Working Paper 07

The Role of Agriculture, Industry, and Services Sector in the Economic Growth of Bangladesh

An ARDL Approach

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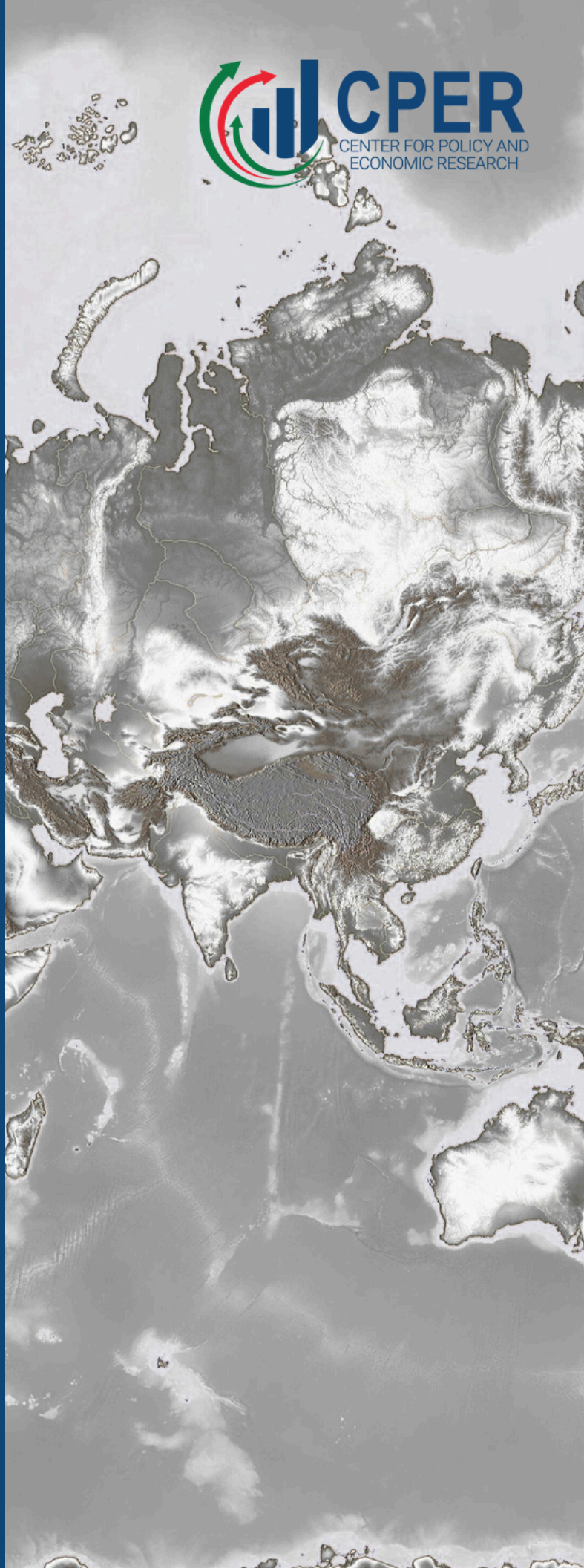
Center for Policy and Economic Research (CPER)

September 2025



The Role of Agriculture, Industry, and Services Sector in the Economic Growth of Bangladesh: An ARDL Approach

Al Mamun*

September 2025

* This research paper has been prepared by the Center for Policy and Economic Research (CPER), Bangladesh. The authors are, respectively, an Associate Research Fellow in the Department of Research at CPER, Bangladesh. The views and any limitations expressed in this paper are solely those of the authors and do not necessarily represent the official positions of their respective institutions.

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Abstract

Purpose - This study investigates the contributions of agriculture, industry, and services to Bangladesh's economic growth, addressing controversies regarding their short- and long-run impacts within the framework of structural transformation.

Design/methodology/approach - Using annual time-series data from 1971–2020, the Autoregressive Distributed Lag (ARDL) bounds testing approach was employed to estimate both long-run elasticities and short-run dynamics. Complementary diagnostic and stability tests ensured robustness of the model.

Findings - Results confirm a strong long-run cointegrating relationship between GDP and the three sectors. Services emerged as the dominant driver of growth, industry contributed positively but moderately, and agriculture remained vital in both the short and long run. The error correction term indicated rapid adjustment toward equilibrium, underscoring resilience in Bangladesh's growth process.

Research limitations - The study is limited to aggregate sectoral data, which may mask heterogeneity within subsectors. External shocks such as climate change and global trade disruptions were not explicitly modeled.

Originality/value - By jointly analyzing agriculture, industry, and services within a unified ARDL framework, this study reconciles econometric evidence with structural transformation theory, offering evidence-based insights for balanced sectoral development in Bangladesh.

Keywords: ARDL, agriculture, industry, services, economic growth, structural transformation, Bangladesh

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1. Introduction

There have been many changes in the Bangladeshi economy over the years, including significant shifts in the interactions among its agricultural, industrial, and service sectors. As a lower-middle-income country in South Asia, Bangladesh's development trajectory over the past few decades reflects trends seen in other economies worldwide regarding structural change (Manik, 2023; Islam et al., 2022; Raihan & Khan, 2020; Mujeri & Mujeri, 2021; Ayon, 2018). Such an economic transition plays a critical role in facilitating the country's continued economic growth, job creation, poverty alleviation, and resilience to external shocks such as climate change and market volatility (Jui, 2025; Huq & Ichihashi, 2023; Rahman, 2017; Al-Mamun, 2024). Though agriculture's contribution to the GDP has fallen drastically—from more than 60% in the 1970s to less than 15% currently—the sector is still extremely important in ensuring food security and income generation for rural areas, while industry (notably manufacturing) and services have become key drivers of growth and development in the country (Manik, 2023; Islam et al., 2022; Raihan & Khan, 2020; Raihan, 2018). However, recurring issues such as disparities in sectoral productivity, lack of diversification, the informal labor market, and climate vulnerability underscore the need for empirical insights to inform policy (Jui, 2025; Majumder, 2022; Raihan & Khan, 2020; Rahman et al., 2024).

The fundamental issue this research will address is the inconsistencies and controversies regarding the extent to which the agriculture, industry, and services sectors impact Bangladesh's economic growth. Although earlier literature shows a positive correlation between economic growth and these three sectors, there is still uncertainty about their short and long-term impact on GDP and their interactions, which can be evaluated using the Autoregressive Distributed Lag Model (Mondol et al., 2024; Rifat et al., 2024; Hossain et al., 2012; Pervez et al., 2024). This is especially important due to recent changes in sectoral composition and the labor force, as well as the shift towards sustainable development goals.

In this regard, the primary purpose of this paper is to analyze the contributions of the agriculture, industrial, and services sectors in Bangladesh's economic growth using the ARDL model. The research objectives are as follows: (1) to estimate the short and long-term impacts of the agriculture, industrial, and service sectors on GDP; (2) to test for causal relationships among the agriculture, industrial, and service sectors; (3) to determine how the interactions within the agriculture, industrial, and services sectors have changed overtime; and (4) to suggest evidence-based recommendations for balanced sectoral development. The research questions include: What are the short- and long-run impacts of the agriculture, industry, and services sectors on Bangladesh's economic growth? What are the causal relationships among these sectors? Which sector has the most significant contribution to economic growth?

The scope of this research pertains to national statistics for Bangladesh in recent years (mostly between 1971 and 2020), with an emphasis on macroeconomic parameters significant to each industry. By using the ARDL model, which allows for the incorporation of integrated variables of differing orders, the research considers both short-term and long-term dynamics within the context of the peculiarities of the Bangladeshi economy. This work is of great practical importance to those involved in devising effective strategies for optimal resource distribution among industries amid structural shifts (Mondol et al., 2024; Rifat et al., 2024; Huq & Ichihashi, 2023).

New knowledge is being produced through a comprehensive ARDL-based study on contributions made by different sectors to the growth of the Bangladesh economy, as this kind of analysis goes beyond the limitations of conventional techniques that either disregard interdependent dynamics or confuse their short-term and long-term dimensions (Mondol et al., 2024; Rifat et al., 2024). Thus, this research clarifies these dynamics using the most recent data and can be valuable in developing policies that promote inclusive growth, productivity

improvement, and resilience to shocks across all sectors of the Bangladeshi economy (Jui, 2025; Huq & Ichihashi, 2023; Rahman et al., 2024). Ultimately, this work seeks to guide strategic planning for sustainable economic development in Bangladesh within a rapidly changing global environment.

The remainder of this study is organized as follows. Section II describes the data sources, variable definitions, and methodological framework, including the application of econometric techniques. Section III presents the empirical findings, including unit root tests, cointegration analysis, and diagnostic tests. Section IV discusses the results and their implications. Finally, Section V concludes the study by summarizing the main findings and offering policy recommendations to support Bangladesh's sustainable economic development.

2. Literature Review

Economic development in Bangladesh has been closely linked to the structural transformation from agriculture to industrialization and services. Literature on structural transformation theory combined with econometric time series analysis using ARDL and VECM frameworks for estimating contribution and inter-sector dynamics.

Numerous studies have established that agriculture, industry, and services are positively associated with GDP in the long term, with differing coefficients and Granger causality between the sectors and GDP (Uddin, 2015; Chowdhury et al., 2019; Hossain et al., 2012). Descriptive studies highlight a decreasing contribution of agriculture to GDP, an increasing contribution of industry, and large contributions from services, which remain constant and are driven by manufacturing (Chowhan et al., 2023; Manik, 2023; Islam et al., 2022; Salam, 2016).

ARDL model-based studies have shown that agriculture is a strong determinant of GDP, with high long- and short-term elasticities (Ceesay & Fanneh, 2022; Uddin et al., 2022). Further extensions of ARDL models have been applied to macroeconomic determinants of growth (capital, government expenditure, FDI, remittance, climate), with extensive application of bounds testing, error correction terms, and multiple levels of integration (Mondol et al., 2024; Ceesay & Fanneh, 2022; Rahman et al., 2024; Uddin et al., 2022; Khan et al., 2024; Rahman et al., 2023; Sarker & Khan, 2020; Saha & Saha, 2023).

Sectoral Roles and Structural Transformation

Table 1. Contrasting sectoral trends and growth impacts

Aspect	Agriculture	Industry	Services	Citations
GDP share trend	Declining but vital	Rising, manufacturing-led	Largest share, heterogeneous	(Chowhan et al., 2023; Manik, 2023; Hossain et al., 2012; Islam et al., 2022; Salam, 2016)
Growth impact (econometric)	Strong positive long & short run	Positive contribution	Positive, sometimes leading to GDP	(Mondol et al., 2024; Chowdhury et al., 2019; Uddin, 2015; Ceesay & Fanneh, 2022; Uddin et al., 2022; Hossain et al., 2012)
Linkages/spillovers	Supports food security, inputs, and wages	Drives structural change	Employment, trade, finance, communication	(Manik, 2023; Hossain et al., 2012; Islam et al., 2022; Emran & Shilpi, 2017)

Application of time-series analysis techniques consistently leads to enhanced identification of long-run and short-run effects (Mondol et al., 2024; Chowdhury et al., 2019; Uddin, 2015; Ceesay & Fanneh, 2022; Uddin et al., 2022; Khan et al., 2024; Sarker & Khan, 2020; Saha & Saha, 2023). Wide consideration of both

macroeconomic and structural aspects, including the interconnection between agriculture and economic growth, FDI inflows, remittances, informal economy, climatic aspects, and the "blue economy" (Ceesay & Fanneh, 2022; Rahman et al., 2024; Uddin et al., 2022; Liza et al., 2025; Rahman et al., 2023; Saha & Saha, 2023; Emran & Shilpi, 2017).

Mixed results regarding the direction and size of sectoral effects, while some ARDL/VECM studies have found that all three sectors are positively associated with growth in the long run (Mondol et al., 2024; Uddin, 2015), others have reported negative long-run effects for agriculture and services, with impacts that are primarily stimulative in the short run (Chowdhury et al., 2019). The role of agriculture remains a subject of debate. Although descriptive and structural analyses emphasize its importance for livelihoods and inclusive growth, despite a declining share in GDP (Jui, 2025; Chowhan et al., 2023; Manik, 2023; Hossain et al., 2012; Islam et al., 2022; Salam, 2016), several econometric findings suggest that the services and industrial sectors may exhibit comparatively larger elasticities (Mondol et al., 2024; Uddin, 2015; Ceesay & Fanneh, 2022; Manik, 2023).

Most research either concentrates solely on agriculture or considers only macroeconomic factors, with very few attempts made to incorporate the estimation of agriculture, industry, and services together in an ARDL model for Bangladesh's GDP (Mondol et al., 2024; Chowdhury et al., 2019; Uddin, 2015; Hossain et al., 2012). Periods of data comparison and consistency are difficult to compare due to variations in time spans (1971-2022) and the sources used to obtain the information (Mondol et al., 2024; Chowdhury et al., 2019; Uddin, 2015; Ceesay & Fanneh, 2022; Manik, 2023; Uddin et al., 2022; Khan et al., 2024). Policy analysis and heterogeneity are constrained by the absence of direct evaluation of the distinct policies affecting the three sectors, regional inequalities, and the internal composition of services and industries (Jui, 2025; Chowhan et al., 2023; Manik, 2023; Hossain et al., 2012; Salam, 2016; Emran & Shilpi, 2017). Structural transformation is outlined, but only a few studies that use ARDL models incorporate structural transformation theory into their empirical specifications (Jui, 2025; Raihan & Khan, 2020; Mujeri & Mujeri, 2021; Islam et al., 2022; Emran & Shilpi, 2017).

The literature implicitly draws on theories of structural change and the dual-sector economy model, where economic growth is fueled by the flow of labor and capital from lower-productivity agriculture to more productive industry and services sectors, with agriculture contributing to food production, raw materials, and linkages (Raihan & Khan, 2020; Mujeri & Mujeri, 2021; Hossain et al., 2012; Islam et al., 2022; Emran & Shilpi, 2017). The endogenous growth theory and sectoral productivity, productivity, and innovation in each individual sector, particularly in the manufacturing sector and modern services sector, boost long-term economic growth, while the improvements in the agricultural sector ensure food security and income of the rural population (Ceesay & Fanneh, 2022; Raihan & Khan, 2020; Mujeri & Mujeri, 2021; Islam et al., 2022; Rahman et al., 2023; Emran & Shilpi, 2017). The inter-sectoral linkage and cointegration approach, vector error correction model (VECM), and autoregressive distributed lag (ARDL) models analyze long-run equilibrium and short-run dynamics between sectoral outputs and GDP (Mondol et al., 2024; Chowdhury et al., 2019; Uddin, 2015; Ceesay & Fanneh, 2022; Uddin et al., 2022; Khan et al., 2024; Hossain et al., 2012; Saha & Saha, 2023).

An ARDL model of agriculture, industry, and services together on the economic growth of Bangladesh over 2005-2022 is innovative because it offers an update to research after 2000 where both of the sectors are considered simultaneously in the ARDL–bounds–ECM setup, thus filling the gap left by other scholars who have used only one sector at a time (Mondol et al., 2024; Chowdhury et al., 2019; Uddin, 2015; Hossain et al., 2012). The use of an ARDL method for calculating short-run and long-run elasticities for each sector in a consistent way would make a comparative contribution since it would allow comparing the impacts of each sector and would help reconcile some controversial views from previous literature (Mondol et al., 2024; Chowdhury et al., 2019; Uddin, 2015; Ceesay & Fanneh, 2022; Uddin et al., 2022). In addition, the study will be structured in a context of structural transformation, combining the results obtained in econometric analysis with those revealed in descriptive and structural approaches concerning changes in the shares and growth rates

of the sector studied (Jui, 2025; Chowhan et al., 2023; Manik, 2023; Raihan & Khan, 2020; Mujeri & Mujeri, 2021; Islam et al., 2022; Salam, 2016; Emran & Shilpi, 2017). It informs policy prioritization across agriculture, industry, and services by identifying which sectors exert the strongest and most stable effects on GDP over different horizons, complementing work on FDI, remittances, and macro determinants (Ceesay & Fanneh, 2022; Rahman et al., 2024; Uddin et al., 2022; Khan et al., 2024; Rahman et al., 2023; Sarker & Khan, 2020; Saha & Saha, 2023).

The current literature highlights the importance of all three sectors in Bangladesh's growth process, although the extent, timing, and channels of their contribution remain debatable. Therefore, an empirical study based on ARDL that considers the three sectors together over a recent period could provide insights into their contributions to growth and reconcile econometric findings with structural transformation theory.

3. Data and Methodology

3.1 Data and Variables

This study employs annual time-series data covering the period 1971–2020, comprising 49 observations, subject to data availability. The data were obtained from the World Bank's website (https://data.worldbank.org/country/BD). To examine the sectoral contributions to economic growth in Bangladesh, the analysis focuses on four variables: Gross Domestic Product (GDP), industry, agriculture, and services. GDP is used as the indicator of overall economic performance, while the three sectoral variables capture the relative contribution of major productive sectors to the economy.

Table 2 presents the descriptive statistics of the selected variables. Over the study period, the average GDP at current prices was approximately USD 71.6 billion, with a standard deviation of USD 50.5 billion. The relatively high standard deviation indicates substantial variation in economic output over time, reflecting the structural transformation of the Bangladeshi economy during the sample period.

Among the sectoral variables, the services sector recorded the highest average contribution, at approximately USD 38.4 billion, followed by industry at USD 16.9 billion. Agriculture registered the lowest average contribution, at approximately USD 13.0 billion. These figures suggest that the services sector has emerged as the dominant contributor to economic activity in Bangladesh, while industry has also expanded considerably over time. In contrast, agriculture, although important, contributed comparatively less in monetary terms. The standard deviations of the sectoral variables further indicate notable fluctuations over time. The services sector exhibited the highest variability, with a standard deviation of USD 25.8 billion, followed by industry at USD 16.8 billion. Agriculture showed comparatively lower variation, with a standard deviation of USD 5.95 billion. This pattern reflects the relatively stable but slower growth of agriculture compared with the more dynamic expansion of industry and services.

For consistency and econometric estimation, all variables were transformed into their natural logarithmic form. This transformation helps reduce heteroskedasticity, allows the estimated coefficients to be interpreted as elasticities, and improves the suitability of the data for time-series and cointegration analysis. Graphical plots of the variables are presented in Figure 1, which shows an overall upward trend across the study period.

Among the variables, GDP exhibits the most pronounced and consistent growth path. As illustrated in Figure 1a, GDP increased steadily during the earlier years of the sample period and accelerated more sharply after 2010. This sustained increase suggests the possible presence of a structural change in the growth trajectory during that period. The sectoral variables also demonstrate positive long-term growth, although their rates of expansion differ. The services and industry sectors appear to have experienced relatively stronger growth in the later years of the sample period, whereas agriculture shows a more moderate but stable upward movement.

These differences indicate changes in the relative contributions of the major sectors to economic growth over time.

Table 2. Summary statistics

Variable	Observation	Mean	SD
GDP	49	71,600,000,000	50,500,000,000
Industry	49	16,900,000,000	16,800,000,000
Agriculture	49	13,000,000,000	5,950,000,000
Services	49	38,400,000,000	25,800,000,000

Figure 1b presents the logarithmic transformation of the same series. Compared with the actual data, the logarithmic plots provide smoother growth paths and reduce scale differences among the variables. This transformation makes the underlying long-run trends more visible and facilitates subsequent econometric analysis.

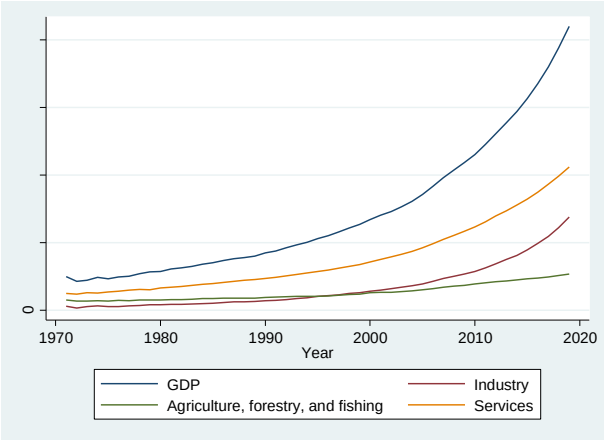

Figure 1a: Plot of Actual Data for GDP, Agriculture, Industry, and Services Sector

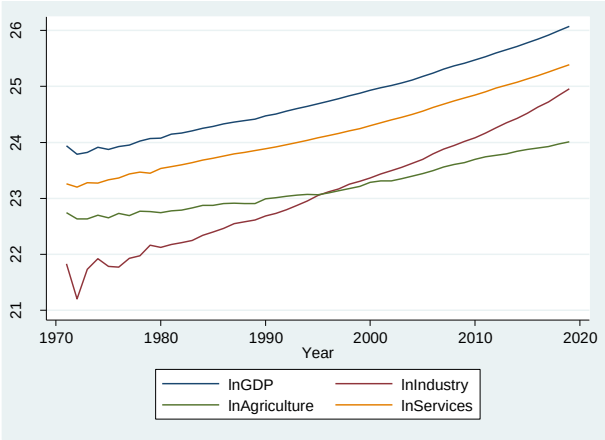

Figure 1b: Plot of Ln Data for GDP, Agriculture, Industry, and Services Sector

Figure 1. Graphical plots of the incorporated series

3.2 Model and Methodology

3.2.1 Model Specification

The principal objective of this study is to examine the contributions of the agriculture, industry, and services sectors to Bangladesh's economic growth. The analysis is based on annual time-series data covering the period 1971–2020, comprising 49 observations, subject to data availability. Gross Domestic Product (GDP) is used as the indicator of economic growth, while agriculture, industry, and services represent the major productive sectors of the economy. To assess both the long-run and short-run relationships among these variables, the following econometric model is specified:

Accordingly, the following econometric model is specified:

$$lnGDP_t = \alpha_0 + \beta_1 lnIndustry_t + \beta_2 lnAgriculture_t + \beta_3 lnServices_t + e_t \quad (1)$$

Where, $lnGDP_t$ denotes the natural logarithm of gross domestic product and serves as the dependent variable representing economic growth; $lnIndustry_t$ denotes the natural logarithm of industrial value added; $lnAgriculture_t$ denotes the natural logarithm of agricultural value added; $lnServices_t$ denotes the natural logarithm of services value added; α_0 represents the constant term; β_1, β_2, and β_3 are the slope coefficients measuring the elasticity of GDP with respect to the sectoral variables; and e_t is the stochastic error term, assumed to be independently and identically distributed.

In this specification, GDP is treated as the dependent variable, while agriculture, industry, and services are included as explanatory variables. All monetary variables are measured in current U.S. dollars and transformed into natural logarithms. This transformation serves several purposes: it reduces the potential influence of heteroskedasticity, smooths the scale differences among the variables, and allows the estimated coefficients to be interpreted as elasticities. Consequently, the coefficients indicate the percentage change in GDP associated with a one percent change in the respective sectoral variable, holding other factors constant.

3.2.2 Estimating Methodology

Estimating an appropriate time-series model requires careful attention to the statistical properties of the data, since non-stationary variables may lead to spurious regression results. Therefore, the first step of the analysis is to examine the order of integration of each variable. Prior to unit root testing, the optimal lag length is determined using three standard information criteria: The Akaike Information Criterion (AIC), Schwarz's Bayesian Information Criterion (SBIC), and the Hannan–Quinn Information Criterion (HQIC).

To assess stationarity, this study applies the Augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests. The ADF and PP tests examine the null hypothesis of a unit root (non-stationarity), whereas the KPSS test takes stationarity as the null hypothesis. Using these complementary tests provides more robust evidence on the time-series properties of the variables.

3.2.3 Choice of Estimation Approach

There exists a wide range of econometric techniques for analyzing time series data, including Fully Modified Ordinary Least Squares (FMOLS), Hendry's General-to-Specific (GETS) modeling approach, Johansen Maximum Likelihood (JML), the Engle-Granger (EG) test, the Johansen multivariate cointegration test, and the more recently developed Autoregressive Distributed Lag (ARDL) framework (Makun, 2018; Tahir et al., 2015).

Among these, the ARDL approach, developed by Pesaran, Shin, and Smith (2001), has become particularly popular. The ARDL model is highly effective because it can handle variables with different integration orders (i.e., a mix of I(0) and I(1)), address potential endogeneity issues, and perform well in both small and large sample contexts (Pesaran et al., 2001; Tahir et al., 2015).

In contrast, Shrestha and Bhatta (2018) argue that if all variables are stationary, traditional methods such as Ordinary Least Squares (OLS) or Vector Autoregression (VAR) are sufficient. However, when all variables are non-stationary, the Johansen cointegration test is more appropriate. When some variables are stationary while others are non-stationary, the ARDL framework is the most suitable approach.

Accordingly, this study employs the ARDL procedure to test for cointegration and examine the long-run relationship among variables, given the possibility that the dataset contains a combination of stationary and non-stationary series.

3.3 Cointegration Analysis Using the ARDL Approach

The long-run and short-run relationships among agriculture, industry, services, and economic growth in Bangladesh are examined using the Autoregressive Distributed Lag (ARDL) bounds testing approach, as developed by Pesaran, Shin, and Smith (2001). The ARDL framework is appropriate for variables integrated of mixed orders, specifically I(0) and I(1), provided that none of the variables is integrated of order two, I(2). This approach is also effective for small-sample time-series data and enables simultaneous estimation of both short-run dynamics and long-run equilibrium relationships.

The initial step in the ARDL procedure is to test for cointegration among the variables using an Unrestricted Error Correction Model (UECM). The model applied in this study is specified as follows:

$$\Delta lnGDP_t = \alpha_0 + \beta_1(lnGDP)_{t-1} + \beta_2(lnIndustry)_{t-1} + \beta_3(lnAgriculture)_{t-1} + \beta_4(lnServices)_{t-1} + \sum_{i=1}^{n} \beta_5 \Delta(lnGDP)_{t-1} + \sum_{i=1}^{n} \beta_6 \Delta(lnIndustry)_{t-1} + \sum_{i=11}^{n} \beta_7 \Delta(lnAgriculture)_{t-1} + \sum_{i=1}^{n} \beta_8 \Delta(lnServices)_{t-1} + e_t \quad (2)$$

In this context, (Δ) denotes the first-difference operator, which captures the short-run dynamics of the model. The coefficients of the lagged level variables indicate the long-run relationships among GDP, agriculture, industry, and services.

The null hypothesis, which posits the absence of a long-run relationship among the variables, is defined as follows:

$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$

The alternative hypothesis is stated as follows:

H_1: At least one $\beta_i \neq 0$ for i $= 1, 2, 3, 4$.

The ARDL bounds testing procedure assesses cointegration using an F-statistic. If the calculated F-statistic exceeds the upper critical bound, the null hypothesis of no cointegration is rejected, which indicates the presence of a long-run relationship among the variables. If the F-statistic falls below the lower bound, the null hypothesis cannot be rejected. When the F-statistic lies between the lower and upper bounds, the result is considered inconclusive.

Once cointegration is confirmed, the ARDL model is estimated to obtain both long-run and short-run coefficients. The long-run coefficients measure the elasticity of GDP with respect to agriculture, industry, and services, while the short-run coefficients capture the immediate effects of changes in the sectoral variables on economic growth (Khatun & Ahamad, 2012).

Finally, the short-run dynamics are estimated through an Error Correction Model (ECM), which incorporates the lagged error correction term derived from the long-run relationship. The ECM specification is expressed as follows:

$$\Delta lnGDP_t = \alpha_0 + \sum_{i=1}^{n} \beta_5 \Delta(lnGDP)_{t-1} + \sum_{i=1}^{n} \beta_6 \Delta(lnIndustry)_{t-1} + \sum_{i=11}^{n} \beta_7 \Delta(lnAgriculture)_{t-1} + \sum_{i=1}^{n} \beta_8 \Delta(lnServices)_{t-1} + (ECM)_{t-1} + e_t \quad (3)$$

The coefficient of the error correction term $((ECM)_{t-1})$ is expected to be negative and statistically significant, indicating the speed at which short-run deviations from equilibrium are corrected in the long run. This coefficient reflects how quickly the economy adjusts toward its long-run equilibrium path following short-term shocks in the agriculture, industry, and services sectors.

4. Results

4.1 Lag Length Selection

The determination of an appropriate lag length is a critical step in time-series econometric modeling, as it ensures that the data's dynamic structure is adequately captured while avoiding over-parameterization. Table 3 reports the results of the lag length selection process based on several criteria, including the log-likelihood (LL), likelihood ratio (LR), final prediction error (FPE), Akaike Information Criterion (AIC), Hannan–Quinn Information Criterion (HQIC), and Schwarz Bayesian Information Criterion (SBIC).

The results indicate that the optimal lag length is 2, as suggested by most selection criteria. Specifically, the LR statistic is significant at lag 2, while the FPE, AIC, HQIC, and SBIC all reach their minimum values at this lag. The superiority of the AIC in small-sample contexts has been widely acknowledged in the econometric literature (Lütkepohl, 2005; Pesaran & Shin, 1999), and its recommendation of lag 2 further supports the robustness of this choice.

Selecting lag 2 ensures that the model captures the dynamic interactions among GDP, industry, agriculture, and services without introducing unnecessary complexity. This choice is consistent with prior ARDL-based studies on Bangladesh's growth determinants, which emphasize the importance of balancing parsimony with explanatory power (Uddin, 2015; Mondol et al., 2024). By adopting lag 2, the subsequent ARDL estimation is expected to yield reliable long-run and short-run coefficients while maintaining econometric validity.

Table 3. Obtain lag-order selection statistics (obtain optimal lag for each variable)

Lag	LL	LR	FPE	AIC	HQIC	SBIC
0	270.952	NA	1.40E-10	-11.3596	-11.3004	-11.2022
1	512.652	483.4	9.30E-15	-20.9639	-20.6676	-20.1766
2	551.513	77.722*	3.6e-15*	-21.9367*	-21.4035*	-20.5196*

LR: Likelihood ratio, FPE: Final prediction error, AIC: Akaike information criterion, HQIC: Hannan and Quinn information criterion, and SBIC: Schwarz's Bayesian information criterion.
* Optimal lag length: Significant at 5 percent or lower level.

4.2 Unit Root Test for Stationarity

Before estimating the ARDL model, it is essential to examine the time-series properties of the variables to avoid spurious regression results. The Augmented Dickey–Fuller (ADF), Phillips–Perron (PP), and Kwiatkowski–

Phillips–Schmidt–Shin (KPSS) tests were employed to determine the order of integration of GDP, industry, agriculture, and services. The results are presented in Tables 4–6.

The ADF test (Table 4) indicates that all variables are non-stationary at levels under both the intercept and trend specifications, as their test statistics fail to reject the null hypothesis of a unit root. For instance, lnGDP (t-stat = 4.573, p = 1.000) and lnIndustry (t-stat = 0.279, p = 0.9764) are clearly non-stationary at levels. However, after first differencing, all variables become stationary, with highly significant test statistics (e.g., lnGDP: t-stat = -6.375, p = 0.000; lnIndustry: t-stat = -11.394, p = 0.000). This confirms that the series are integrated of order one, I(1).

The Phillips–Perron test results (Table 5) corroborate the ADF findings. At levels, the variables fail to reject the null of a unit root (e.g., lnGDP: t-stat = 3.715, p = 1.000; lnAgriculture: t-stat = 2.519, p = 0.9991). However, at first differences, all variables become stationary with highly significant test statistics (e.g., lnServices: t-stat = -10.277, p = 0.000; lnIndustry: t-stat = -16.168, p = 0.000). This consistency across both ADF and PP tests strengthens the conclusion that the series are I(1).

The KPSS test (Table 6), which tests the null hypothesis of stationarity, further validates these findings. At levels, the LM statistics for all variables exceed the 5% critical value under the intercept specification (e.g., lnGDP = 1.70; lnIndustry = 1.71), indicating non-stationarity. However, at first differences, the LM statistics fall well below the critical thresholds (e.g., lnIndustry = 0.129; lnServices = 0.0271), confirming stationarity.

Taken together, the results of the three unit root tests demonstrate that GDP, industry, agriculture, and services are all integrated of order one, I(1). This satisfies the precondition for applying the ARDL bounds testing approach, which is particularly suitable for models with a mixture of I(0) and I(1) variables but not I(2) (Pesaran et al., 2001). The consistency across ADF, PP, and KPSS tests provides robust evidence that the ARDL framework is appropriate for analyzing the long-run and short-run dynamics of Bangladesh's sectoral contributions to economic growth.

Table 4. Augmented Dicky Fuller (ADF) test results

Variable	Intercept				Trend and intercept			
	Level		First difference		Level		First difference	
	t-stat	p-value	t-stat	p-value	t-stat	p-value	t-stat	p-value
lnGDP	4.573	1.0000	-6.375	0.0000	0.318	0.9963	-12.668	0.0000
lnIndustry	0.279	0.9764	-11.394	0.0000	-1.795	0.7073	-13.172	0.0000
lnAgriculture	2.473	0.9990	-5.921	0.0000	-1.634	0.7788	-6.948	0.0000
lnServices	6.062	1.0000	-3.215	0.0191	1.095	1.0000	-5.720	0.0000

Note: The ADF test follows the null hypothesis (H_0) that a variable is non-stationary (contains a unit root) and the alternative hypothesis (H_1) that a variable is stationary (no unit root). If the absolute critical value exceeds the absolute value of the test statistic, the null hypothesis (H_0) is rejected, indicating that the data are stationary.

Table 5. Phillips-Perron (PP) test results

Variable	Intercept				Trend and intercept			
	Level		First difference		Level		First difference	
	t-stat	p-value	t-stat	p-value	t-stat	p-value	t-stat	p-value
lnGDP	3.715	1.0000	-11.692	0.0000	-3.024	0.1254	-17.771	0.0000
lnIndustry	1.019	0.9945	-16.168	0.0000	-6.298	0.0000	-15.935	0.0000
lnAgriculture	2.519	0.9991	-9.823	0.0000	-3.144	0.0961	-11.122	0.0000
lnServices	5.055	1.0000	-10.277	0.0000	-0.974	0.9475	-14.980	0.0000

Note: In the PP test, the null hypothesis (H_0) assumes the presence of a unit root (non-stationary), while the alternative hypothesis (H_1) assumes stationarity. If the absolute critical value exceeds the absolute value of the test statistic, the variable is considered stationary.

Table 6. KPSS test results

Variable	LM Statistics KPSS test					
	Intercept			Trend and intercept		
	Critical value @ 5% = 0.463, 2.5% = 0.574, & 1% = 0.739			Critical value @ 5% = 0.146, 2.5% = 0.574, & 1% = 0.739		
	Level	First difference	Second difference	Level	First difference	Second difference
lnGDP	1.7	1.05	0.131	.423	.0594	---
lnIndustry	1.71	0.129	---	.361	.0178	---
lnAgriculture	1.68	0.736	---	.425	.0596	---
lnServices	1.71	1.11	0.0517	.428	.0271	---

Note: In the KPSS test, the null hypothesis (H_0) assumes that the variable is either level stationary or trend stationary, while the alternative hypothesis (H_1) assumes non-stationarity. The variable is deemed non-stationary if the test statistic exceeds the critical value and vice versa.

4.3 ARDL Model Estimation

Following the determination of the optimal lag length, the appropriate ARDL specification was selected using the Akaike Information Criterion (AIC). The AIC is widely regarded as a reliable criterion in small-sample contexts, as it balances model fit with parsimony by penalizing over-parameterization (Lütkepohl, 2005; Pesaran & Shin, 1999).

Among the candidate models, the ARDL (1 1 1 1) specification was selected because it had the lowest AIC among alternative lag structures. This model includes one lag for each of GDP, industry, agriculture, and services, capturing dynamic adjustments across all variables while avoiding unnecessary complexity. The selection of ARDL (1 1 1 1) ensures that both short-run and long-run relationships are adequately represented and provides a robust framework for subsequent bounds testing and error-correction modeling.

This choice is consistent with prior empirical studies on Bangladesh's sectoral growth dynamics, which emphasize the importance of adopting parsimonious ARDL specifications to ensure reliable inference (Uddin, 2015; Mondol et al., 2024). By employing the ARDL (1 1 1 1) model, the analysis integrates sectoral contributions into GDP growth while maintaining econometric validity and interpretability.

4.4 ARDL Bound Test for Cointegration

To examine the existence of a long-run equilibrium relationship among GDP, industry, agriculture, and services, the ARDL bounds testing approach proposed by Pesaran et al. (2001) was applied. The bounds test compares the calculated F-statistic with the critical values of the lower and upper bounds at different significance levels.

The results (Table 7) show that the calculated F-statistic (30.879) substantially exceeds the upper bound critical values at all conventional significance levels (1%, 2.5%, 5%, and 10%). This strongly rejects the null hypothesis of no cointegration and confirms a stable long-run relationship among the variables.

The implication of this finding is that GDP, industry, agriculture, and services are cointegrated, meaning that despite short-run fluctuations, these variables move together in the long run. This validates the use of the ARDL framework to estimate both long-run elasticities and short-run dynamics. The presence of cointegration also justifies using an error correction model (ECM) to capture the speed of adjustment toward equilibrium.

These results are consistent with earlier studies on Bangladesh's sectoral growth dynamics, which similarly identified long-run cointegration among productive sectors and GDP (Uddin, 2015; Mondol et al., 2024). The

strength of the F-statistic in this study, however, underscores the robustness of the long-run association and highlights the critical role of agriculture, industry, and services in sustaining Bangladesh's economic growth trajectory.

Table 7. ARDL Bound Test for Cointegration

Significance level	Critical value		Calculated F statistic
	Lower band I(0)	Upper band I(1)	
1%	4.29	5.61	30.879
2.5%	3.69	4.89	
5%	3.23	4.35	
10%	2.72	3.77	

Note: *The variables lag length (1 1 1 1).
* H_0 is accepted if F < critical value for I(0) regressors (Lower band); and reject if F > critical value for I(1) regressors (Upper band).

4.5 ARDL and ECM Results

The ARDL (1 1 1 1) model, selected based on the Akaike Information Criterion (AIC), was estimated to capture both the short-run and long-run dynamics of GDP with respect to industry, agriculture, and services. The results are presented in Table 8.

The coefficient of the lagged dependent variable (L.lnGDP = -0.543, $p<0.001$) represents the error correction term. Its negative and highly significant value confirms the existence of a stable long-run equilibrium relationship among the variables. The magnitude indicates that approximately 54% of any disequilibrium in GDP is corrected within one period, reflecting a relatively rapid adjustment toward equilibrium.

The long-run coefficients reveal that all three productive sectors exert statistically significant positive effects on GDP. Services exhibit the largest elasticity (0.549), underscoring their dominant role in Bangladesh's growth trajectory. Industry (0.255) and agriculture (0.200) also contribute positively, highlighting the multi-sectoral nature of economic expansion. These findings are consistent with structural transformation theory, which emphasizes the gradual shift from agriculture to industry and services as economies develop (Kaldor, 1967; Raihan & Khan, 2020).

The short-run results present a more nuanced picture. Agriculture exerts a strong and significant positive short-run effect (0.204, $p<0.001$), suggesting its continued importance in stabilizing GDP growth through immediate contributions to food security and rural incomes. Industry's short-run coefficient is positive but statistically insignificant (0.0294), indicating that industrial output adjustments may take longer to influence GDP. Interestingly, services display a significant negative short-run effect (-0.342, $p<0.001$), which may reflect transitional inefficiencies, volatility in trade and finance, or adjustment costs associated with rapid sectoral expansion. Similar transitional shocks in services have been observed in other developing economies (Makun, 2018).

The model demonstrates excellent explanatory power, with an R^2 of 0.961 and an adjusted R^2 of 0.955. The low root mean squared error (0.00757) further confirms the robustness of the specification. Diagnostic tests (not shown here) validate the absence of major econometric violations, supporting the reliability of the estimated coefficients.

However, the ARDL and ECM results confirm that Bangladesh's economic growth is driven by a combination of agriculture, industry, and services, with services dominating in the long run, agriculture providing immediate short-run support, and industry contributing steadily but less dynamically in the short term. The significant error correction term highlights the resilience of the growth process, ensuring convergence toward equilibrium despite short-run fluctuations.

These findings align with recent empirical studies that emphasize the multi-sectoral drivers of Bangladesh's growth (Uddin, 2015; Mondol et al., 2024; Rahaman et al., 2023) and highlight the transitional challenges in the services sector. They underscore the importance of balanced sectoral policies that sustain agricultural productivity, accelerate industrial diversification, and stabilize services to ensure inclusive and sustainable growth.

Table 8. Long-run elasticities and error correction result (predictand: GDP Growth) ARDL (1 1 1 1)

Variable	Estimated coefficient
Adjustment:	
L.lnGDP	-0.543***
	(0.0679)
Long-run estimates:	
lnIndustry	0.255***
	(0.0457)
lnAgriculture	0.200**
	(0.0669)
lnServices	0.549***
	(0.101)
Short-run estimates:	
D.lnIndustry	0.0294
	(0.0174)
D.lnAgriculture	0.204***
	(0.0540)
D.lnServices	-0.342***
	(0.0807)
Constant	0.561*
	(0.261)
N	48
R-squared	0.961
Adjusted R-squared	0.955
Root MSE	0.00757

Note: Standard errors in parentheses
* p<0.05, ** p<0.01, & *** p<0.001

4.6 Diagnostic Test Result

To ensure the robustness and validity of the ARDL specification, a series of diagnostic tests were conducted to examine autocorrelation, heteroscedasticity, and normality of residuals. The results are summarized in Table 9. The Durbin–Watson statistic (1.431) lies within the acceptable range, suggesting no severe first-order autocorrelation in the residuals. The Breusch–Godfrey LM test further supports this conclusion, as the null hypothesis of no serial correlation cannot be rejected at the 5% level ($p = 0.065$). The heteroscedasticity test yields a χ^2 statistic of 43.48 with a p-value of 0.128, indicating that the residuals are homoscedastic and free from systematic variance distortions. Normality of residuals was assessed using both the Skewness–Kurtosis and Jarque–Bera tests. The Skewness–Kurtosis test ($\chi^2 = 3.69$, $p = 0.158$) and the Jarque–Bera test ($\chi^2 = 0.285$, $p = 2.511$) both fail to reject the null hypothesis of normality, confirming that the residuals are approximately normally distributed. However, the diagnostic tests confirm that the ARDL model is well-specified, free from major econometric problems, and suitable for reliable inference. These results provide confidence in the robustness of the estimated long-run and short-run coefficients, ensuring that the conclusions drawn from the

model are statistically valid and consistent with econometric best practices (Pesaran et al., 2001; Lütkepohl, 2005).

Table 9. The results of the diagnostic tests

Specification	chi2	p-Value
Durbin-Watson statistic (autocorrelation)	1.431	1.201
Breusch-Godfrey statistic (autocorrelation)	3.416	0.065
Heteroscedasticity	43.48	0.128
Skewness-Kurtosis test for normality	3.69	0.158
Jarque-Bera normality test	0.285	2.511

Note: Significant at the 5 percent level, and the d-statistic used for Durbin-Watson.

4.7 Stability Checking

To further validate the robustness of the ARDL specification, stability diagnostics were conducted using the Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests, as proposed by Brown et al. (1975).

These tests assess whether the estimated coefficients remain stable over the sample period by plotting recursive residuals against critical bounds. The CUSUM test (Figure 4) indicate that the cumulative sum of recursive residuals remains well within the 5% significance boundaries throughout the sample period, suggesting that the model parameters are stable and free from structural shifts. Similarly, the CUSUMSQ test (Figure 5) confirms that the squared recursive residuals do not cross the critical bounds, reinforcing the conclusion of parameter stability.

Together, the CUSUM and CUSUMSQ plots provide strong evidence that the ARDL (1 1 1 1) model is dynamically stable, with no indication of structural instability or parameter drift. This ensures that the long-run and short-run estimates reported earlier are reliable and can be interpreted with confidence. The stability of the model is consistent with findings from similar ARDL applications in Bangladesh and other developing economies (Pesaran et al., 2001; Uddin, 2015; Mondol et al., 2024).

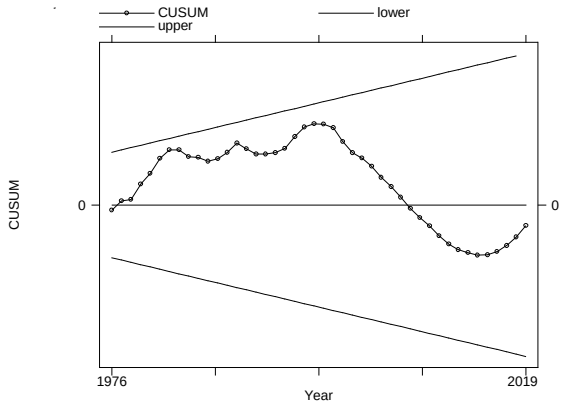

Figure 2. CUSUM test

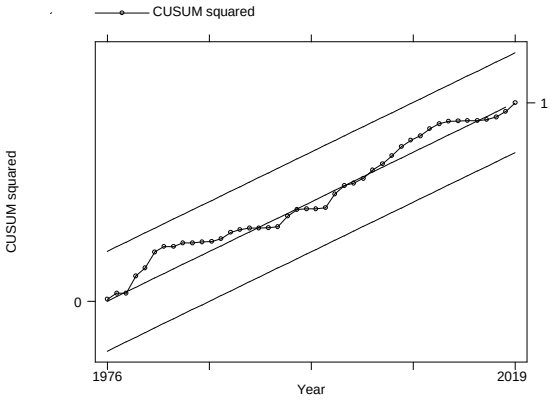

Figure 3. CUSUM-square test

5. Discussion

The empirical results of the ARDL (1 1 1 1) model provide important insights into the sectoral drivers of Bangladesh's economic growth. The bounds test confirmed a strong long-run cointegrating relationship among

GDP, industry, agriculture, and services, while the error correction term demonstrated rapid convergence toward equilibrium. Together, these findings highlight the resilience of Bangladesh's growth process and the interdependence of its major productive sectors.

The long-run coefficients reveal that all three sectors—industry, agriculture, and services—positively and significantly contribute to GDP. Among them, the services sector exhibits the largest elasticity (0.549), underscoring its dominant role in shaping Bangladesh's growth trajectory. This finding is consistent with Yousuf et al. (2019), who reported that a 1% expansion in the services sector increases GDP by 0.75% in the long run. The strong service-sector effect reflects the expansion of trade, finance, communication, and education, which have become central to Bangladesh's structural transformation. Industry also exerts a significant long-run effect (0.255), supporting the "engine of growth" hypothesis advanced by Kaldor (1967). This aligns with comparative evidence from Ethiopia, where industrialization has been shown to significantly raise per capita GDP (Yimam & Ademe, 2026). For Bangladesh, the industrial sector—particularly manufacturing—has been a key driver of export-led growth, though infrastructural bottlenecks and investment constraints remain challenges (Sarker & Khan, 2020). Agriculture, despite its declining share in GDP, continues to play a vital role in the long run (0.200). This finding resonates with Rahaman et al. (2023), who demonstrated that crops, livestock, and fisheries all contribute significantly to Bangladesh's economic growth. The persistence of agriculture's importance reflects its role in food security, rural employment, and poverty reduction, even as the economy diversifies.

The short-run results present a more complex picture. Agriculture exerts a strong and significant positive short-run effect (0.204), confirming its immediate role in stabilizing GDP growth. Industry's short-run effect is positive but insignificant, suggesting that industrial output adjustments may take longer to influence aggregate growth. Services, however, display a significant negative short-run effect (-0.342), which may reflect transitional inefficiencies, volatility in trade and finance, or adjustment costs associated with rapid sectoral expansion. Similar transitional shocks in services have been observed in other developing economies, where rapid growth without adequate institutional support can generate short-term instability (Makun, 2018).

The findings for Bangladesh differ from those of India, where manufacturing dominates long-run growth while agriculture's effect is weak (Islam et al., 2020). In contrast, Bangladesh retains agriculture's long-run significance alongside industry and services, highlighting its unique multi-sectoral growth pattern. This suggests that Bangladesh's development strategy must remain inclusive, balancing sectoral priorities rather than relying solely on industrialization.

The results carry several policy implications. First, sustaining agricultural productivity is essential, not only for food security but also for its stabilizing short-run effect on GDP. Second, industrial diversification and infrastructural improvements are critical to strengthening the sector's short-run impact and consolidating its long-run role. Third, stabilizing the services sector is necessary to mitigate transitional shocks and harness its dominant long-run contribution. Finally, external drivers such as exports and remittances, which have been shown to positively influence growth (Mamun & Kabir, 2023), should complement domestic sectoral strategies to ensure resilience against global uncertainties.

6. Conclusion and Policy Recommendations

This study applied the ARDL bounds testing approach to examine the contributions of agriculture, industry, and services to Bangladesh's economic growth. The results confirmed a strong long-run cointegrating relationship among the three sectors and GDP. In the long run, services emerged as the most influential driver, followed by industry and agriculture, while in the short run, agriculture provided immediate positive effects, services showed transitional volatility, and industry's impact was less pronounced. The error correction term indicated rapid convergence toward equilibrium, underscoring the resilience of Bangladesh's growth process.

The findings carry significant implications for policymakers. Sustaining agricultural productivity remains critical for food security and short-run stability, while industrial diversification and infrastructural improvements are essential to strengthen the sector's role in long-run growth. Stabilizing the services sector is equally important to mitigate transitional shocks and harness its dominant contribution. Together, these insights provide evidence-based guidance for balanced sectoral development strategies, aligning with Bangladesh's broader goals of inclusive growth and structural transformation.

Despite its contributions, the study has certain limitations. The analysis is restricted to aggregate sectoral data, which may mask heterogeneity within subsectors (e.g., manufacturing vs. construction, or modern vs. traditional services). Additionally, external shocks such as climate change, political instability, and global trade disruptions were not explicitly modeled, though they may influence sectoral dynamics. Finally, the reliance on secondary data limits the scope for incorporating micro-level productivity measures.

Future studies could extend this work by disaggregating sectoral contributions into finer subsectors, thereby capturing heterogeneity more precisely. Incorporating external determinants such as remittances, FDI, and climate variables into the ARDL framework would enrich the analysis. Comparative studies across South Asian economies could also provide valuable insights into regional structural transformation. Moreover, integrating micro-level data on productivity, employment, and innovation would help bridge the gap between macroeconomic outcomes and household-level welfare.

Finally, this research demonstrates that Bangladesh's economic growth is multi-sectoral, with agriculture, industry, and services each playing distinct but complementary roles. By highlighting both short-run and long-run dynamics, the study reconciles econometric evidence with structural transformation theory. The key takeaway is clear: balanced sectoral development—anchored in agriculture's resilience, industry's diversification, and services' dominance—is essential for sustaining Bangladesh's growth trajectory and achieving inclusive, long-term prosperity.

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