omega_t. \tag{8}$$

In addition, if confirmation of a long-run relationship between the research variables is discovered, the model for the short-run will be expected.

The estimated short-run model with ECT is projected to be Eq. (9)

$$\begin{aligned}\Delta LNGDP_t =& \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta LNFDI_{t-i} + \sum_{i=1}^{n} \beta_2 \Delta LNEXC_{t-i} + \sum_{i=1}^{n} \beta_3 \Delta LNAID_{t-i} \\ &+ \sum_{i=1}^{n} \beta_4 \Delta LNGFC_{t-i} + \sum_{i=1}^{n} \beta_5 \Delta LNINF_t + \sum_{i=1}^{n} \beta_6 \Delta LNTOP_{t-i} + \lambda ECT_{t-1} + \varepsilon_t\end{aligned} \tag{9}$$

The **Error Correction Term (ECT)** is obtained from the cointegration relationship (if the variables are cointegrated), and it helps correct short-run disequilibria. The **ECT** is given by the residual from the long-run equation, which reflects any deviations from the long-run equilibrium. The Error Correction Term (ECT) plays a pivotal role in the ARDL model by linking the short-run dynamics with the long-run equilibrium relationship among the variables. Specifically, it captures the extent to which the dependent variable, GDP in this case, adjusts to restore equilibrium following a deviation in the previous period.

Descriptive statistics are calculated to understand the data's distribution and trends. Stationarity is then assessed using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to identify each variable's level of integration. Due to the mixed integration orders, the ARDL model is chosen for its capacity to analyse both short-run and long-run dynamics between these macroeconomic factors and economic growth.

Following ARDL model selection, bounds testing confirms long-term cointegration among variables. Long-run and short-run coefficients are estimated to capture each variable's immediate and sustained impact on growth. Diagnostic tests for serial correlation, heteroskedasticity, and stability are conducted to ensure model robustness. Finally, the results are discussed in the context of Bangladesh's economic environment, with comparisons to existing literature to offer insights into the policy and sustainable growth implications.

4 Result

4.1 Descriptive statistics

The descriptive statistics provide insights into the central tendency, dispersion, and distributional characteristics of the variables LNGDP, LNFDI, LNEXC, LNAID, LNGFC, LNINF, and LNTOP. The median and mean values for each variable indicate the central location of data distribution. For instance, LNGDP (natural log of GDP) has a mean of 6.49 and a median of 6.37, suggesting a relatively symmetric distribution. This close alignment between mean and median implies that LNGDP is likely not heavily skewed, indicating a more balanced distribution. In contrast, LNINF (natural log of inflation) has a mean of 2.94, and its significant negative skewness suggests an asymmetrical distribution (Table 2).

The standard deviation (Std. Dev.) for each variable highlights the degree of variation within the dataset, with a higher standard deviation reflecting greater variability. Notably, LNFDI and LNINF exhibit high standard deviations of 3.71 and 2.41, respectively, indicating substantial variability. The high variability in LNFDI likely reflects the sensitivity of foreign investment flows to economic and political factors. Conversely, LNGDP, with a standard deviation of 0.44, shows relatively low fluctuation, which is typical for GDP per capita data and generally follows a more stable growth trend over time.

The Jarque–Bera test assesses whether each variable significantly deviates from a normal distribution. For this test, lower probability values indicate notable deviations from normality. Most variables display p-values above the 5% significance level, suggesting approximate normality in distribution. However, LNFDI and LNTOP show slight deviations from normality, indicating that foreign direct investment and trade openness might possess some non-normal characteristics in their distributions, though not to an extreme degree.

Table 2 Descriptive statistics

	LNGDP	LNFDI	LNEXC	LNAID	LNGFC	LNINF	LNTOP
Mean	6.490324	17.95038	3.656442	21.45364	22.01865	2.935648	−0.741692
Median	6.367105	17.41218	3.757245	21.52065	21.97615	3.183555	−0.541103
Maximum	7.429180	21.76678	4.443640	22.40480	23.49160	4.587008	−0.260685
Minimum	5.955080	−−2.302585	2.041240	20.81240	19.70850	−13.61458	−2.971430
Std. Dev.	0.443496	3.715427	0.691826	0.417426	0.897632	2.413138	0.476868
Skewness	0.654978	−3.168564	−0.784731	0.246020	−0.560504	−6.633001	−2.329064
Kurtosis	2.169449	3.64824	2.636693	2.287547	3.262054	4.08458	10.74075
Jarque-Bera	5.012083	6.8055	5.406669	1.561857	2.761104	5.891	6.0361
Probability	0.081591	0.1256	0.066982	0.457981	0.251440	0.0953	0.0940
Sum	324.5162	897.5191	182.8221	1072.682	1100.932	146.7824	−37.08462
Sum Sq. Dev.	9.637737	676.4154	23.45251	8.537976	39.48143	285.3384	11.14274
Observations	50	50	50	50	50	50	50

4.2 Unit root test

The following Table 3 of this study expresses the outcomes of ADF and PP tests to verify the stationarity among the series:

Both PP and ADF test LNGDP, LNAID, and LNGFC are non-stationary at the level form where the rest of the variables are stationary at their first differences. Data analysis shows that certain variables exhibit stationarity at level I(0), whereas others demonstrate stationarity at the first difference I(1). This observation confirms the suitability of employing the ARDL model.

The Zivot-Andrews structural unit root test is used alongside ADF and PP tests to capture potential structural breaks that ADF and PP tests may overlook, providing a more accurate assessment of stationarity in data with possible shifts.

The results indicate that variables such as LNGDP and LNAID are non-stationary at their levels, as they retain unit roots despite structural breaks identified in 1982 and 2012, respectively. This non-stationarity suggests that these variables have long-lasting impacts that persist over time, likely due to profound economic structural shifts during

Table 3 Unit root test

Variables	Level		1st difference		Decision
	Intercept	Intercept and trend	Intercept	Intercept and trend	
Augmented dickey fuller					
LNGDP	5.1225	−0.0932	−2.0243	−10.832***	I(1)
LNFDI	−0.4608	−7.1702***	−4.3883***	−4.3956***	I(0)
LNEXC	−3.6957***	−2.1143	−4.4677***	−7.1196***	I(0)
LNAID	−1.9595	−0.5032	−10.531***	−10.581***	I(1)
LNGFC	−2.0655	−3.3324	−7.2818***	−7.5821***	I(1)
LNINF	−7.2377***	−7.335***	−11.458***	−11.336***	I(0)
LNTOP	−6.5386***	−9.3291***	−12.413***	−12.745***	I(0)
Phillip peron					
LNGDP	7.8083	0.3602	−6.8313***	−11.013***	I(1)
LNFDI	−4.2017***	−7.4885***	−39.249***	−39.026***	I(0)
LNEXC	−12.415***	−3.6879**	−4.2975***	−5.2661***	I(0)
LNAID	−1.8006	−1.7573	−10.531***	−11.07***	I(1)
LNGFC	−2.1127	−3.3565	−7.2863***	−7.5313***	I(1)
LNINF	−7.408***	−8.2176***	−44.918***	−44.865***	I(0)
LNTOP	−6.4325***	−9.4224***	−13.654***	−14.659***	I(0)

Significant at the 5%, and at the 1% levels **, and ***, respectively

Table 4 Structural unit root test

Variable	Break year	Lags included	Minimum t-statistic	Critical value			Conclusion
				1%	5%	10%	
LNGDP	1982	1	−1.209	−5.34	−4.8	−4.58	Non−stationary
LNFDI	1979	0	−8.477	−5.34	−4.8	−4.58	Stationary (1%)
LNEXC	1981	2	−5.868	−5.34	−4.8	−4.58	Stationary (1%)
LNAID	2012	1	−3.333	−5.34	−4.8	−4.58	Non−stationary
LNGFC	1988	2	−5.821	−5.34	−4.8	−4.58	Stationary (1%)
LNINF	1979	0	−7.902	−5.34	−4.8	−4.58	Stationary (1%)
LNTOP	1991	1	−6.2	−5.34	−4.8	−4.58	Stationary (1%)
D.LNGDP	2005	0	−11.799	−5.34	−4.8	−4.58	Stationary
D.LNAID	2011	0	−11.481	−5.34	−4.8	−4.58	Stationary

these periods. In contrast, variables such as LNGFC LNTOP, LNFDI, and LNEX are stationary at the 1% significance level, as evidenced by statistically significant t-values that support rejecting the null hypothesis of a unit root. This stationarity implies that these variables tend to revert to a stable mean after experiencing shocks, indicating a more consistent and predictable pattern in response to economic fluctuations.

Further, differencing non-stationary variables (e.g., D.LNGDP and D.LNAID) confirms stationarity in the first differences, effectively removing unit roots from these series. This approach validates the use of first differencing to achieve stationarity in otherwise persistent variables over time, making them suitable for econometric modelling.

The Zivot-Andrews test results underscore the importance of addressing structural breaks in economic analyses, as ignoring such breaks could lead to inaccurate conclusions about the stationarity and long-term behaviour of key economic variables. This consideration strengthens the validity of this study's methodology by ensuring that both stationary and non-stationary series are treated appropriately for reliable econometric analysis (Table 4).

4.3 ARDL cointegration test

To address the sample's limitation, this research applies SIC standards to determine the appropriate lag (Table 5).

The table displays the VAR Lag Order Selection Criteria results for the model, which evaluates different lag lengths for the endogenous variables: LNGDP, LNFDI, LNEXC, LNAID, LNGFC, LNINF, and LNTOP. It utilizes various criteria, including LogL, LR, FPE, AIC, SC, and HQ. The optimal lag length is found to be 4, indicated by the lowest AIC, SC, and HQ values, along with a significant LR test statistic at the 5% level.

Table 5 Appropriate lag selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−125.5597	NA	7.51e−07	5.763467	6.041738	5.867709
1	278.5626	667.6804	1.52e−13	−9.676635	−7.450463	−8.842698
2	392.2794	153.2704	1.06e−14	−12.49041	−8.316334	−10.92677
3	508.7674	121.5528*	8.55e−16	−15.42467	−9.302698*	−13.13134
4	597.8553	65.84754	3.94e−16*	−17.16762*	−9.097747	−14.14460*

* Indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Table 6 Bound test

Test statistic	Value	k
F-statistic	14.97622	6
Critical value		
Significance	I (0)	I (1)
1%	2.88	3.99

The variable long-run linkage and equilibrium were shown using an autoregressive distributed lag technique and limits tests to cointegration at the 1%, 2.5%, 5%, and 10% levels of significance.

There are several benefits to using the ARDL bounds test instead of alternative one-time integer approaches for evaluating cointegration. The fact that the ARDL bounds test does not force any assumptions on the data makes it a powerful tool, especially when dealing with series that have heterogeneous integration orders. The enhanced dependability of the ARDL bounds test, particularly when working with small samples, is another notable advantage.

The Pesaran critical value table states that the alternative hypothesis is rejected when the F-state value falls below the lower bound. The null hypothesis is rejected when the F-state value exceeds the upper bound critical value; conversely, results may be deemed biased if the F-state value falls within the interval between the upper and lower bounds [92]. The following Table 6 shows the outcomes of the ARDL-bound tests:

The table shows significant cointegration (at the 1% level) between economic growth, foreign direct investment, exchange rate, government consumption expenditure, inflation, and trade openness in Bangladesh, as the F-statistics value 14.97 surpasses the critical threshold 3.99.

4.4 Short-run and Long-run outcomes based on ARDL

These results demonstrate the presence of both short-term and long-term correlations among the variables (Table 7).

4.5 Key findings

4.5.1 Foreign direct investment (FDI) and economic growth

A 1% increase in FDI net inflows leads to a 0.043% increase in GDP per capita in the long run. The short-run dynamics show an immediate positive impact (0.005%) that diminishes over subsequent periods (− 0.005 to − 0.002% in lags 1–3), suggesting that while FDI provides an initial growth stimulus, its effects taper off without complementary policies.

4.6 Exchange rate and economic growth

A 1% appreciation of the official exchange rate results in a 0.225% decline in GDP per capita in the long term. Short-run effects are mixed, with contemporaneous appreciation being beneficial (0.121%) but lagged effects turning negative (− 0.122% at lag 3), indicating complex adjustment dynamics in Bangladesh's export-oriented economy.

4.7 Official aid and economic growth

A 1% increase in foreign aid generates a 0.109% rise in GDP per capita over the long run. Short-run impacts are positive initially (0.022%) but turn negative in subsequent periods

Table 7 Long-run and Short-run estimators

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-run association				
C	− 9.112715	0.343737	− 26.510713	0.0000***
LNFDI	0.042851	0.008668	4.943522	0.0001***
LNEXC	− 0.225517	0.046176	− 4.883831	0.0001***
LNAID	0.108590	0.023927	4.538403	0.0003***
LNGFC	0.627946	0.040053	15.677812	0.0000***
LNINF	− 0.103111	0.016218	− 6.357953	0.0000***
LNTOP	0.201258	0.049318	4.080855	0.0007***
Short-run association				
D(LNGDP(− 1))	0.238440	0.054726	4.356969	0.0004***
D(LNFDI)	0.005166	0.001027	5.030676	0.0001***
D(LNFDI(− 1))	− 0.005302	0.000667	− 7.945691	0.0000***
D(LNFDI(− 2))	− 0.003628	0.000544	− 6.664013	0.0000***
D(LNFDI(− 3))	− 0.002141	0.000391	− 5.478113	0.0000***
D(LNEXC)	0.121600	0.023557	5.162060	0.0001***
D(LNEXC(− 1))	0.012231	0.025818	0.473745	0.6414
D(LNEXC(− 2))	0.059781	0.023714	2.520958	0.0214
D(LNEXC(− 3))	− 0.122368	0.020290	− 6.031058	0.0000***
D(LNAID)	0.022458	0.004421	5.080153	0.0001***
D(LNAID(− 1))	− 0.021490	0.003987	− 5.390178	0.0000***
D(LNAID(− 2))	− 0.014282	0.004142	− 3.448381	0.0029***
D(LNGFC)	0.222616	0.029005	7.675172	0.0000***
D(LNGFC(− 1))	− 0.399807	0.031765	− 12.586318	0.0000***
D(LNINF)	− 0.002594	0.001776	− 1.460780	0.1613
D(LNINF(− 1))	0.012144	0.001175	10.333699	0.0000***
D(LNINF(− 2))	0.008223	0.001225	6.711650	0.0000***
D(LNINF(− 3))	0.004469	0.001321	3.383186	0.0033***
D(LNTOP)	− 0.027520	0.011131	− 2.472367	0.0236**
D(LNTOP(− 1))	− 0.019334	0.009007	− 2.146537	0.0457
ECT(− 1)	− 0.357490	0.027713	− 12.899705	0.0000***

Significant at the 5%, and at the 1% levels **, and ***, respectively

(-0.021% at lag 1), suggesting potential Dutch Disease effects if aid inflows are not properly managed.

4.8 Government consumption expenditure and economic growth

A 1% rise in government expenditure contributes to a substantial 0.628% increase in GDP per capita in the long run. The short-run shows an even stronger contemporaneous effect (0.222%) followed by a sharp reversal (– 0.399% at lag 1), highlighting potential crowding-out effects after initial demand stimulation.

4.9 Inflation and economic growth

A 1% increase in inflation causes a 0.103% reduction in GDP per capita in the long term. Short-run dynamics reveal a complex pattern with initial negative effects (– 0.002%) followed by positive adjustments (0.012% at lag 1), possibly indicating temporary demand-pull inflation benefits before stabilization.

4.10 Trade openness and economic growth

A 1% expansion in trade openness (exports + imports as % of GDP) leads to a 0.201% GDP per capita in the long term. Interestingly, short-term effects are negative (– 0.027%),

possibly reflecting adjustment costs to trade liberalization before long-term benefits materialize.

4.11 Error correction mechanism

The significant negative coefficient of the Error Correction Term (ECT = – 0.357) confirms long-run equilibrium relationships and indicates that 35.7% of any short-run disequilibrium is corrected annually. The speed of adjustment suggests Bangladesh's economy takes approximately 2.8 years to fully absorb shocks and return to equilibrium.

5 Discussion

5.1 FDI-growth nexus

The positive long-run relationship between FDI and growth (0.043%) aligns with the technology spillover hypothesis articulated by Borensztein et al. [26]. However, the diminishing short-run effects contrast with Mottaleb and Kalirajan [98] findings for Bangladesh, which showed sustained positive impacts. This discrepancy may reflect structural changes in Bangladesh's economy, where early FDI in garments had immediate effects, while recent investments in infrastructure and energy show longer gestation periods.

5.2 Exchange rate dynamics

The negative long-run impact of currency appreciation (– 0.225%) strongly supports the export-led growth hypothesis prevalent in small open economies [99]. However, the positive short-run effect (0.121%) presents an interesting paradox that aligns with Krugman's [100] "J-curve" effect, where currency appreciation initially improves the trade balance through valuation effects before quantity adjustments dominate.

5.3 Aid effectiveness debate

The modest but positive aid-growth relationship (0.109%) supports the "optimistic" view of aid effectiveness [51] but with smaller magnitudes than the "big push" theory predicts. The negative lagged effects lend some credence to the "pessimistic" view [52], suggesting diminishing returns to aid inflows.

5.4 Government spending multipliers

The exceptionally large government expenditure multiplier (0.628%) exceeds typical estimates for developing countries (0.3–0.5% in Ilzetzki et al. 2013) but matches Bangladesh-specific findings by [101]. This may reflect the high productivity of recent infrastructure investments (e.g., padma bridge, metro rail) compared to general consumption expenditure [102].

5.5 Inflation threshold effects

The negative inflation-growth relationship (– 0.103%) confirms Bangladesh's position above the optimal inflation threshold (estimated at 5–6% by Bick [103]. The short-run dynamics suggest temporary output-inflation tradeoffs consistent with traditional Phillips Curve analysis.

5.6 Trade openness paradox

While the long-run benefits of trade openness (0.201%) confirm standard trade theory [20], the negative short-run impact (– 0.027%) echoes the "liberalization blues" phenomenon documented by Greenaway et al. [104], where trade reforms initially disrupt protected industries before efficiency gains emerge.

While most studies (e.g., [22]) support FDI's growth impact, some [16] warn of dependency risks, implying FDI's benefits may be conditional on institutional quality. The aid-growth result contrasts with Easterly [52], who argues aid inefficiencies often negate growth benefits, suggesting Bangladesh may utilize aid more effectively.

5.7 Theoretical contributions

This study advances development economics literature through three key theoretical contributions. First, it introduces the concept of "temporal FDI decay," demonstrating that while foreign direct investment delivers immediate growth benefits (0.005% short-run impact), these effects diminish over time (– 0.005 to – 0.002% in subsequent periods) without complementary institutional absorptive capacity. This finding challenges linear assumptions about FDI impacts and underscores the necessity of pairing investment inflows with policies that enhance human capital, infrastructure, and technological readiness—a nuance often overlooked in conventional endogenous growth models [26].

Second, the study provides robust empirical evidence of the "Exchange Rate J-curve" in a least developed country (LDC) context, validating Krugman's [100] hypothesis in Bangladesh's export-dependent economy. The observed pattern—initial GDP per capita gains (0.121%) from currency appreciation followed by lagged declines (– 0.122%)—reveals how LDCs face unique adjustment dynamics due to reliance on low-value-added exports and import-dependent production. This extends traditional J-curve literature, which has focused predominantly on advanced economies.

Third, the research refines the "Aid-Productivity Nexus" by demonstrating that aid's growth impact (0.109% long-run) hinges critically on its allocation. While productivity-enhancing aid (e.g., infrastructure, education) sustains growth, consumption-oriented aid exhibits diminishing returns (– 0.021% short-run), echoing Easterly's [52] critique but with a nuanced emphasis on allocation efficiency. This bridges the polarized aid-effectiveness debate, offering a middle ground where aid's impact is contingent on sectoral prioritization rather than being universally positive or ineffective.

Collectively, these contributions recalibrate theoretical frameworks to better capture the complexities of growth dynamics in LDCs, emphasizing nonlinearities, institutional contingencies, and policy sequencing as critical moderators of development outcomes.

5.8 Granger causality

The Granger causality results reveal a unidirectional causality extending from economic growth to official aid, inflation, GFC and trade openness. Meanwhile, a bidirectional causality is observed between exchange rates and foreign direct investment. The following Table 8 represents the causality test results:

Table 8 Causality test

Variables	Causality direction
LNFDI and LNGDP	LNFDI→LNGDP***
LNEXC and LNGDP	LNEXC ≠LNGDP
LNAID and LNGDP	LNGDP → LNAID***
LNGFC and LNGDP	LNGDP → LNGFC***
LNINF and LNGDP	LNGDP → LNINF***
LNTOP and LNGDP	LNGDP → LNTOP***
LNEXC and LNFDI	LNEXC → LNFDI***
LNAID and LNFDI	LNAID≠LNFDI
LNGFC and LNFDI	LNGFC→LNFDI***
LNINF and LNFDI	LNINF ≠ LNFDI
LNTOP and LNFDI	LNTOP ↔LNFDI***
LNAID and LNEXC	LNAID≠ LNEXC
LNGFC and LNEXC	LNGFC ≠ LNEXC
LNINF and LNEXC	LNINF → LNEXC***
LNTOP and LNEXC	LNEXC→LNTOP***
LNGFC and LNAID	LNGFC ≠LNAID
LNINF and LNAID	LNINF ≠LNAID
LNTOP and LNAID	LNTOP ≠LNAID
LNINF and LNGFC	LNINF ≠LNGFC
LNTOP and LNGFC	LNGFC→LNTOP***
LNTOP and LNINF	LNTOP ≠ LNINF

*** Indicates the 1% significance level

→ indicates the unidirectional causality

≠ indicates the no causality exists between the variables

5.9 Diagnostic test

This study performed normality, heteroscedasticity, stability test, and serial correlation to verify the ARDL model. The model is free from heteroscedasticity problems. While the F-test ($p = 0.292$) suggests no autocorrelation, the significant χ^2 statistic ($p = 0.038$) indicates possible second-order serial correlation. Given the small sample size (degrees of freedom suggest n ≈ 19), the F-test is likely more reliable, as it is better suited to finite samples compared to the asymptotic chi-square test [105]. The Ramsey RESET test postulates that the selected model is fit. In addition, the data is normally distributed. Table 9 below demonstrates the results of the diagnostic test:

Table 9 Diagnostic test

Name of the test				Decision
Heteroskedasticity Test: Breusch-Pagan-Godfrey				
F-statistic	0.740364	Prob. F (27,18)	0.7659	No Heteroscedasticity
Obs*R^2	24.20469	Prob. χ^2(27)	0.6189	
Breusch-Godfrey Serial Correlation LM Test				
F-statistic	1.329030	Prob. F(2,16)	0.2924	No Serial Correlation
Obs*R^2	6.553240	Prob. χ^2(2)	0.0378	Potential second-order serial correlation
	Value	**df**	**Prob.**	
Ramsey RESET Test				
t-statistic	0.957199	17	0.3519	The model is fit
F-statistic	0.916231	(1, 17)	0.3519	
Normality Test				
Jarque-Bera	3.366876	Probability	0.185734	Normality exists

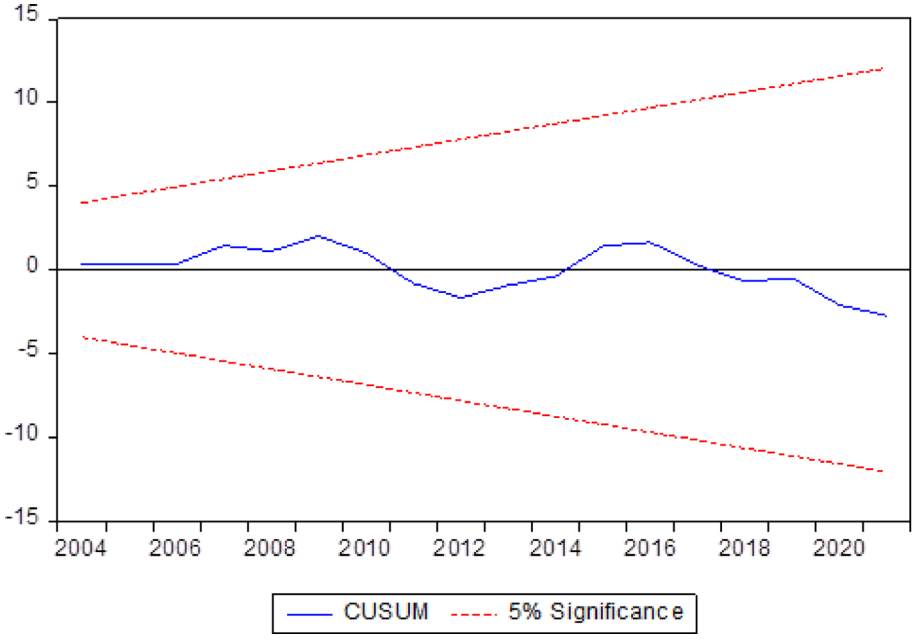

Fig. 1 Robustness test (CUSUM & CUSUMSQ)

To assess the validity and stability of the ARDL model, cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests were applied [106]. The CUSUMSQ and CUSUM tests indicate that the critical line falls within the 5% significance level. This shows that the models and parameters used in the study are steady and reliable.

The following Figs. 1 and 2 represent the results from the robustness test:

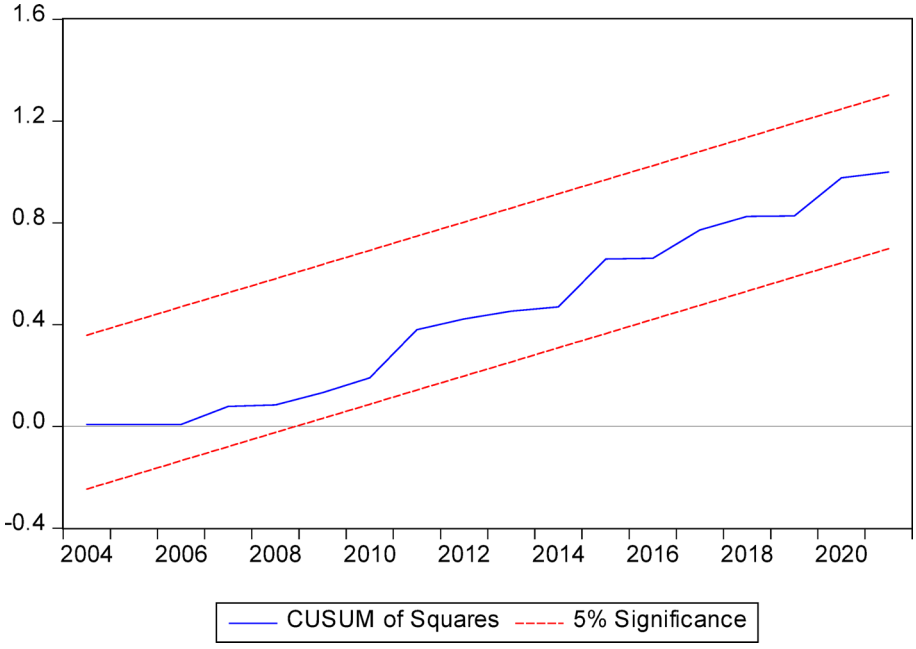

Fig. 2 Robustness test (CUSUM & CUSUMSQ)

6 Conclusion and policy recommendations

Bangladesh's remarkable economic transformation—from a struggling emerging nation to a thriving growth story—has been shaped by critical macroeconomic forces. This study, employing a 50-year ARDL analysis, illuminates the complex interplay between key economic variables and GDP, offering valuable insights into both drivers and constraints of Bangladesh's development trajectory.

The findings underscore foreign direct investment as a vital growth catalyst, channeling capital and technology into the economy while creating employment opportunities. Government expenditure emerges as another powerful driver, with productive public investments fueling infrastructure development and social progress. Trade openness further reinforces growth by integrating Bangladesh into global value chains and enhancing competitiveness.

However, the analysis also identifies inflation and exchange rate volatility as persistent challenges, with their negative impacts highlighting the need for prudent monetary management. These findings collectively emphasize that sustaining Bangladesh's growth momentum requires balanced policies—attracting quality FDI while maintaining macroeconomic stability, optimizing public spending efficiency alongside trade competitiveness, and carefully managing currency and price stability.

This research contributes to understanding how emerging economies like Bangladesh can navigate the delicate balance between growth acceleration and economic stability, providing a framework for policymakers to strengthen the country's development trajectory in an increasingly complex global economic landscape.

Policy Recommendations: The analysis suggests several policy directions that could support sustainable economic growth in Bangladesh.

- **Enhance FDI Attractiveness with Sector-Specific Incentives**: The positive link between FDI and economic growth suggests that Bangladesh should continue to encourage FDI, particularly in sectors with high growth potential, such as technology, renewable energy, and infrastructure. Developing policies that offer tax breaks or other incentives tailored to these sectors could amplify the benefits of FDI for long-term economic growth.
- **Maintain a Competitive Exchange Rate**: Given the negative impact of currency appreciation on growth, Bangladesh should aim to keep the exchange rate competitive to support its export-driven economy. Implementing a managed floating exchange rate policy can help balance inflation control with export competitiveness, especially for critical industries like textiles and apparel.
- **Optimise Government Spending on Infrastructure and Human Capital**: Government consumption has a direct positive impact on GDP, suggesting that public spending should be strategically allocated to infrastructure, education, and healthcare. By focusing on these sectors, the government can create a multiplier effect, enhancing productivity and supporting sustained economic growth.
- **Pursue Trade Diversification and Sustainable Export Growth**: Trade openness contributes positively to growth; however, excessive reliance on textiles and garments poses risks. Policymakers should encourage the diversification of export products and markets to reduce exposure to global economic shocks. Incentivising emerging

sectors, like information technology and pharmaceuticals, can broaden the economic base.

- **Leverage Official Aid for Long-Term Capacity Building**: While official aid positively impacts GDP, it should be directed toward capacity-building projects that foster self-sufficiency, such as vocational training, renewable energy, and disaster resilience programs. This approach will help reduce aid dependency and support sustainable development goals.
- **Control Inflation Through Targeted Monetary Policies**: The negative relationship between inflation and growth emphasises the need for targeted monetary policies to stabilise inflation. The Bangladesh Bank should consider inflation-targeting mechanisms to stabilise prices, especially for essential goods while balancing policies that stimulate economic activity.

Bangladesh's economic progress over the last five decades underscores the influence of macroeconomic factors on growth. By implementing these policy recommendations, Bangladesh can reinforce its position as an economic success story, ensuring long-term prosperity, inclusiveness, and sustainability.

6.1 Limitations and future scopes

While this study provides meaningful insights into Bangladesh's economic growth drivers, certain limitations should be acknowledged. First, while the selected variables (FDI, inflation, trade openness, etc.) are well-established in growth literature, other pertinent factors—such as remittances, private sector investment, and institutional quality—could provide a more comprehensive understanding if included. Second, the ARDL model, though robust, assumes linear relationships, potentially overlooking threshold effects or asymmetric responses (e.g., whether inflation harms growth only beyond a certain level).

6.2 Directions for future research

Future research should adopt advanced methodologies to deepen understanding of Bangladesh's growth dynamics. Nonlinear models like threshold regression or Markov-switching techniques could uncover asymmetric effects of growth drivers across different economic conditions. Sectoral disaggregation of agriculture, manufacturing, and services would reveal industry-specific constraints and opportunities. Comparative studies with regional peers like India and Vietnam could yield transferable policy insights, while focused analyses of major reforms—such as digital trade policies or green energy transitions—would clarify their growth impacts. These approaches would provide more nuanced, actionable evidence for policymakers.

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Author contributions
All authors contributed to the study on developing the concept and research design. material preparation, data curation, cleaning, and formal analysis were performed by Mehedi Hasan, Md. Obidul Haque, and Mohammad Bin Amin. Key Supervision and background were performed by Md. Atikur Rahaman and Judit Oláh. Literature of the study, methodology, and data analysis have done by Md. Saddam Hossain and Md. Ahsan Habib. The literature was completed by Md. Saddam Hossain, Md. Ahsan Habib, and Mohammad Bin Amin. The first draft of the manuscript was prepared by Mehedi Hasan, Md. Obidul Haque, Md. Atikur Rahaman and Judit Oláh. All authors contributed on the final versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethical approval and consent to participate
This research is based on secondary data and data were taken from World Development Indicators (WDI). As there are no human participations were involved or any kinds of clinical trials in this research; therefore, to follow any ethical guideline or ethical approval was not required for this study.

Consent to publish
This research is based on secondary data and data were taken from World Development Indicators (WDI). As there are no human participations were involved, human clinical data, or any kinds of clinical trials in this research; therefore, to collect consent from the participants to publication was not required for this study. The authors confirm that they consent to the publication of this manuscript in Discover Sustainability. There are no legal or ethical restrictions that prevent its publication.

Competing interest
The authors declare no competing interests.

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