



Macroeconomic Determinants of Foreign Exchange Reserves in Bangladesh: Evidence from the ARDL Bounds Testing Approach

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Abstract The study empirically examines the macroeconomic determinants of Foreign Exchange Reserve (FER) in Bangladesh using Auto Regressive Distributed Lag (ARDL) Model by using the data for the period of 1980 to 2024. Prior to estimation, the stationarity properties of the variables are examined using Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and KPSS tests. The results indicate that the variables are integrated of order I (0), I (1), or a mixture of both, with no evidence of I (2) behavior, thereby supporting the use of the ARDL framework. The bounds test confirms the presence of a long-run relationship among Foreign Exchange Reserves (FER), Personal Remittances (PR), Foreign Direct Investment (FDI), Foreign Loans and Grants (FLG), and the Current Account Balance (CAB). The long-run estimates show that foreign loans and grants and the current account balance are positively and significantly associated with Bangladesh's foreign exchange reserves. By contrast, personal remittances and foreign direct investment show positive but statistically insignificant long-run coefficients in the preferred specification. The error correction term is negative and statistically significant, indicating adjustment toward long-run equilibrium after short-run deviations. Diagnostic and stability tests suggest that the model is free from serial correlation, heteroskedasticity and major functional-form problems, and remains stable over the sample period. The findings suggest that strengthening the current account position and reducing excessive reliance on debt-creating inflows are important for sustainable reserve management in Bangladesh.

Keywords: Foreign Exchange Reserves; Bangladesh; ARDL Bounds Test; Current Account Balance; Foreign Loans and Grants; External Sector Stability.

JEL Classification: F31, F32, F21, F24, F34, C22.

1 Introduction

Foreign Exchange Reserve (FER) refers to the supply of foreign currency held by a country. FER was defined by the IMF in 2000 as “foreign reserve defined as the external stock of assets, which is available to the country’s monetary authorities to cover external payment imbalances or to influence the exchange rate of the domestic currencies through intervention in the exchange market or for other purposes”.

The interest in the topic of Foreign Exchange Reserve (FER) arose after the Asian Financial Crisis of 1990s (Aizenman and Marion, 2002; Lane and Burke, 2001). In that crisis, countries with larger reserve holdings (Singapore, Taiwan) were least affected. A healthy FER is

a sensitive indicator for any government from economic and political perspectives. Therefore, FER has been considered an effective tool for policymakers in the Asia-Pacific region. Due to its importance, the IMF urges maintaining a FER that can be used to pay off four-month equivalent import bill payments.

There are two schools of thought regarding whether a country should hold a large volume of foreign exchange reserves. One school of thought points out that holding more reserves is costly. They argue that, reserve held in dollar-denominated treasuries usually earn a modest return. It usually lies far below the government’s own cost of borrowing. The critic also points that; yield on the reserve fund is significantly lower. They think that,

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if the reserve were to invest in the economy, it would earn higher profit.

Most of the FER-holding countries are concentrated in Asia. The paper, therefore, investigates the determinants of FER in Bangladesh, a South Asian emerging economy. This study is motivated by the recent fluctuations in FER holdings by Bangladesh. The country has experienced a record stockpile of FER of 48.06 billion USD in August 2021. It has also experienced a sharp decline and hovered around 21.39 billion USD in 2024.

This study examines the short-run and long-run macroeconomic determinants of foreign exchange reserves in Bangladesh using annual time-series data from 1980 to 2024. The specific aim is to develop a model that can determine the accumulation of FER by utilizing WDI data in the context of Bangladesh. By doing so, this study tries to find out the strength of various factors which is associated with FER.

This study will apply an ARDL model. ARDL is appropriate because of three reasons. First, it examines the stationary properties of variables using ADF, PP and KPSS tests. Second, it tests for a long-run relationship among the variables. Third, it distinguishes between long-run coefficients and short-run adjustment dynamics through an error correction representation. This is particularly relevant for Bangladesh because reserve movements may respond differently to immediate external inflows and to longer-term structural changes in the current account position. The study conducts diagnostic tests for serial correlation, heteroskedasticity, model specification and residual normality, along with CUSUM and MOSUM stability tests.

The study contributes to the literature in three ways. First, it updates the empirical evidence on Bangladesh by using a longer annual dataset covering 1980–2024. Second, it applies a time-series methodology that is more suitable for variables with mixed $I(0)$ and $I(1)$

properties. Third, it provides policy-relevant evidence on the relative importance of debt-creating and non-debt-creating external inflows for reserve accumulation. The findings indicate that foreign loans and grants and the current account balance are positively and significantly associated with foreign exchange reserves in the long run, while remittances and FDI are not statistically significant in the preferred long-run specification. These results suggest that reserve management policy should place greater emphasis on improving the current account position and strengthening sustainable external inflows.

The remainder of the paper is organized as follows. Section 2 presents the objectives of the study. Section 3 reviews the relevant literature. Section 4 discusses the theoretical framework and variable selection. Section 5 describes the data and methodology. Section 6 presents the empirical results. Section 7 discusses the findings and policy implications. Section 8 concludes the paper.

2 Objective of the Study

The broad objective of this study is to examine the short-run and long-run macroeconomic determinants of foreign exchange reserves in Bangladesh using an appropriate time-series econometric framework.

The specific objectives of the study are:

- i To examine the time-series properties of foreign exchange reserves and selected macroeconomic variables by applying unit-root tests.
- ii To investigate whether a long-run relationship exists among Foreign Exchange Reserves, personal remittances, foreign direct investment, foreign loans and grants, and Current Account Balance in Bangladesh.
- iii To estimate the short-run and long-run associations between foreign exchange reserves and selected external-sector vari-

- ables using the ARDL bounds-testing approach.
- iv To assess the stability and diagnostic reliability of the estimated model through serial-correlation, heteroskedasticity, functional-form, residual-normality and parameter-stability tests.
 - v To provide policy-relevant insights for strengthening Bangladesh's foreign exchange reserve position based on the empirical findings.

3 Literature Review

3.1 Conceptual Background

Foreign Exchange Reserve (FER) or FX Reserve refers to external stock or deposit of foreign currency currently being held by the central bank or monetary authority of a country to cover external payment imbalance or to influence the exchange rate of domestic currency or for other purposes (Chowdhury et al., 2014; Irefin and Yaaba, nd; Khomo et al., 2018; Salas et al., 2025). FER is held by a central bank in the form of foreign currency, foreign bonds and precious metal such as gold and silver (Ali and Ismail, 2024).

Earlier, FER were held in gold. But after the advent of the Bretton-Woods system US dollar was pegged to gold, and the gold standard was abandoned (Irefin and Yaaba, nd). Nowadays, FER comprises various international currencies, including the US Dollar, Yen, Euro, IMF Special Drawing Rights (SDR) and Gold. US Dollar is the most common currency available in reserves of most countries (Chowdhury et al., 2014).

3.2 Importance of FER

During the Bretton-Woods system, FER was used by the central banks to maintain the value of their respective currencies. However, after the breakdown of Bretton-Woods in the 1970s, the importance of FER has reduced

in keeping the value of currencies (Prabheesh et al., 2007). FER also plays an important role in any country as it provides liquidity coverage and face future contingencies and sudden changes in capital flows (Lanteri, 2013). Having a high level of FER also plays a role as a deterrent against speculation (Salas et al., 2025). A study conducted by (Lane and Burke, 2001) shows that, smaller and more volatile countries usually hold larger amounts of FER than those of less volatile countries. Countries are showing interest in accumulating FER for macroeconomic stability. Therefore, central banks increase their reserve in response to greater exposure to external shocks (Olokoyo et al., 2009).

However, the large accumulation of FER by the emerging countries has distorted the global balance of FER (Delatte and Fouquau, 2011). Emerging economies have saved a lot of money, and these extra savings have been enough to cancel out the impact of America's trade deficit. As a result, global interest rates have gone down (Bernanke, 2005).

Several objectives of holding Foreign Exchange Reserve (FER) by developing countries have been identified by (Blackman, 1981). These are maintaining the availability of Foreign Currency (FC) to sell to the commercial banks, precautions against "rainy day", maintenance of value of local currency and political considerations. (Chen et al., 2007) mentioned another objective of holding FER which is to gain confidence of international creditors, international investors, rating agencies and international business community. An optimum FER assures them that they will be able to repatriate their profit to home country along with their investment.

3.3 Theories Motivating FER

Some countries accumulate FER to create a barrier against the unexpected withdrawal of Foreign Exchange. This theory is called as "Precautionary Motive Theory" of FER.

Few countries accumulate Foreign Exchange to control exchange rates to support the export sector. Such moves by countries are often termed as “Mercantilist Motives Theory” (Karim et al., 2021).

3.4 Cost of Reserve Accumulation

IMF urges every country to hold FER equivalent to mitigate a four-month import bill. If a country holds more or less than the optimum level of FER, there will be problems.

If a country holds a higher level of reserves as a buffer, the domestic investment will be low and GDP will be reduced. On the other hand, if a country holds less than the optimum level of FER, it will face volatility in maintaining the value of the currency (Clark, 1970). The high amount of reserves accumulation by the countries is reducing marginal benefits and raising marginal costs which indicates that every country should have the appropriate amount of FER (Irefin and Yaaba, nd).

3.5 Determinants of FER

FER of a country depends on Economic size, Current Account Vulnerability, Capital Account, Exchange Rate and Opportunity cost (Gosselin and Parent, 2005). In another study (Aizenman and Marion, 2003), conducted on 122 countries over the period 1980-86, reveals a population of the country, real GDP per capita, volatility of real export receipts, share of imports to GDP and volatility of the Nominal Effective Exchange Rate as a set of explanatory variables in determining FER. These factors explained 88% of the variations in reserve accumulation.

3.5.1 Foreign Direct Investment (FDI)

Foreign Exchange Reserve (FER) plays a pivotal role in attracting Foreign Direct Investment. A good amount of FER represents a secure environment for currency transactions, which is key to investor confidence and economic growth (United Nations Conference on

Trade and Development, 2021). FDI is essential for a country as it provides capital input to the economy, which ultimately expedite economic growth and progress (Thakur, 2024).

3.5.2 Balance of Payment and Current Account Balance (CAB)

Balance of Payments (BOP) represents the systematic record of all economic transactions between a country and the rest of the world over a specific period. It consists primarily of the current account, capital account, and financial account, reflecting trade balance, capital inflows, and financial transfers. A surplus in the BOP indicates that a country receives more foreign currency than it spends, thereby contributing positively to the accumulation of Foreign Exchange Reserves (FER). Conversely, a deficit in the BOP implies higher outflows than inflows, leading to depletion of reserves. According to standard macroeconomic theory, persistent current account deficits exert downward pressure on reserves unless offset by capital inflows such as FDI or foreign borrowing. Empirical studies (Khomu et al., 2018) have demonstrated that improvements in BOP position significantly enhance reserve accumulation in developing economies. In the context of Bangladesh, where trade deficits are common due to high import dependency, the role of BOP becomes crucial in determining reserve dynamics. Therefore, BOP is expected to have a positive relationship with FER, as an improvement in BOP contributes to reserve accumulation.

3.5.3 Foreign Loan and Grant (FLG)

A country needs large funds and loans for implementing large development projects. Many countries, as well as various organizations within a country, take loans from other countries, banks or international organizations. Countries use foreign loans for various development activities. When foreign loan and Grant (FLG) enters into a country, its FER

increases (Anwar et al., 2019). However, when countries repay the loan, their FER reduces.

3.6 Global and Regional Trends

Due to its contribution in stabilizing the macro economy of a country, research on FER has gained momentum since 1980s (Chowdhury et al., 2014). Holding of FER by countries, especially by East Asian Countries has been increasing since East Asian Crisis 1997-1998 (Prabheesh et al., 2007). Until 2000, many countries accumulated FER out of a precautionary motive, a safety buffer against potential future financial or economic shocks. However, since 2000, countries are accumulating FER to support monetary policy and exchange rate policy (Arslan and Cantú, 2019; Rana, 2024). China achieved the top position in the accumulation of FER in 2008. Prior to that, Japan was in the top of the list (Gantt, 2010).

In recent years, Asian Central Banks have accumulated a large amount of FER (Gosselin and Parent, 2005). IMF (2001) in a study concluded that FER in Asia has reached a point where some slowdown in the process of accumulation is needed. In 1997-98, East Asian Countries faced a financial crisis. Since then, most of the developing and middle-income emerging countries have been involved in accumulating foreign reserves more than the standard requirement. The standard requirement is the ability to cover the import bill for three months (Ali and Ismail, 2024; Kim, 2025).

3.7 FER in Bangladesh Perspective

Most of the developed countries have strong financial markets. These markets are sufficiently deep to absorb and manage the shocks (Williams, 2005). The management of the Foreign Exchange Reserve is hardly an issue for them. The importance of FER for developed countries reduces with the advent of general floating of currencies (Blackman, 1981).

Unlike developed countries, for developing countries like Bangladesh, FER is a critical element of any strategy of economic development. In past few years, FER in Bangladesh has shown major fluctuations (Goswami et al., 2025). This warrants further research.

4 Theoretical Framework

Foreign exchange reserve accumulation is commonly explained through the precautionary and external-balance perspectives. Under the precautionary motive, countries hold foreign exchange reserves to protect the economy against external shocks, sudden changes in capital flows, import-payment pressures and exchange-rate volatility. This motive is particularly relevant for developing economies, where external financing conditions, remittance flows, export earnings and import requirements may fluctuate over time. In addition, the buffer-stock view of reserve holding suggests that reserves act as a stabilizing stock that helps monetary authorities manage temporary imbalances in the external sector.

In the context of Bangladesh, foreign exchange reserves are influenced by several external-sector variables. Personal remittances provide a major source of foreign currency inflow and are expected to support reserve accumulation. Foreign direct investment may also contribute to reserve growth by bringing non-debt-creating foreign currency inflows into the economy. Foreign loans and grants increase foreign currency availability in the short and medium term, although excessive dependence on such inflows may create future repayment obligations. The current account balance reflects the broader external-sector position of the economy. An improvement in the current account position is expected to reduce pressure on reserves and support long-run external stability.

Based on these theoretical considerations and the availability of annual data, this study specifies foreign exchange reserves as a function

Table 1: Description of the variables included in the model

Variable	Notation	Measurement	Expected Association with FER	Source	Period
Foreign Exchange Reserves	FER	Total reserves including gold, current US\$	Dependent variable	WDI	1980–2024
Personal Remittances	PR	Personal remittances received, current US\$	Positive	WDI	1980–2024
Foreign Direct Investment	FDI	Foreign direct investment, net inflows, current US\$	Positive	WDI	1980–2024
Foreign Loans and Grants	FLG	Net official development assistance and official aid received, current US\$	Positive	WDI	1980–2024
Current Account Balance	CAB_-GDP	Current account balance as percentage of GDP	Positive	WDI	1980–2024
Trade Balance	TB_GDP	Exports minus imports as percentage of GDP	Positive	WDI	1980–2024

of personal remittances, foreign direct investment, foreign loans and grants, and current account balance. The variables measured in current US dollars are transformed into natural logarithms to reduce scale differences and to allow proportional interpretation. Since current account balance is expressed as a percentage of GDP, it is retained in ratio form.

The expected positive association between personal remittances and foreign exchange reserves is based on the role of remittances as a stable source of foreign currency inflow. A positive relationship is also expected for FDI because it represents non-debt-creating capital inflow. Foreign loans and grants are expected to be positively associated with reserves because they directly increase foreign currency availability, although the sustainability of such inflows depends on future repayment obligations. Current account balance is expected to have a positive association with reserves because an improved current account position reduces pressure on reserve depletion

and strengthens external-sector stability.

This theoretical framework supports the use of a dynamic time-series model. Since the variables may respond to one another with time lags and may share a long-run equilibrium relationship, the ARDL bounds-testing approach is suitable for examining both short-run adjustments and long-run associations among the selected variables.

5 Data and Methodology

5.1 Data Source and Sample Period

This study uses annual time-series data for Bangladesh covering the period 1980–2024. The data were collected from the WDI (WDI) database of the World Bank. The extended sample period improves the empirical coverage of the study and allows a more reliable time-series investigation than a shorter sample period.

The dependent variable of the study is foreign

exchange reserves (FER). The explanatory variables include personal remittances (PR), foreign direct investment (FDI), foreign loans and grants (FLG), and current account balance as a percentage of GDP (CAB_GDP). The current account balance is included to capture the broader external-sector position of Bangladesh. A trade-balance-to-GDP variable is also used as a robustness check.

The variables measured in current US dollars are transformed into natural logarithms to reduce scale differences and allow elasticity-based interpretation. However, current account balance and trade balance are expressed as percentages of GDP and are therefore used in ratio form.

5.2 Description of the Variables

This study uses annual time-series data for Bangladesh covering the period 1980–2024. The extended sample period improves the empirical coverage and allows a more reliable time-series investigation. The variables measured in current US dollars are transformed into natural logarithms, while current account balance and trade balance are expressed as percentages of GDP. The study has considered usual form of the FER is:

$$FER = f(PR, FDI, FLG, CAB_GDP, TB_GDP) \quad (1)$$

After logarithmic transformation of the variables measured in current US dollars, the empirical model is written as:

$$\ln(FER_t) = \beta_0 + \beta_1 \ln(PR_t) + \beta_2 \ln(FDI_t) + \beta_3 \ln(FLG_t) + \beta_4 CAB_GDP_t + \varepsilon_t \quad (2)$$

Since macroeconomic time-series variables often exhibit trends and non-stationarity, this study does not rely on a static OLS model as the main estimation technique. Instead, the Autoregressive Distributed Lag (ARDL) bounds-testing approach is applied to examine both short-run and long-run associations

among the variables.

5.3 Unit-Root Testing

Before estimating the ARDL model, the stationarity properties of the variables are examined using three unit-root tests: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test, and the KPSS test.

The ADF and PP tests examine the null hypothesis that a variable has a unit root, meaning that it is non-stationary. In contrast, the KPSS test examines the null hypothesis that a variable is stationary. Using all three tests provides a more robust assessment of the order of integration of the variables.

The ARDL bounds-testing approach is appropriate when the variables are integrated of order zero, $I(0)$, order one, $I(1)$, or a mixture of $I(0)$ and $I(1)$. However, the ARDL approach is not suitable if any variable is integrated of order two, $I(2)$. Therefore, unit-root testing is necessary to confirm that no variable is $I(2)$.

5.4 ARDL Bounds-Testing Approach

The ARDL approach is suitable for this study for several reasons. First, it can be applied when variables have mixed orders of integration, provided that none is $I(2)$. Second, it performs relatively well in small or moderate samples. Third, it allows the estimation of both short-run dynamics and long-run relationships within a single framework.

The ARDL model for this study can be expressed as follows:

$$\begin{aligned} \Delta LFER_t = & \beta_0 + \sum_{i=1}^p \beta_1 \Delta LFER_{t-i} + \sum_{i=0}^{q_1} \beta_2 \Delta LPR_{t-i} \\ & + \sum_{i=0}^{q_2} \beta_3 \Delta LFDI_{t-i} + \sum_{i=0}^{q_3} \beta_4 \Delta LFLG_{t-i} \\ & + \sum_{i=0}^{q_4} \beta_5 \Delta CAB_GDP_{t-i} + \lambda_1 LFER_{t-1} \\ & + \lambda_2 LPR_{t-1} + \lambda_3 LFDI_{t-1} \\ & + \lambda_4 LFLG_{t-1} + \lambda_5 CAB_GDP_{t-1} + u_t \end{aligned} \quad (3)$$

Where Δ denotes the first-difference operator, p and q indicate optimal lag lengths deter-

mined by AIC or SIC, and u_t is the white-noise error term.

The null hypothesis of the bounds test is:

$$H_0 : \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0 \quad (4)$$

The alternative hypothesis is:

$$H_1 : \gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq 0 \quad (5)$$

Which indicates the presence of a long-run relationship. If the calculated F-statistic exceeds the upper critical bound, the null hypothesis of no cointegration is rejected. If it falls below the lower bound, the null hypothesis cannot be rejected. If it lies between the lower and upper bounds, the result is inconclusive.

5.5 Error Correction Model

Once a long-run relationship is confirmed, the short-run adjustment process is examined through the error correction model (ECM). The ECM is specified as:

$$\begin{aligned} \Delta LFER_t = & \gamma_0 + \sum_{i=1}^p \gamma_1 \Delta LFER_{t-i} \\ & + \sum_{i=0}^{q_1} \gamma_2 \Delta LPR_{t-i} + \sum_{i=0}^{q_2} \gamma_3 \Delta LFDI_{t-i} \\ & + \sum_{i=0}^{q_3} \gamma_4 \Delta LFLG_{t-i} + \sum_{i=0}^{q_4} \gamma_5 \Delta CAB_GDP_{t-i} \\ & + \theta ECT_{t-1} + \mu_t \end{aligned} \quad (6)$$

Where ECT_{t-1} is the lagged error correction term. The coefficient of the error correction term, θ , is expected to be negative and statistically significant. A negative and significant coefficient indicates that deviations from the long-run equilibrium are corrected over time.

5.6 Diagnostic and Stability Tests

Several diagnostic tests are conducted to examine the reliability of the estimated model. The Breusch-Godfrey LM test is used to test for serial correlation. The Breusch-Pagan test is used to examine heteroskedasticity. The Ramsey RESET test is used to assess

functional-form misspecification. The Jarque-Bera test is applied to examine the normality of residuals.

In addition, parameter stability is examined using the CUSUM and MOSUM tests. These tests help determine whether the estimated coefficients remain stable over the sample period. Structural-break analysis is also conducted as an additional check, given the major external shocks experienced by Bangladesh during the sample period.

5.7 Robustness Checks

To assess the robustness of the findings, two additional checks are conducted. First, the current account balance variable is replaced by trade balance as a percentage of GDP. Second, shock dummy variables are introduced to account for major external disturbances, including the COVID-19 period and the post-2022 external shock period.

These robustness checks help determine whether the main findings remain stable under alternative model specifications and period-specific controls.

5.8 Scope of Interpretation

The study uses observational macroeconomic time-series data. Therefore, the estimated coefficients are interpreted as short-run and long-run associations, not as strict causal effects. This distinction is important because foreign exchange reserves may also influence some explanatory variables, such as foreign borrowing capacity and investor confidence. Accordingly, the findings are presented as evidence of macroeconomic determinants and long-run relationships rather than direct causal impacts.

6 Empirical Results

6.1 Descriptive Statistics

Table 3 presents the descriptive statistics of the variables used in the empirical analysis. Foreign exchange reserves show substantial variation during the study period, ranging from USD 0.16 billion to USD 46.17 billion, with an average value of USD 10.43 billion. This wide range reflects the long-term expan-

sion of Bangladesh's reserve position as well as the volatility experienced in recent years. Personal remittances also increased substantially over time, with a minimum value of USD 0.34 billion and a maximum value of USD 22.21 billion. The average personal remittance inflow during the sample period is USD 7.05 billion.

Foreign direct investment remains relatively smaller than remittance and foreign loans and grants. The average FDI inflow is USD 0.78 billion, while the maximum is USD 2.83 billion. Foreign loans and grants range from USD 0.81 billion to USD 5.68 billion, with an average of USD 1.95 billion. The current account balance as a percentage of GDP ranges from -5.02% to 3.47% , indicating that Bangladesh experienced both deficit and surplus positions during the sample period. In contrast, the trade balance as a percentage of GDP remains negative throughout the period, ranging from -12.39% to -3.49% , reflecting persistent import dependence.

6.2 Unit Root Test

Before estimating the ARDL model, the stationarity properties of the variables were examined using the Augmented Dickey-Fuller, Phillips-Perron and KPSS tests. The results are reported in Table 4.

The ADF and PP tests treat non-stationarity as the null hypothesis, while the KPSS test treats stationarity as the null hypothesis. Using these three tests provides a more reliable basis for identifying the order of integration of the variables.

The results show that the logged variables, namely foreign exchange reserves, personal remittances, foreign direct investment, and foreign loans and grants, are mostly non-stationary at level. However, these variables become stationary after first differencing, particularly according to the PP and KPSS tests. The current account balance and trade balance variables show mixed evidence at level, but both are stationary after first differencing. Therefore, the variables are either $I(0)$,

$I(1)$, or a mixture of both. Since none of the variables is found to be integrated of order two, the ARDL bounds-testing approach is appropriate for the analysis.

This finding is important because using a static OLS model with non-stationary macroeconomic time-series variables may produce spurious results. The unit-root results therefore justify the use of a dynamic time-series framework rather than relying only on the earlier OLS specification.

6.3 ARDL Model Selection

The ARDL model was selected using the Akaike Information Criterion (AIC). The selected model is $ARDL(1, 2, 0, 1, 1)$, which includes one lag of foreign exchange reserves, two lags of personal remittances, no lag of foreign direct investment, one lag of foreign loans and grants, and one lag of current account balance as a percentage of GDP.

Table 5: ARDL Lag Selection

Variable	Selected Lag
LFER	1
LPR	2
LFDI	0
LFLG	1
CAB.GDP	1

Source: Authors' own calculation.

The selected ARDL specification is appropriate because it allows both short-run dynamics and long-run relationships to be examined within the same framework. The inclusion of lagged variables is particularly relevant for foreign exchange reserves because reserve movements often respond with delay to changes in remittances, external borrowing, investment inflows and current account conditions.

The selected ARDL specification is appropriate because it allows both short-run dynamics and long-run relationships to be examined within the same framework. The inclusion of lagged variables is particularly relevant for for-

Table 3: Descriptive Statistics of Variables

Variable	Mean	Median	Maximum	Minimum	Std. Dev.
FER (USD Billion)	10.4300	7.3500	46.1700	0.1600	12.4800
PR (USD Billion)	7.0500	5.6200	22.2100	0.3400	6.3400
FDI (USD Billion)	0.7800	0.6100	2.8300	0.1200	0.7200
FLG (USD Billion)	1.9500	1.7400	5.6800	0.8100	1.2300
CAB_GDP (%)	–	–	3.4700	–5.0200	–
TB_GDP (%)	–	–	–3.4900	–12.3900	–

Source: Authors' own calculation.

Table 4: Unit Root Test Results Summary

2*Variable	Test Decision			2*Integration
	ADF	PP	KPSS	Order
LFER	Non-stationary	Non-stationary	Non-stationary	I(1)
LPR	Non-stationary	Non-stationary	Non-stationary	I(1)
LFDI	Non-stationary	Non-stationary	Non-stationary	I(1)
LFLG	Non-stationary	Non-stationary	Non-stationary	I(1)
CAB_GDP	Non-stationary	Non-stationary	Stationary	I(0)/I(1)
TB_GDP	Non-stationary	Non-stationary	Stationary	I(0)/I(1)

Note: All variables become stationary at first difference except CAB_GDP and TB_GDP which are stationary at level according to KPSS. The mixed order of integration supports the use of the ARDL bounds testing approach.

Source: Authors' own calculation.

foreign exchange reserves because reserve movements often respond with delay to changes in remittances, external borrowing, investment inflows, and current account conditions.

6.4 ARDL Bounds Test for Cointegration

The ARDL bounds test was applied to examine whether a long-run relationship exists among the variables. The null hypothesis of the test is that there is no long-run relationship among foreign exchange reserves and the selected macroeconomic variables.

The bounds test produces an F-statistic of 7.4918 with a p-value of 0.0008. This result rejects the null hypothesis of no cointegration and confirms the presence of a long-run relationship among foreign exchange reserves, per-

sonal remittances, foreign direct investment, foreign loans and grants, and current account balance in Bangladesh.

Table 6: ARDL Bounds Test for Cointegration

Test	F-Statistic	p-value	Decision
ARDL Bounds F-test	7.4918	0.0008	Reject null of no cointegration

Source: Authors' own calculation.

This result is central to the revised empirical analysis. It indicates that the variables do not merely move together because of common trends; rather, there is statistical evidence of a long-run equilibrium relationship among them.

Therefore, the long-run ARDL estimates and the error correction model can be interpreted meaningfully.

6.5 Long-Run ARDL Estimates

The long-run estimates are reported in Table 8. The results show that foreign loans and grants and the current account balance are positively and statistically significantly associated with foreign exchange reserves in the long run. The coefficient of foreign loans and grants is 2.3137 and statistically significant at the 1% level. This suggests that foreign loans and grants have a strong positive long-run association with Bangladesh's foreign exchange reserves. However, this result should be interpreted as an association rather than a causal effect, because foreign exchange reserves may also influence a country's access to external financing.

The coefficient of current account balance as a percentage of GDP is 0.5874 and statistically significant at the 1% level. This indicates that an improvement in the current account position is associated with higher foreign exchange reserves. This finding is economically meaningful because a stronger current account position reduces pressure on reserve depletion and supports external-sector stability.

Personal remittances and foreign direct investment show positive coefficients, but they are not statistically significant in the preferred long-run specification. The coefficient of personal remittances is 0.0101 with a p-value of 0.9824, while the coefficient of FDI is 0.0917 with a p-value of 0.4726. This does not imply that remittances and FDI are unimportant for Bangladesh's economy. Rather, it suggests that after controlling for foreign loans and grants and the current account position, their independent long-run statistical association with reserves is not strong in the preferred ARDL model.

This revised finding is more cautious than the earlier OLS-based interpretation. The evidence now suggests that reserve accumulation in Bangladesh is more consistently linked with

foreign loans and grants and current account performance than with FDI or remittances in the long-run ARDL specification.

6.6 Short-Run Error Correction Model

After establishing cointegration, the short-run dynamics were examined using the error correction model. The results are presented in Table ???. The error correction term is negative and statistically significant, with a coefficient of -0.2892 and a p-value below 0.001. This confirms that deviations from the long-run equilibrium are corrected over time. Specifically, approximately 28.9% of any short-run disequilibrium is corrected within one year.

In the short run, the change in current account balance is positive and statistically significant. The coefficient of $\Delta\text{CAB_GDP}$ is 0.1272 and significant at the 1% level. This indicates that short-run improvements in the current account position are associated with increases in foreign exchange reserves. The change in foreign loans and grants is positive and marginally significant at the 10% level, suggesting that short-run external financing flows may also be associated with reserve movements. The short-run coefficients of remittance changes are positive but statistically insignificant. This may reflect the fact that remittance inflows, although important, may be partly offset by import payments, consumption-related foreign exchange demand, or other current account movements.

6.7 Diagnostic Tests

Several diagnostic tests were conducted to examine the reliability of the preferred ARDL model. The results are reported in Table 9. The Breusch-Godfrey LM tests for serial correlation show p-values of 0.6171 and 0.3364 for order 1 and order 2, respectively. Therefore, the null hypothesis of no serial correlation cannot be rejected. The Breusch-Pagan test gives a p-value of 0.2202, indicating no evidence of heteroskedasticity. The Ramsey RESET test has a p-value of 0.5283, suggesting that the functional form of the model is acceptable.

Table 7: Long-Run ARDL Estimates

Variable	Estimate	Std. Error	t-Statistic	p-value	Significance
(Intercept)	-28.482	8.719	-3.2667	0.0027	***
LPR	0.0101	0.4533	0.0222	0.9824	
LFDI	0.0917	0.1261	0.7274	0.4726	
LFLG	2.3137	0.7360	3.1435	0.0037	***
CAB_GDP	0.5874	0.2085	2.8172	0.0085	***

Note: *** indicates significance at the 1% level.

Source: Authors' own calculation.

Table 8: Short-Run ARDL Estimates

Variable	Estimate	Std. Error	t-Statistic	p-value	Significance
(Intercept)	-28.482	8.719	-3.2667	0.0027	***
LPR	0.0101	0.4533	0.0222	0.9824	
LFDI	0.0917	0.1261	0.7274	0.4726	
LFLG	2.3137	0.7360	3.1435	0.0037	***
CAB_GDP	0.5874	0.2085	2.8172	0.0085	***

Note: *** indicates significance at the 1% level.

Source: Authors' own calculation.

The Jarque-Bera test produces a p-value of 0.6260, indicating that the residuals are approximately normally distributed.

These diagnostic results support the reliability of the preferred ARDL model. They also address the methodological concern that time-series regression results may be affected by serial correlation, heteroskedasticity, or model misspecification.

6.8 Stability Test Results

The stability of the preferred ARDL model was assessed using the Recursive CUSUM and OLS-MOSUM tests. The CUSUM test gives a statistic of 0.5421 with a p-value of 0.5325, while the MOSUM test gives a statistic of 0.5806 with a p-value of 0.5339. In both cases, the null hypothesis of parameter stability cannot be rejected.

The CUSUM and MOSUM plots also support this conclusion. In both figures, the empirical fluctuation process remains within the critical

boundary lines throughout the sample period. This indicates that the preferred ARDL specification is stable and does not suffer from major parameter instability. This is particularly important because Bangladesh experienced several external-sector shocks during the sample period, including the COVID-19 period and post-2022 external pressures.

6.9 Robustness Checks

Two robustness checks were conducted. First, trade balance as a percentage of GDP was used instead of current account balance. The trade-balance specification produced a bounds F-statistic of 2.3778 with a p-value of 0.3831, indicating no strong evidence of cointegration. This suggests that the current account balance is a more comprehensive and suitable external-sector indicator than trade balance alone for explaining reserve dynamics.

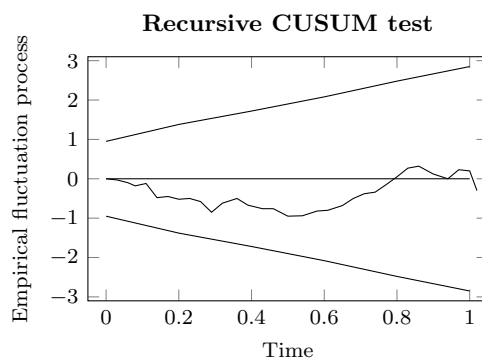
Second, shock dummy variables were included to account for the COVID-19 period, the post-

Table 9: Diagnostic Test Results

Test	Statistic	p-value	Decision
Breusch-Godfrey LM Test (Order 1)	0.2499	0.6171	No serial correlation
Breusch-Godfrey LM Test (Order 2)	2.1787	0.3364	No serial correlation
Breusch-Pagan Test	11.8793	0.2202	No heteroskedasticity
Ramsey RESET Test	0.6529	0.5283	No functional-form problem
Jarque-Bera Test	0.9368	0.6260	Residuals approximately normal

Source: Authors' own calculation.

2022 external shock period, and the IMF programme period. The shock dummy results show that the COVID-19 dummy, post-2022 dummy, and IMF dummy are not statistically significant. However, foreign loans and grants remain positive and statistically significant, and current account balance remains marginally significant. This supports the robustness of the main finding that foreign loans and grants and current account conditions are strongly associated with Bangladesh's foreign exchange reserves.

**Figure 1:** Recursive CUSUM Test**Table 10:** Stability Test Results

Test	Statistic	p-value	Decision
Recursive CUSUM Test	0.5421	0.5325	Stable
OLS-MOSUM Test	0.5806	0.5339	Stable

Source: Authors' own calculation.

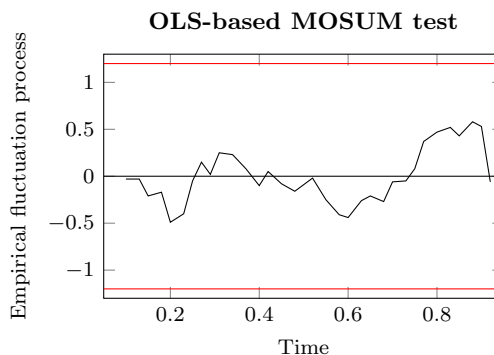
**Figure 2:** OLS-based MOSUM Test

Table 12: Robustness Check: Shock Dummy Variables

Variable	Coefficient	Std. Error	t-Statistic	p-value	Significance
(Intercept)	-14.6704	3.8268	-3.8336	0.0005	***
LPR	0.9681	0.1808	5.3560	0.0000	***
LFDI	-0.0449	0.0639	-0.7023	0.4873	
LFLG	0.7725	0.2446	3.1586	0.0033	***
CAB_GDP	0.0896	0.0506	1.7714	0.0855	*
covid_dummy	-0.0428	0.3848	-0.1113	0.9120	
post_2022_dummy	-0.1123	0.5134	-0.2187	0.8282	
imf_dummy	-0.7252	0.6141	-1.1810	0.2458	

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' own calculation.

Table 11: Robustness Check: Trade Balance Specification

Model	F-Statistic	p-value	Decision
ARDL with TB_GDP	2.3778	0.3831	No strong evidence of cointegration

Source: Authors' own calculation.

The VIF results indicate that multicollinearity remains relatively high for personal remittances, with a VIF of 13.1344, and moderately high for FDI, with a VIF of 7.6226. However, the VIF values for foreign loans and grants and current account balance are lower. The higher VIF for remittances is not unexpected in macroeconomic time-series data because external-sector variables often share common long-run trends. Although the VIF for remittances exceeds the conventional threshold, the variable is retained because of its strong theoretical relevance to Bangladesh's external sector. The issue is acknowledged as a limitation, and the interpretation of individual coefficients is therefore made cautiously.

7 Discussion

The empirical results provide evidence that Bangladesh's foreign exchange reserves are linked with both external financing flows and the broader current account position. The

ARDL bounds test confirms a long-run relationship among foreign exchange reserves, personal remittances, foreign direct investment, foreign loans and grants, and current account balance. This finding is consistent with the broader reserve-demand literature, which suggests that foreign exchange reserves are influenced by external vulnerability, capital flows, trade-related pressures, and macroeconomic stability considerations (Lane and Burke, 2001; Aizenman and Marion, 2003; Gosselin and Parent, 2005).

The long-run coefficient of foreign loans and grants is positive and statistically significant. This result is consistent with studies that identify foreign borrowing, external assistance, or external financing as important sources of reserve accumulation in developing economies (Anwar et al., 2019; Nurjanah and Mustika, 2021). The finding also aligns with the buffer-stock view of reserve holding, where external inflows strengthen reserve availability in the short and medium term (Irefin and Yaaba, nd; Khomo et al., 2018). However, the result should be interpreted carefully. Foreign loans and grants may support reserve accumulation, but they are not always a sustainable source of reserve strength because loan-based inflows can create future repayment obligations. Therefore, the positive association between FLG and reserves does not imply that

greater reliance on foreign borrowing is always desirable.

The current account balance is also positively and significantly associated with foreign exchange reserves in the long run. This finding is theoretically expected because an improvement in the current account position reduces net foreign currency outflows and eases pressure on reserve depletion. Previous studies have also emphasized the importance of current account developments, import pressure, and external-sector vulnerability in explaining reserve behaviour (Gosselin and Parent, 2005; Khomo et al., 2018; Prabheesh et al., 2007). In the Bangladesh context, the result suggests that reserve sustainability depends not only on inflows from borrowing or remittances, but also on the country's ability to improve its external balance through export performance, import management, and stable current account conditions.

The long-run coefficient of personal remittances is positive but statistically insignificant in the preferred ARDL specification. This finding should not be interpreted as evidence that remittances are unimportant. Remittances remain one of Bangladesh's major sources of foreign exchange and have been widely recognized as an important stabilizing inflow for developing economies (Chowdhury and Chakraborty, 2021; Naima et al., 2025). However, the insignificant coefficient suggests that after controlling for foreign loans and grants and the current account position, remittances do not show a strong independent long-run association with reserves in this model. One possible explanation is that remittance inflows may be partly offset by import demand, consumption-related foreign exchange outflows, or broader current account movements.

Similarly, foreign direct investment shows a positive but statistically insignificant long-run coefficient. This differs from studies that find a stronger role for FDI in reserve accumulation or external-sector strengthening (Olokoyo et al., 2009; Naima et al., 2025). In

Bangladesh, the weaker statistical role of FDI may reflect the relatively modest size of FDI inflows compared with remittances, external borrowing, and the overall size of the external sector. Although FDI is theoretically important because it represents non-debt-creating capital inflow, its long-run association with reserves appears weaker in the preferred ARDL model.

The error correction term is negative and statistically significant, indicating that deviations from the long-run equilibrium are corrected over time. The estimated adjustment coefficient suggests that approximately 28.9% of short-run disequilibrium is corrected within one year. This result is consistent with the use of ARDL and ECM approaches in reserve-demand studies, where short-run deviations are expected to adjust gradually toward long-run equilibrium (Irefin and Yaaba, nd; Khomo et al., 2018).

The diagnostic and stability tests further support the reliability of the preferred model. The Breusch-Godfrey, Breusch-Pagan, Ramsey RESET, and Jarque-Bera tests indicate that the model does not suffer from major serial correlation, heteroskedasticity, functional form, or residual-normality problems. The CUSUM and MOSUM tests also suggest parameter stability over the sample period. This model applies unit-root testing, ARDL bounds testing, diagnostic checks, and stability tests as well.

Overall, the results suggest that Bangladesh's reserve position is more consistently associated with foreign loans and grants and current account performance than with remittances or FDI alone. This finding has important policy implications. In the short and medium term, foreign loans and grants may support reserve accumulation, but long-term reserve sustainability requires improvement in the current account position and greater reliance on stable, non-debt-creating inflows. Therefore, policy should focus on strengthening export competitiveness, managing import pressure, improving remittance channels, attracting quality

FDI, and ensuring prudent use of foreign borrowing.

8 Conclusion

The study finds that foreign loans and grants and current account balance are positively and significantly associated with foreign exchange reserves in the long run. Personal remittances and FDI show positive but statistically insignificant long-run coefficients in the preferred ARDL specification. Therefore, sustainable reserve management should focus on improving current account performance, strengthening non-debt-creating inflows, and reducing excessive reliance on debt-creating external financing.

8.1 Limitation

Exchange rate was not included in the preferred specification due to data consistency limitations over the full sample period. Future research may extend the analysis by incorporating exchange rate, inflation, and import-cover indicators.

8.2 Declaration of Using AI

The author declares that Artificial Intelligence (AI) tools were used only for language refinement, grammar correction, and improving the academic tone and clarity of the manuscript. No AI tool was used to generate the research idea, theoretical arguments, data, econometric analysis, interpretation of results, findings, policy implications, or conclusions.

All research design, data collection, statistical analysis, interpretation, and academic judgments were independently carried out by the author. The author takes full responsibility for the accuracy, originality, integrity, and scholarly content of the manuscript.

8.3 Disclaimer

The views, opinions, analysis, findings, and conclusions expressed in this manuscript are solely those of the author and do not represent the official position, views, or policies of Bangladesh Bank, the Bangladesh Financial Intelligence Unit, or any other institution with

which the author is affiliated.

Disclosure Statement

Views expressed in this paper are the authors' own and do not necessarily reflect the views of institutions they are affiliated with.

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