Macroeconomic Determinants of Bangladesh's Foreign Exchange Reserves: Evidence from Time Series Analysis

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ABSTRACT

There is no denying that an optimal level of foreign exchange reserves is crucial for maintaining macroeconomic stability and achieving steady economic growth. Additionally, it can serve as a development tool by financing import payments and supporting essential development spending, making it a symbol of the country's economic sustainability. This study utilizes monthly data from January 2008 to July 2022, sourced from the Bangladesh Bank, the central bank of Bangladesh, to examine the determinants of Bangladesh's foreign exchange reserves. A standard time series approach was used, which involved testing for stationarity and selecting the appropriate lag length before applying the Johansen cointegration test to identify the presence and rank of cointegrating relationships. This study identified multiple cointegrating equations and, therefore, employed the Vector Error Correction Model (VECM) to investigate the long-term relationships among the variables. The results indicated that exports, remittances, and foreign direct investment have a positive influence on foreign exchange reserves, while imports and the exchange rate have a negative impact. Short-term dynamics and the error correction term (ECT) were also analyzed to demonstrate adjustment processes. Following the econometric analysis, diagnostic tests, including autocorrelation, normality, and stability tests, were performed. The results showed that autocorrelation and stability tests were satisfactory; however, only imports followed a normal distribution, as confirmed by the normality test. Based on these findings, this study recommends several policy measures to help Bangladesh maintain an optimal level of foreign exchange reserves. Since exports, remittances, and foreign direct investment positively affect Bangladesh's foreign exchange reserves, efforts should focus on expanding these sectors through export diversification, improved support for remitters, and providing additional facilities or incentives to attract foreign direct investment.

JEL Classification Code: G 21

Key words: Bangladesh, Error Correction Term (ECT), Foreign Exchange Reserve, Johansen Co-integration Test, Vector Error Correction Model (VECM)

INTRODUCTION

Countries worldwide participate in international trade. Some nations run trade deficits while others have trade surpluses. Conversely, impoverished or underdeveloped nations often borrow money from wealthy countries or financial institutions such as the World Bank (WB), International Monetary Fund (IMF), and Asian Development Bank (ADB). They borrow funds to develop infrastructure and cover import costs. Countries urgently need foreign currencies, especially U.S. dollars ($), to repay overseas debts and pay for imports. Foreign exchange reserves are crucial in a country's financial sector, signaling the nation's solvency and monetary policy stability to the international market (Salan et al., 2023). These reserves are assets held by countries in foreign currencies, mainly in hard currencies like the U.S. dollar, euro, and yen, along with gold and IMF special drawing rights (SDRs) (Naima et al., 2025). The IMF defined Foreign Exchange Reserves in 2000 as "an external stock of assets accessible to the country's monetary authority to cover external payment imbalances or to

influence the exchange rate of domestic currencies through intervention in the exchange market or for other purposes (Kester, 2000)." This includes multiple foreign currencies and gold reserves. However, this study focuses solely on currencies, which are maintained by a country's central bank or monetary authority to balance the payments. Initially, gold was the only reserve asset, but now five additional currencies are included: the U.S. dollar, euro, Japanese yen, British pound, and Chinese renminbi.

For a developing country like Bangladesh, foreign reserves are vital. In Bangladesh, the main contributors are Ready-Made Garments (RMG) and remittances, along with grants from industrialized nations in foreign currency. On the other hand, import costs and international loan repayments are the primary demands for foreign exchange. Countries must keep a minimum level of reserves, enough to cover at least three months of imports. Falling below this level can signal economic instability. Maintaining a certain reserve level is essential for economic stability, although higher reserves are generally better. This study is particularly important because it explores the macroeconomic factors influencing foreign exchange reserves and their potential volume. The goal is to analyze all possible causes and approaches to achieving an ideal reserve level. Looking at Bangladesh's history, after gaining independence in 1971, the country initially had no foreign currency reserves. Its infrastructure was severely damaged, and rapid export growth was limited. During this period, international aid and grants were primary sources of foreign exchange. Bangladesh began exporting jute and raw jute after overcoming initial hardships. In the 1980s, RMG became the largest contributor to foreign exchange reserves. The trade liberalization in the 1990s also allowed Bangladesh to export labor abroad, with remittances becoming the second-largest source of foreign exchange. Initially, food items were the main imported goods, but after the rise of RMG, raw materials like cotton, textiles, and buttons replaced them as the primary imports. This import composition remains dominant.

The study will examine five key factors: exports, imports, the exchange rate, remittances, and foreign direct investment, along with their long-term effects. Research on foreign exchange reserves and their determinants has gained increasing relevance recently. The COVID-19 pandemic and the Russia-Ukraine conflict severely disrupted global trade, leading to reserve depletion worldwide. Bangladesh faces similar challenges. Additionally, Bangladesh's historically negative trade balance and reliance on the RMG sector for exports create significant post-pandemic challenges (Mahidud et al., 2021). These factors motivate this study, which aims to provide valuable insights into the literature on foreign exchange reserves. From a development perspective, reserves are critical for meeting a country's international obligations. Therefore, understanding the key factors impacting these reserves based on data from the past 14 years is vital. This knowledge will support strategies to increase reserves or reach an optimal level, helping maintain a stable external position. The ongoing crises and external shocks have increased interest in this topic.

LITERATURE REVIEWS

Numerous prominent scholars have analyzed foreign exchange reserves, with some focusing on the factors that influence demand and others analyzing the main determinants based on data from their respective countries. Heller (1968) proposed that optimal reserves are inversely related to imports and opportunity costs, mainly held for precautionary reasons. Early studies identified three main reasons for reserve accumulation: transaction motive, precautionary motive, and speculative motive. The need for cash as part of the precautionary motive may positively relate to national wealth and the costs of covering unexpected shortfalls, while negatively correlating with returns from alternative assets (Reddy & Y.V., 2002). Additionally, a country's ability to service foreign debt and meet commitments heavily depends on its reserves.

Several authoritative publications also discuss factors influencing reserves. According to the IMF (2013), international reserves and foreign currency liquidity (IRFCL) include all overseas assets controlled by financial regulators that are available for immediate use. Macroeconomic factors such as exports, exchange rate flexibility, and trade openness have played crucial roles in developing foreign exchange reserves. Moreover, institutional quality is vital for reserve accumulation (Abuh-Amasi et al., 2022). Sultan (2011) found that real imports, real income, the relative price of imports, and real foreign currency reserves show long-term equilibrium relationships. Both short-term and long-term analyses suggest that foreign currency reserves are key determinants of import demand. Similarly, Abuh-Amasi et al. (2022) studied Nigeria and found that trade openness, total exports, the opportunity cost of holding reserves, institutional strength, and exchange rate flexibility influence the country's reserve accumulation. Das and Narayanan (2011) identified that imports and exchange rate volatility are important predictors of reserves, even after controlling for other variables. A shock to the exchange rate has long-term effects on reserves, affecting both their level and volatility.

Regarding the importance of maintaining optimal foreign exchange reserves, Chowdhury et al. (2014) argue that substantial reserves help stabilize a country's currency and prevent exchange rate fluctuations. Das and Narayanan (2011) also suggested a possible link between reserve volatility and exchange rate volatility. Their findings indicate a strong long-term relationship among reserve volatility, exchange rate volatility, the net capital

account, and the call money rate. Additionally, Suman and Aman (2021) used a double log regression model and identified exports, foreign direct investment, exchange rate, and time variables as significant determinants of foreign exchange reserves in India, showing their reliability. In India, increasing foreign exchange reserves has been more of a strategy to mitigate financial crises than to control the exchange rate. Currency appreciation harms exporters, so the global trend is to prevent appreciation and allow depreciation within controlled limits (Gokhale & Raju, 2013). Therefore, Bangladesh Bank should actively manage reserves to quickly restore equilibrium (Islam, S., 2021).

Concerning trade liberalization's effects on foreign reserves, Choudhury et al. (2014) observed that developing countries like Bangladesh, which have high import demands relative to exports, may face negative impacts from liberalization and free capital flows. Reserves are also significantly influenced by GDP, money supply, exports, domestic interest rates, and exchange rates. A 2004 study by Hviding, Nowak, and Ricci, covering 28 countries from 1986 to 2002, showed that high reserve levels reduce currency crisis and sudden stop risks, as well as lower external borrowing costs. The effect of increased reserves on short-term exchange rate volatility depends on the initial reserve level, with higher reserves generally reducing volatility (Hviding, Nowak, & Ricci, 2004). Ali and Medhekar (2012), analyzing data from 1971 to 2010, found that reserves are positively linked with exports, imports, foreign aid, remittances, and GDP. Foreign aid plays a primary role in Bangladesh's reserves, and sustained growth in remittances, exports, and foreign direct investment could bolster reserves (Ahmmed et al., 2012). Conversely, Chowdhury et al. (2014) noted that aid accounts for less than 1% of GDP, and Bangladesh receives relatively little foreign aid. In summary, scholarly research on this subject is limited, and existing studies focus on various factors using different models. Gajurel (2022), in his study of Nepal, used the ARDL error correction model and found that foreign exchange reserves, with a one-period lag, along with lagged domestic credit to the private sector, current and lagged external debt, current inflation, broad money, and lagged trade variables, positively influence reserves in the short run. Similarly, Jena and Sethi (2021), examining Brazil, identified a long-term relationship between foreign exchange reserves, the current account balance to GDP ratio, debt to GDP ratio, domestic credit to the private sector as a percentage of GDP, exchange rate, inflation, per capita GDP, and the real interest rate, using the robust ARDL model.

Although many important aspects and determinants of foreign exchange reserves have already been discussed, the macroeconomic determinants specific to Bangladesh remain underexplored in contemporary literature. This is the gap that the current study aims to fill.

Conceptual Framework

Under the Bretton-Woods system, central banks all over the world used their foreign reserves to retain the external rate of their currencies at a particular level. When the Bretton-Woods system collapsed in the early 1970s, nations initiated executing a more flexible exchange rate system where reserves only performed a minor role. Nevertheless, between 1960 and 2002, the global foreign exchange reserve rose from 1.75 to 7.8 percent of global GDP. There were numerous efforts to ease trade after the GATT was established in 1948. Export and import were made easier thanks to reductions in non-tariff trade barriers and tariffs. Here, the foreign exchange reserve is necessary. Since foreign currencies are used in international trade.

Therefore, in analyzing Bangladesh's foreign exchange reserve, this study attempts to investigate the effects of export, import, exchange rates, foreign direct investment, and remittances on it.

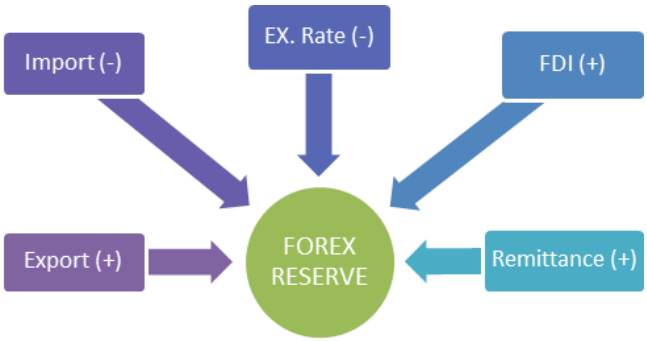


Figure 1: Expected Impact of Explanatory Variables
Source: Authors' Constitution

The preceding chart suggests that exports, remittances, and FDI will have a beneficial effect. These, as is well-known, are a key source of domestic currency. However, imports and the currency rate should hurt the country's foreign exchange reserve.

Research Methodology and Design

This study used secondary data from the Bangladesh Bank's "Monthly Economic Trend" publication on key economic variables. Bangladesh Bank was established on December 16, 1971, and has played a pioneering role in implementing monetary policy. The dependent variable of this study is Foreign Exchange Reserve (FXR), and the Independent Variables are Export (EX), Import (IM), Remittance (RM), Exchange Rate (ER), and Foreign Direct Investment (FDI). This study will analyze monthly data on foreign exchange reserves, exports, imports, exchange rates, remittances, and foreign direct investment from January 2008 to July 2022, totaling 175 observations for each variable. Since the data are time series, a standard time series analysis will be conducted to examine the long-term relationships among the variables. Firstly, the stationarity of the variables will be checked. If the mean

and variance are consistent, the variable is considered stationary; otherwise, it is nonstationary or has a unit root. The Augmented Dickey-Fuller test will be used to assess stationarity and test for the presence of a unit root. Next, this study will determine the optimal lag length for the model using various information criteria. If all variables are stationary at first difference, the Johansen Co-integration model will be employed to examine co-integration. If co-integration exists, as indicated by trace and maximum Eigen statistics, the Vector Error Correction Model (VECM) will be used to analyze long-term equilibrium relationships. Throughout, multiple diagnostic tests will be performed to check for autocorrelation, normality, and model stability. This approach ensures the appropriate analysis of the time series data, which will adhere strictly to this methodology.

$$FXR_t = \alpha + \beta_1 EX_t + \beta_2 IM_t + \beta_3 ER_t + \beta_4 FDI_t + \beta_5 RM_t + \varepsilon_t$$

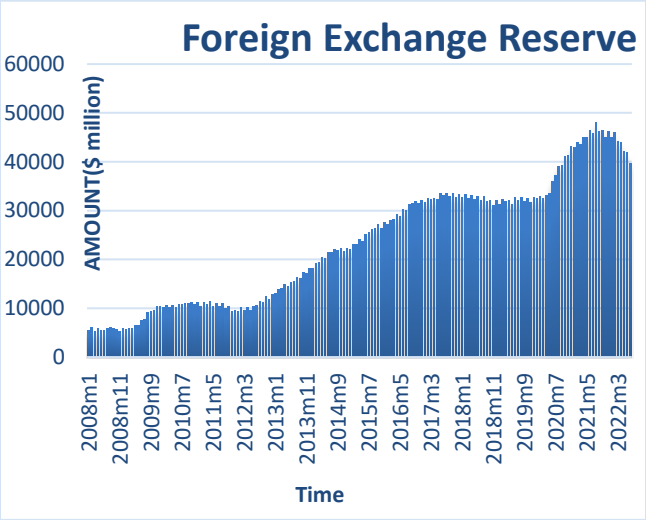


Figure 2: Trends in Foreign Exchange Reserve
Source: Author's Computation from Monthly Economic Trend

The foreign exchange reserve has been increasing steadily over the past decade, as seen in the line graph above. Since we are looking at monthly statistics, you can see that the FX reserve has been steadily growing. In 2022, however, the reserve suddenly drops. This is because there will be a greater total number of new "letter of credit" accounts being opened in 2021. Because of this, there has been a rise in the total quantity of imports. And that has a chilling effect on the country's stockpile of foreign currency. Conversely, throughout this time period, remittance inflow was on the decline. This contributed to a downward trend in the foreign exchange reserve this year.

The gross foreign exchange reserve of Bangladesh for the previous two fiscal years is shown in the table above. We can also observe a pattern of diminishing foreign exchange reserves. However, the following fiscal year saw an increase in the foreign exchange reserve.

Table 1: Recent Trends of Gross Foreign Exchange Reserves of Bangladesh Bank (In million US$)

Month	2023-24		2024-25	
	FXR (Gross)	FXR (as per BPM6)	FXR (Gross)	FXR (as per BPM6)
June	26714.2	21686.3	31772.0	26740.0
May	24197.2	18646.2	25798.2	20520.9
Apr	25365.2	19975.8	27429.7	22025.5
Mar	25231.7	19913.0	25512.0	20369.9
Feb	25966.6	20780.0	26175.7	20945.9
Jan	25111.9	19963.5	25305.6	19962.4
Dec	27130.0	21867.6	26214.8	21394.7
Nov	24894.6	19300.6	24350.2	18611.4
Oct	26481.0	20710.2	25486.7	19830.0
Sep	26911.0	21059.8	24863.0	19861.5
Aug	29260.7	23255.1	25580.8	20475.4
July	29732.1	23374.3	25823.6	20393.7

Source: Bangladesh Bank Statistical Data

RESULTS AND ANALYSIS

A random time series variable Y is called stationary or not having a unit root if its mean & variance are constant over time, and the value of covariance between two time periods depends on only the distance between two time periods and not on the actual time at which the variance is calculated. With a view to checking the stationarity of the variables, we can apply unit root tests like the Augmented Dickey-Fuller (1981) and Phillips-Perron (1988) tests.

This study has applied the Augmented Dickey-Fuller test on the Foreign Exchange Reserve, Export, Import, Remittance, Exchange Rate, and Foreign Direct Investment. Using the econometric software Stata-14, we have tested the stationarity of the variables using the Augmented Dickey-Fuller approach. In the following diagram, we can see the path of each variable.

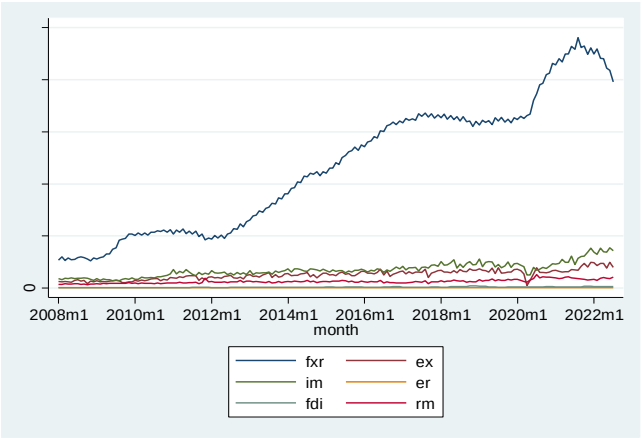
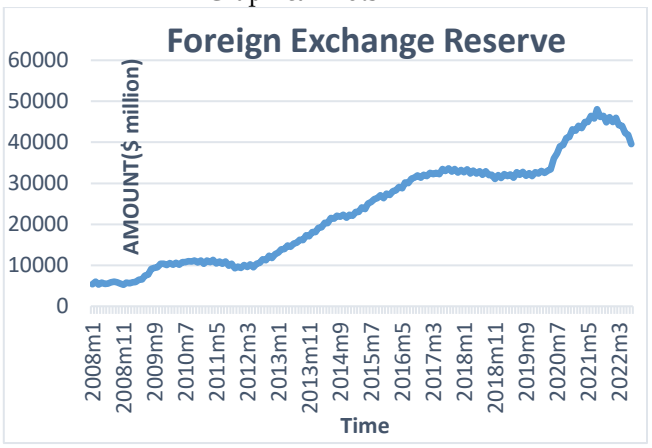


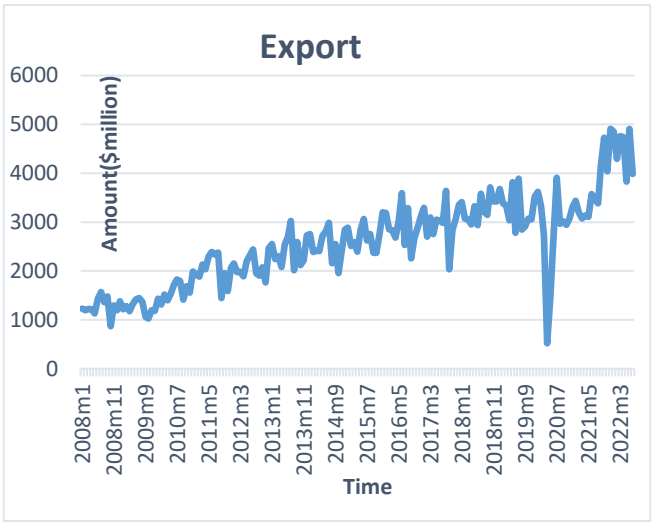
Figure 3: Trends of All the Variables of the Study
Source: Author's Computation from Monthly Economic Trend

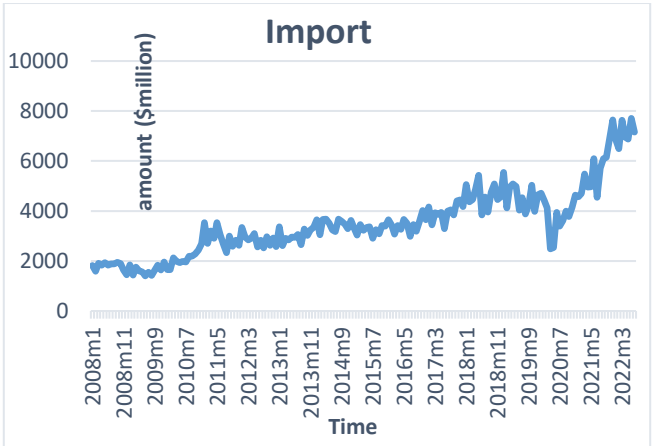
This diagram exhibits the line plots of all the variables of the study, plotting the numerical value on the vertical axis and time on the horizontal axis. It illustrates an upward trend of the foreign exchange reserve, where other variables have identical patterns. Moreover, there is a dramatic fall in foreign exchange reserves, exports, imports, remittances, and foreign direct investment after 2020 as COVID-19 hit at that time. Besides, the exchange rate has significantly risen at the beginning of 2022.

Requirement of the Unit Root Test

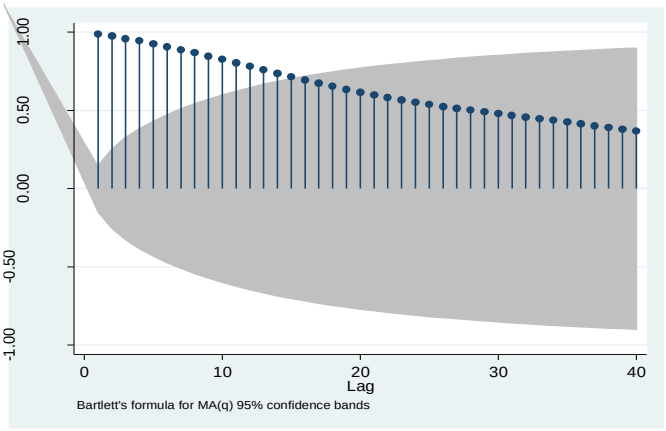
Graphical Plots

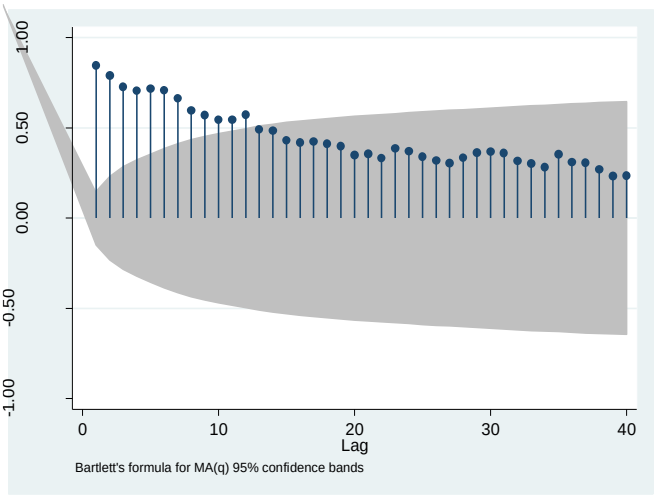


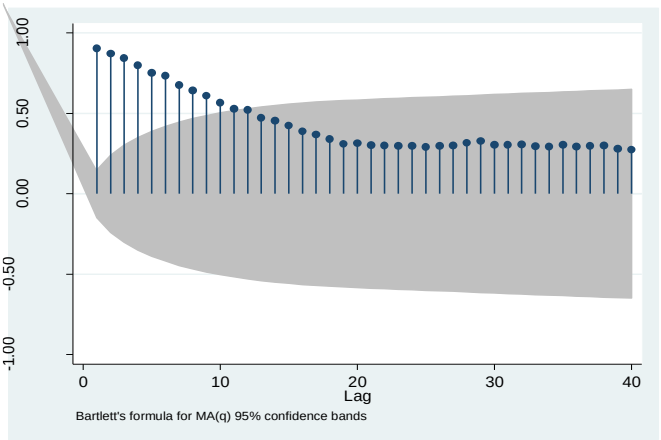




Correlograms of ACF







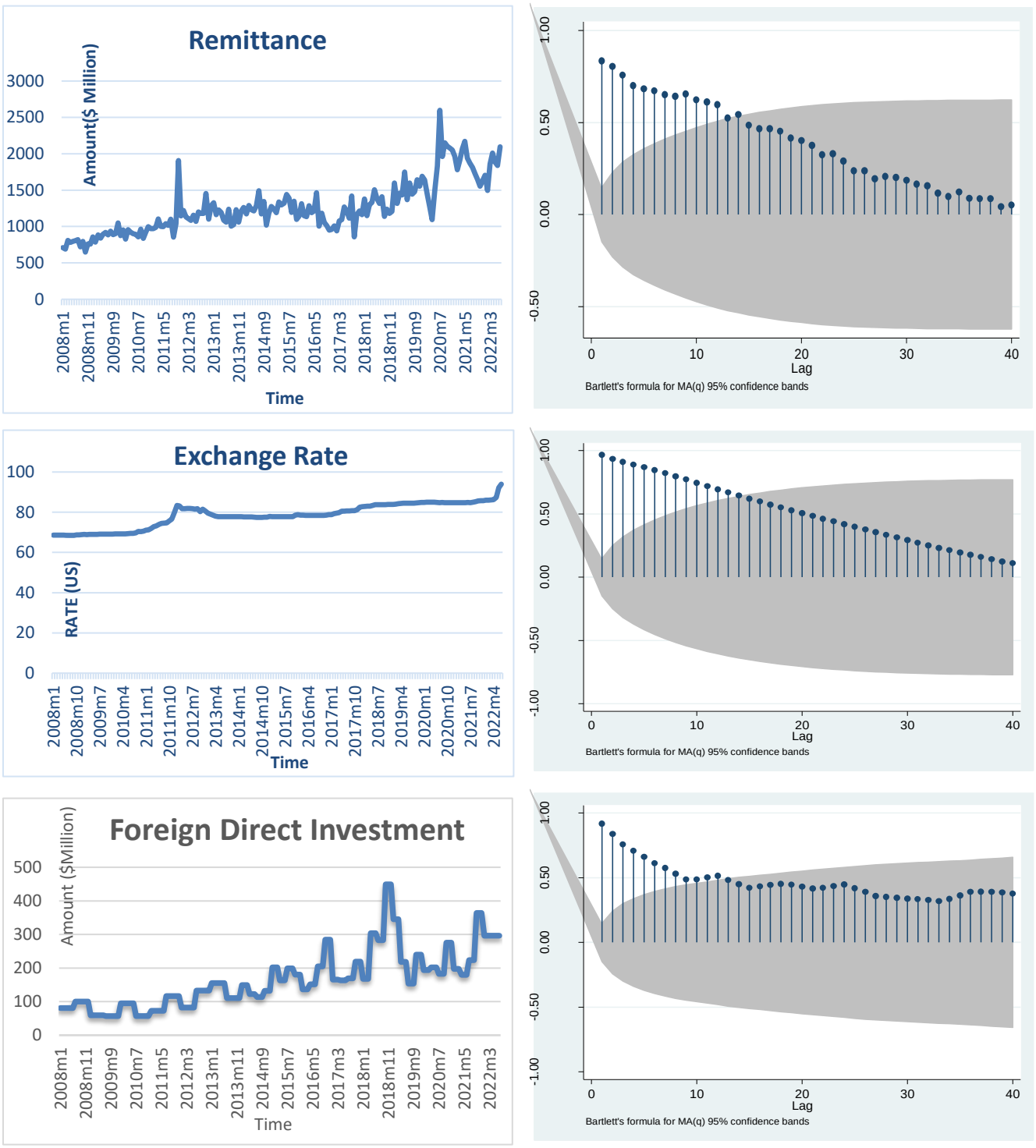


Figure 4: Graphical Plots of Variables and Their Correlogram
Source: Author's Calculation

This figure illustrates the individual graphical plots of variables of interest and respective correlograms. The graphical plots facilitate the understanding of the trends or patterns of the variables, while correlograms assist in getting the insights about the stationarity of the variables at the level. The decision criteria for this approach are that if the correlation of the time series variable over several lag values isn't declining quickly, then we will be certain that there is non-stationarity in the variable. In the pattern of the correlograms for all the variables, it is clear that as the lags increase, the correlation is declining, but the rate is slow. This indicates that there is a presence of non-stationarity in the variables. Moreover, from the OLS model, we find that the goodness of fit, which means R^2 is

0.8251, meaning 82.51% variation of the dependent variable can be explained by the variation in the explanatory variables. On the other hand, we can see that when we do the D-Watson test, the value of the d-statistic (6, 175) = 0.3888869. As the value of the d-statistic is lower than the value of R^2, this indicates the presence of a unit root in the model, or there is non-stationarity in the model. So, we need to test the stationarity of the model. The Null Hypothesis H_0 = Non-stationary, and the Alternative H_A = Stationary.

The decision criterion at 5% significance level is if the value of the t-statistic > 5% critical value, reject the null. Again, if the t-statistic < 5% critical value, do not reject the null. That implies, there is a presence of a unit root or the variable is nonstationary.

Table 2: Augmented Dickey-Fuller Test

Stationarity Test at a Level				Stationarity Test at First-Difference			
Variables	t- statistics	Critical value at 5%	Decision	t- statistics	Critical value at 5%	Decision	Status
FXR	-0.432	-2.885	Nonstationary	-3.242	-2.885	Stationary	I (1)
EX	-2.323	-2.885	Nonstationary	-11.841	-2.885	Stationary	I (1)
IM	-0.391	-2.885	Nonstationary	-15.238	-2.885	Stationary	I (1)
ER	0.014	-2.885	Nonstationary	-6.571	-2.885	Stationary	I (1)
RM	-2.080	-2.885	Nonstationary	-9.213	-2.885	Stationary	I (1)
FDI	-2.446	-2.885	Nonstationary	-13.046	-2.885	Stationary	I (1)

Source: Author's Computation

The above table shows that all the variables are nonstationary at the level. That means the absolute value of the t-statistics for every variable is lower than the 5% critical value. So, this study needs to use the first difference of each variable to test the stationarity. Taking the first difference, it is revealed that the absolute values of the t-statistics are greater than that of the 5% critical value. Therefore, we can conclude that all the variables are stationary at the first difference. Hence, this study needs to select the optimum lag for the model.

Optimum Lag Selection

Table 3: Optimum Lag Selection

Selection-order criteria								
Sample: 2008m1 - 2022m7				Number of obs = 175				
|lag |	LL	LR	df	p	FPE	AIC	HQIC	SBIC
|0 |	-6803.12				1.0e+28	81.5464	81.5919	81.6584
|1 |	-5829.64	1947	36	0.000	1.4e+23	70.319	70.6373	71.1032
|2 |	-5680.51	298.26	36	0.000	3.6e+22	68.9642	69.5552	70.4205*
|3 |	-5598.14	164.72	36	0.000	2.1e+22*	68.4089*	69.2728*	70.5374
|4 |	-5567.9	60.491	36	0.006	2.2e+22	68.4778	69.6145	71.2784

Source: Author's Computation

There are several lag selection criteria, such as Final Prediction Error (FPE), Akaike's Information Criterion (AIC), Schwartz's Bayesian Information Criterion (SBIC), and Hannan and Quinn Information Criterion (HQIC). It is observed from the above table that Final Prediction Error (FPE), Akaike's Information Criterion (AIC), and Hannan and Quinn Information Criterion (HQIC) suggest the optimum lag equals 3. On the contrary, Schwartz's Bayesian Information Criterion (SBIC) has suggested that the optimum lag should be 2. Hence, this study has used 3 as the optimum lag as it is suggested by the majority of the information criteria, and run the Johansen Co-integration test and VECM afterwards. Adding a smaller number of lags is considered to be too short to capture the short-run dynamics and the autoregressive structure in monthly data. As this study has one optimum lag (3), so will run the Johansen test taking 3 as the optimum lag.

Johansen Test for Co-integration with trend constant (ρ=3)

Here, the study gets the value for the trace statistic and max Eigen statistic with the critical values of 5% significance level. The hypothesis for 5% significance level, the decision criterion is, reject the null hypothesis if the Trace and Max statistics > 5% critical value; otherwise, fail to reject the null.

From the above table, it's clear that when there is a 0 co-integrating equation or rank equals 0, then both the Trace and Max statistic values are greater than the 5% critical values. So, there are more than 0 co-integrating equations. Now check this for the rank 1 or 1 co-integrating equation, then we can see both the Trace and Max statistics values are greater than the 5% critical values. So, reject the null of 1 co-integrating equation.

Table 4: Johansen Co-Integration Result

Rank	Trace statistics	5% critical value	Max statistics	5% critical value	Decision
0	171.3466	94.15	84.2397	39.37	Reject the null
1	87.1068	68.52	39.8860	33.46	Reject the null
2	47.2209	47.21	24.7810*	27.07	(Don't reject/reject) the null
3	22.4398*	29.68	17.4138	20.97	Don't reject the null.
4	5.0260	15.41	4.9771	14.07	Don't reject the null.
5	0.0489	3.76	0.0489	3.76	Don't reject the null.

Source: Author's Computation

Again, test the 2 co-integrating equations, then this study finds that the Trace statistic value is just higher than the 5% critical value. So, this study won't reject the null of 2 co-integrating equations. Hence, in terms of the Trace statistic, there are 2 co-integrating equations. However, the Max statistic is lower than the 5% critical value. So, there are 2 co-integrating equations in the model on the basis of the Max statistics. Moreover, for rank 3 or 3 co-integrating equations, the Trace statistic is lower than the 5% critical value. So, this study won't reject the null of 3 co-integrating equations. Hence, in terms of the Trace statistic, there are 3 co-integrating equations. As there are more than 0 co-integrating equations, this study uses the Vector Error Correction Model to check the long-run relationship. Therefore, this study uses a lag order (ρ) equals 3 for the computations.

Vector Error Correction Model: (ρ=3)

Table 5: VECM Results for Long-Run Relationship

Variables	Coef. / Std. Err	Z	P>|Z|	[95% conf. Interval]	
Fxr	1	-		Lower Bound	Upper Bound
Ex	-274.9332 (30.90819)	-8.90	0.000	-335.5121	-214.3543
Im	159.1503 (24.6182)	6.46	0.000	110.8996	207.4011
Er	9161.887 (2898.174)	3.16	0.002	3481.57	14842.2
Fdi	-419.8104 (160.6952)	2.61	0.009	104.8536	734.7672
Rm	-257.1563 (47.90207)	-5.37	0.00	-351.0426	-163.27
constant	-35158.9				

Source: Author's Computation

The above table shows that the value of the coefficient of the exchange rate is 274.9332 and the significance at the 5% level. This indicates that there is a positive impact of exports on foreign exchange reserves. This aligns with our prior expectation, as we expect exports to positively affect foreign exchange reserves. Looking at the coefficient of import (im), here the value is 159.1503, and after inversion, it becomes -159.1503. This coefficient is statistically significant at the 5% level. This implies that, in the long run, imports negatively affect foreign exchange reserves. Regarding the exchange rate (er), the coefficient is 9161.887, and after inversion, it becomes -9161.887. This coefficient is also statistically significant at the 5% level. Therefore, the study concludes that the exchange rate has a negative impact on foreign exchange reserves. When examining foreign direct investment, the coefficient is -419.8104, and after inversion, it becomes 419.8104. This coefficient is statistically significant at the 5% level. This suggests that foreign direct investment has a positive impact on foreign exchange reserves. Finally, the coefficient of remittance is -257.1563, and after inversion, it is 257.1563. The coefficient is statistically significant at the 5% level. This indicates that, in the long run, remittance has a positive impact on foreign exchange reserves. From this analysis, we can conclude that exports, remittances, and foreign direct investment have a positive impact on foreign exchange reserves, while imports and the exchange rate have a negative impact.

Here, the short-run adjustments and error-correcting term (ECT)

$$ECT_{t-1} = [1.00\,FXR_{t-1} + 159.1503\,IM_{t-1} + 9161.887ER_{t-1} + 419.8104FDI_{t-1} - 257.1563\,RM_{t-1} - 35158.9]$$

$$\Delta FXRt = \sigma + \sum_{i=1}^{k-2} \rho i\ \Delta FXR_{t-2} + \sum_{j=1}^{k-2} \beta j\ \Delta EX_{t-2} + \sum_{l=1}^{k-2} \alpha l\ \Delta IM_{t-2} + \sum_{m=1}^{k-2} \pi m\ \Delta ER_{t-2} + \sum_{n=1}^{k-2} \varphi n\ \Delta FDI_{t-2} + \sum_{o=1}^{k-2} \tau o\ \Delta RM_{t-2} + \gamma\ ECT_{t-2} + Ut$$

$$\Delta FXRt = 46.366 + 0.861\ \Delta FXR_{t-2} + 0.137\ \Delta EX_{t-2} - 0.231\ \Delta IM_{t-2} - 0.478\ \Delta ER_{t-2} + 1.446\ \Delta FDI_{t-2} + 0.147\ \Delta RM_{t-2} - 0.00103\ ECT_{t-2}$$

The above model presents that the ECT is -0.00103, and it is statistically significant at 5% level of significance. This illustrates that errors from preceding months (or deviations from long-run equilibrium) are corrected

within the current month at a convergence speed of 0.103 percent. Here, the coefficients of short-run adjustments show the effect of lag 3 on the long-run relationship.

DIFFERENT DIAGNOSTIC TESTS

Here, this study conducts three diagnostic tests to check the model. As a result, this study employs the vector error correction model (VECM) with a lag of 3. That means the long-run relationship among the dependent and independent variables is consistent with the prior expectations in this model.

Autocorrelation test

Lagrange-multiplier test

Table 6: Results of Autocorrelation Test

Lag	Chi^2	df	Prob > Chi^2
1	49.1493	36	0.07082
2	77.4386	36	0.00007
3	50.2289	36	0.05792

Source: Author's Computation

The null hypothesis is "no autocorrelation at lag order." From (table-06), the lag order is 1, and the probability value is higher than the 5% critical value (0.05). So, the null hypothesis is accepted as if p-value (0.0708) > 5% critical value (0.05). This implies that at lag order 1, there is no autocorrelation. However, the lag order 2 as the p-value (0.00007) is less than the 5% critical value 0.05. So here, the null hypothesis of no autocorrelation at the lag order 2 is rejected. On the other hand, the lag order 3, the p-value (0.05792) > 5% critical value (0.05) implies there is no autocorrelation at lag order 3. This exhibits the accuracy of the model as well as estimation.

Normality Test

Jarque-Bera Test

Table 7: Jarque-Bera test

Equation	Chi^2	df	Prob > Chi^2
D_fxr	7.770	2	0.02055
D_ex	800.322	2	0.00000
D_im	2.600	2	0.27257
D_er	1319.459	2	0.00000
D_fdi	338.118	2	0.00000
D_rm	1158.913	2	0.00000
All	3627.180	12	0.00000

Source: Author's Computation

The above table demonstrates that the value of the probability for import is greater than the 5% critical value. Here, the H_0= data are normally distributed, and the H_A= data are not normally distributed. That means only the observations of the import are normally distributed. On the other hand, from the above table, it is found that all the p-values of other variables are smaller than the 5% critical value. This indicates that the data or observations of the foreign exchange reserve, exports, exchange rate, foreign direct investment, and remittances aren't normally distributed. Again, in the last row, the normality of the model is tested, and the model isn't normally distributed. As this is the monthly data, there can be variations in the observations over the months. So, this result isn't something very spurious. Therefore, this study will test the stability of the model using the Eigenvalue stability condition.

Eigenvalue Stability Test

Table 8: Stability Test Result

Eigenvalue	Modulus
1	1
-.9507653	.950765
.8247204	.82472
.4063437 + .5037671i	.647222
.4063437 - .5037671i	.647222
-.4681924 + .4309323i	.636323
-.4681924 - .4309323i	.636323
-.3016626 + .4842594i	.570533
-.3016626 + .4842594i	.570533
-.5493439	.549344
.3994844 + .3639336i	.540403
.3994844 - .3639336i	.540403
.05470301 + .2421583i	.24826
.05470301 + .2421583i	.24826
Comment	The VECM specification imposes 5-unit moduli.

Source: Author's Computation

From (table-08), it is observed that the study represents that the Vector Error Correction Model (VECM) specification imposes 5-unit moduli. This indicates that this model is stable.

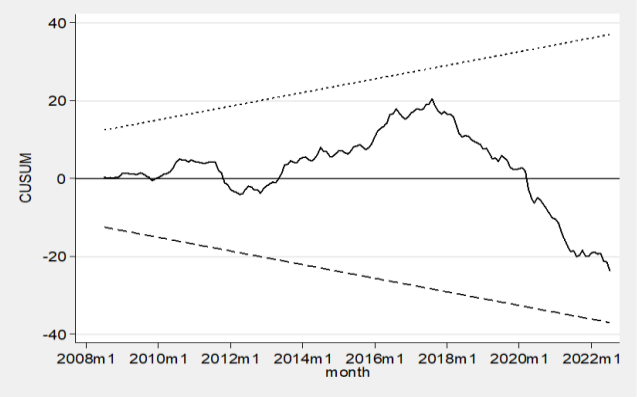
So, from the diagnostic tests, the study got mixed results for the model. Where autocorrelation isn't present in the model at lag order 1, but it is present at lag order 2. Again, from the normality of the model, it was found that only import observations are normally distributed. Other variables and overall, the model aren't normally distributed. Finally, the study has verified the stability of the model. The result shows that the model is stable.

Stability Tests

The Cumulative Sum (CUSUM) of Recursive Residuals and the Cumulative Sum of Squares (CUSUMSQ) of Recursive Residuals tests are utilized to test the parameter stability. The first one identifies the systematic changes in the regression coefficients, and the second one investigates the sudden changes in the constancy of the regression coefficients. Figure 05 demonstrates the findings from these two tests. CUSUM indicates the stability of the regression coefficients as the plot falls inside the critical bands of a 1 percent confidence interval of parameter stability, while CUSUMSQ indicates sudden changes in the constancy of the coefficients. Though two

tests generate conflicting results, the coefficients are stable, as the CUSUM indicates, over the sample period for Bangladesh.

Plot of Cumulative Sum of Recursive Residuals



Plot of Cumulative Sum of Squares of Recursive Residuals

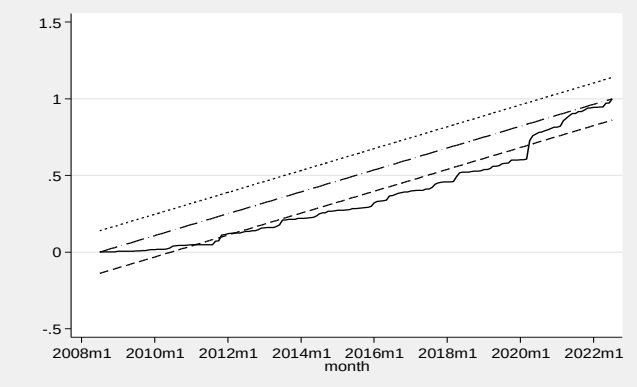


Figure 5: CUSUM and CUSUMSQ Tests for Parameter Stability (Brown et al., 1975)

Source: Author's Calculation

Discussion

Foreign exchange reserves play a vital role in strengthening a country's ability to meet international obligations and absorb external shocks. To better understand their determinants, this study applied econometric techniques that revealed several important findings.

We first conducted standard time-series diagnostics. Using the Augmented Dickey-Fuller (ADF) test, we confirmed that the variables were non-stationary in levels but became stationary after first differencing, which is consistent with earlier studies on Bangladesh (Chowdhury et al., 2014). To determine the optimal lag length, multiple criteria were used: Schwarz Bayesian Information Criterion (SBIC) suggested lag 2, while Akaike's Information Criterion (AIC), Final Prediction Error (FPE), and Hannan-Quinn Information Criterion (HQIC) pointed to lag 3. Therefore, lag 3 was selected for the Vector Error Correction Model (VECM).

The Johansen co-integration test indicated the existence of multiple long-run relationships among foreign exchange reserves, exports, imports, exchange rate, foreign direct investment (FDI), and remittances, which supports findings from previous econometric research in South Asia (Rahman & Shahbaz, 2013; Ullah et al., 2024a). At lag 3, the Trace test suggested three co-integrating equations, while the Max-Eigen statistic suggested two, further confirming the presence of stable long-run linkages.

The VECM estimates revealed that exports, remittances, and FDI have a positive impact on reserves, whereas imports and the exchange rate have negative effects. A depreciation of the Bangladeshi Taka (an increase in the exchange rate) was associated with declining reserves, consistent with previous studies that highlight adverse impacts of depreciation on the balance of payments (Morshed & Hossain, 2022; Chowdhury et al., 2014). Conversely, remittances and exports were significant contributors to reserve accumulation, reinforcing earlier evidence that remittance inflows are a key buffer for Bangladesh's external sector (Dhar & Haque, 2022).

Short-term dynamics, captured through the error-correction term, indicated that deviations from long-run equilibrium are corrected at a speed of approximately 0.103% per period. This slow adjustment process suggests that while long-run relationships are strong, short-run shocks may take time to stabilize. Diagnostic tests for autocorrelation, normality, and stability showed no major issues at lag 1 and lag 3, though autocorrelation was detected at lag 2. Since the preferred model used lag 3, this does not undermine the reliability of the results.

Overall, the findings confirm that maintaining a healthy balance between trade, remittance inflows, and foreign capital is crucial for building sustainable foreign exchange reserves in Bangladesh, a conclusion consistent with recent empirical studies in emerging economies (Chowdhury et al., 2014; Ullah et al., 2024b).

Conclusion and Policy Recommendations

An optimal level of foreign exchange reserves specifies the robustness of the external sector of a country. Hence, there is no substitute for keeping a considerable amount of foreign exchange reserves in a country if the government wants to keep domestic currency stable and to evade instability of the exchange rate (Chowdhury et. al., 2014). After a lengthy analysis of the macroeconomic determinants of Bangladesh's foreign exchange reserve using monthly time series data from January 2008 to July 2022 from Bangladesh Bank's "monthly economic trend" publication, this study has concluded that export, remittances, and foreign direct investment have a positive and significant impact on Bangladesh's foreign exchange reserve, while imports and the exchange rate have negative and significant effects on Bangladesh's foreign exchange reserve. COVID-19 and the Russia-Ukraine war

have caused inflationary pressure in all economies. Consequently, export has been significantly impeded. Therefore, authorities should always be mindful of the foreign exchange reserve to pay for imports of essential products, oil, and food. As there are five statistically significant explanatory variables and these variables have asymmetric effects on foreign exchange reserve in the long run. Therefore, here must implement policies to either increase the foreign exchange reserve or achieve the optimal level of reserve necessary to meet foreign obligations and mandatory import costs.

However, the majority of exports are RMG products, which are extremely competitive and do not have a higher value addition. On the other hand, the authority must provide the necessary facilities and incentives to the entrepreneur or business owners who operate the export items industry. Again, special economic zones, export processing zones, simple legislative procedures, simple power infrastructure, transport facilities, and simple finance facilities can enable export expansion and diversification. Moreover, this will facilitate the intrusion of foreign direct investment. By contrast, imports need to be minimized. Policies such as decreasing the issuance of letters of credit, increasing the domestic production of agriculture, conducting a cost-benefit analysis before undertaking projects that require a large quantity of imported equipment or machinery, and launching a "made in Bangladesh" campaign can guarantee a reduction in imports, which will eventually have a positive effect on the foreign exchange reserve. When the currency rate depreciates, the foreign exchange reserve will grow. However, decreasing or depreciating the exchange rate should not be the sole purpose, as this will have severe repercussions in other areas. Remittance has a favorable effect on Bangladesh's foreign exchange reserve. Therefore, require attempt is required to enhance the influx of remittances to increase the foreign exchange reserve. However, as there are several obstacles in this regard, like Hundi services. This has a detrimental effect on the remittance flow in the formal channel. Therefore, strict regulations are required to encourage senders to send money transfers formally, as well as steps are required to improve the inflow of foreign direct investment.

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