

Modelling and Forecasting Foreign Reserve Dynamics: Applications of ARIMA and GARCH Model

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DOI: 10.29322/IJSRP.14.10.2024.p15440

Paper Received Date: 21st September 2024

Paper Acceptance Date: 24th October 2024

Paper Publication Date: 30th October 2024

Abstract: The primary purpose of holding reserve is to guarantee that a central government agency has cash reserves in case its national currency rapidly depreciates or runs out of money. Reserves provide central banks with the ability to exert control over the value of their currency, regulate inflation levels, and execute efficient monetary policies. This paper investigates how exchange rate and export influence foreign reserve in the long run using yearly time series data for Bangladesh from 1985 to 2022. Augmented Dickey Fuller test is used to check the stationarity of foreign reserve, export and dollar exchange rate, and all the given variables are stationary at the first difference. And Johansen's cointegration shows long-run relationship among variables. As a result, The VECM estimation identifies that export causes reserve positively and exchange rate causes negatively at 5% significant level. Therefore, forecasting of reserve is estimated for next ten years through Box-Jenkins methodology noticing ups and down trend in reserve ensuring white noise residual and stationarity of ARIMA model. Finally, ARCH and GARCH terms are highly significant to influence the current year's volatility of reserve. Understanding both actual and forecasted reserves is crucial for planning and decision-making, especially in fields like finance, resource management, and long-term strategic planning. The novelty of this research article lies in its innovative methodologies, frameworks, and practical applications that enhance the understanding and management of reserves. By introducing new tools and approaches, it provides valuable contributions to the field of financial and operational management.

JEL Classification: C22, C53, E52, F31

Introduction: Central bank ensures equilibrium in international payments and stabilise the exchange rate through foreign exchange reserves. It is a widespread practice in countries worldwide for a central bank to maintain a substantial quantity of reserves in its foreign exchange, which are not only utilised to support liabilities but also have an impact on monetary policy. These reserves serve as a precautionary measure, allowing nations to effectively handle economic recessions, stabilise their currency, and maintain consistent investor confidence. Maintaining a foreign exchange reserve can be viewed as a safeguard against a potential financial crisis that could arise from an unplanned cessation of inflow of funds, including capital and revenue [2]. The United States' economic strength in the post-World War II era resulted in the US Dollar becoming the preeminent currency for transfer in international markets. Numerous non-dollar economies continue to opt for

international transactions that involve the dollar. Before engaging in any business or trade transactions, it is common practice to convert these smaller and less widely recognized currencies to U.S. dollars. For instance, the U.S. dollar and pound sterling comprised 0% and 62% of global reserves, respectively, in 1900. However, the pound now accounts for only 4.7% of global currency reserves in 2020, while the U.S. dollar is nearly 60% [13]. A sufficient number of currencies are required in reserve as the worth of global trade is approaching \$20 trillion in value. In reality, an approximated \$5 trillion in currency exchanges occur daily [13]. Foreign reserve accumulation in emerging nations has been an issue of debate in the field of international macroeconomics since the early 2000s[12]. The reserves of many Middle Eastern economies that export oil have also increased significantly [8]. China has amassed substantial foreign exchange reserves with the ultimate objective of advancing its own political survival to shield C from unexpected disruptions in capital flows and financial crises generally [7]. For instance, Kruskovic and Maricic (2014) and Akpan (2016) discovered the beneficial impacts of accumulating reserves on investment and economic stability.

The subject of foreign exchange reserves was less elucidated in the 1980s, and countries were obligated to adhere to fixed exchange rate regimes [6]. The free-float exchange rate system was the driving force behind the Asian financial crises and the substantial demand for reserve acquisition [2]. Foreign reserves are significantly affected by inflation, the exchange rate, FDI, and exports [11]. The country's long-term reserves demand function is determined by the exchange rate, the ratio of current account deficit to GDP, the interest rate differential (measured as opportunity cost), and remittances [2]. Foreign debt and export are positively and exchange rate are negatively affecting foreign reserve in Indonesia but inflation does not affect that [1]. The need for foreign reserves is strongly influenced by the vulnerability of the capital account, but it is less affected by the opportunity cost associated with it. [2]. Reserves provide central banks with the ability to exert control over the value of their currency. If the domestic currency is depreciating, the reserve value would be reduced. There is an asymmetric causal relationship between reserve and exchange rate [4].

The foreign reserve and exchange rate are likely the most significant regulators in Bangladesh, given the limited open and import-dependent nature of the economy. Since the beginning of the conflict between Russia and Ukraine in 2022, the global economy is confronted with the new obstacle of inflation.

Consequently, Bangladesh is experiencing a shortage of foreign reserves because the cost of imports, which make up a significant portion of essential everyday items, is expensive. Persistently high inflation is reducing purchasing power and widening income inequality. Foreign reserve was 31.2 billion dollars on 30 June in 2023 but it was about 50 billion before Russia- Ukraine war. Now it is 21.78 billion which makes importer, government and people worried. Import expenditure raise while exchange rate of dollar increase [14].

Monetary policy is the most important macroeconomic decision on which economic growth, employment and inflation depend. One of the major goals of monetary policy is to maintain a balance of payment equilibrium, which includes managing reserves and exchange rates. Comprehending and forecasting the behaviour of reserve is crucial for monetary policy. Forecasting has been the subject of numerous investigations such as Godknows M. Isenah1 and Olusanya E. Olubusoye (2016) using univariate autoregressive conditional heteroscedasticity (ARCH).

The guidelines for monetary policy are determined by observing the determinants of volatility and measuring its magnitude. Foreign exchange volatility refers to the risk linked to unforeseen fluctuations in the reserve. Exchange rate volatility can be attributed to economic fundamentals such as the interest rate, inflation rate, and balance of payments, all of which have been more volatile in the 1980s and early 1990s [5]. By monitoring volatility, policymakers can ascertain the proper number of reserves and implement appropriate measures to mitigate financial market volatility. The general consensus is that higher levels of exchange rate volatility impede the expansion of international trade [5]. Economic crises may result from sudden and unexpected fluctuations in exchange rates that are not adequately monitored [3]. The volatility of foreign reserve positively affects the price of stock [16]. Only a small number of studies have attempted to model and predict the foreign reserve. However, some limitations are observed in existing literature. The literature demands more research on that subject to address these gaps.

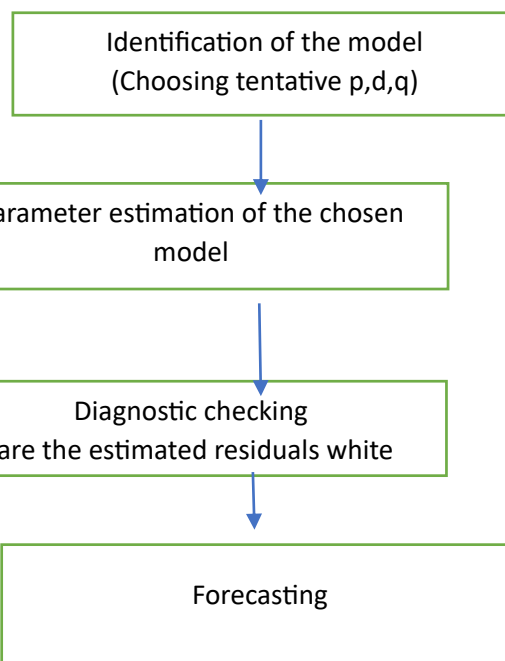
Objectives of the study:

1. To find out the relation of exchange rate and export to foreign reserve in the long run.
2. To check the effectiveness previous period’s volatility of reserve to current period.
3. To forecast the tendency of reserve in next decade.

Data and Methodology:

The analysis is based on annual time series data on foreign reserve in US dollar, exchange rate of dollar, and current export in local currency (in billion taka). The data has been taken from Bangladesh economic review for the period 1985-2022. This paper has taken several modelling issues to confirm the

dynamics linkages among the variables. Augmented Dickey Fuller test has been applied to check unit root problem and Johansen cointegration has been also used to find out the long-run association among variables. Autoregression integrated moving average (ARIMA), popularly known as the Box-Jenkins (1970) methodology, has been used to forecast. The B-J model has three steps which are illustrated by the flow chart at the end of this section. The order of p,d,q is determined in the first step where by applying partial autocorrelation, stationary test (ADF) and autocorrelation p,d,q are selected. And this paper also used ARCH model to check the volatility of dependent variable. Statistical software Sata 15 has been used to check the objectives of this study.



The Box-Jenkins methodology: Source[15]

Empirical Results:

Unit root: From table 1, we can conclude that all variables have unit root problem at level means they are non-stationary at level but at first difference all are stationary which is precondition for analysing time series data.

Table1: Stationary test: Dickey Fuller test

Variable	ADF value	5% Critical value	P value
Inreseve	0.692	2.969	0.8489
Inexcg	1.517	2.975	0.5251
Inexport	1.442	2.972	0.5618
D. Inreseve	4.368	2.972	0.0003
D.Inexcg	3.225	2.978	0.0186
D.Inexport	2.832	2.975	0.0539

Source: The author’s computation using STATA 15

Cointegration Test:

The application of Johansen’s co-integration helps to determine if variables are co-integrated, given that all variables are stationary at the first difference. Table 2 shows the result of cointegration to determine the order of rank. Rank 0 indicating there is long run relationship among variables as trace statistic is greater than critical value at 5% significance level where null hypothesis is no cointegration. By accepting null hypothesis at rank 1, one cointegrating equation among variables, as trace statistics is less than 5% critical value we conclude that long-run association is present among variables.

Table2: Johansen tests for cointegration

Maximum Rank	trace statistic	5% Critical value
0	29.2091	20.97
1	8.3614	14.07

Source: The author’s computation using STATA 15

Long-run cointegrating Equation (Regression result):

$$\text{Inreserve} = 8.80 - 7.55\text{exc} + 3.23\text{lnexport} + u_t$$

Above regression result shows that export enhance foreign reserve positively whereas exchange rate negatively affect reserve. Furthermore, a number of time series forecasting techniques, particularly regression modelling, rely on the presumption that the residuals—that is, the difference between the fitted model and the data—do not exhibit any autocorrelation. To check autocorrelation, we can apply Brusch Godfrey test. Here null hypothesis is no autocorrelation and alternative is autocorrelation in residual. Since p-value is more than 5 %, we accept null in table 3.

Autocorrelation test:

Table 3: Lagrange-Multiplier test

Lag	Chi2	Df	P value
Lag1	10.1981	9	0.33469
Lag 2	7.6603	9	0.56870

Source: The author’s computation using STATA 15

ARIMA MODEL: Forecasting

The B-J type time series model allows dependent variable to be explained by past, or lagged, values of dependent itself and stochastic error terms such as following:

$$\text{Reserve}_t = \beta_0 + \beta_1\text{reserve}_{t-1} + \beta_2\text{reserve}_{t-2} + \beta_3\text{reserve}_{t-3} + \beta_4\text{reserve}_{t-4} + e_t$$

Where Reserve is foreign reserve in US dollar and $\beta_1, \beta_2, \beta_3, \beta_4$ are the coefficient of lagged values of reserve. If we have to difference a time series d times to make it stationary and then apply the ARMA (p,q) model to it, we say that the original time series is ARIMA (p,d,q), that is, it is an autoregressive integrated moving average time series, where p denotes the number of

autoregressive terms which is explained in figure 2, d the number of time series has to be differenced before it becomes stationary, and q the number of moving average that is showed in figure 1. Our underlying ARIMA time series has to be differenced twice (d=2).

Figure 1: Autocorrelation

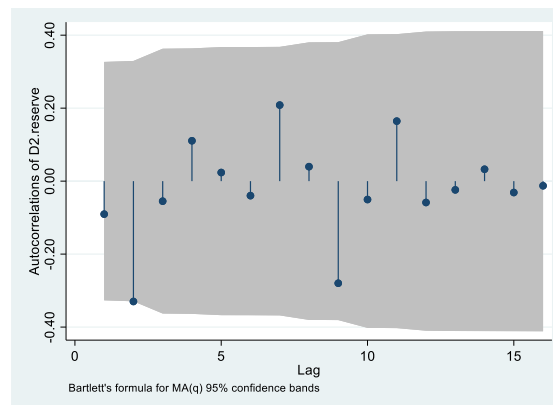


Figure 2: Partial Autocorrelation

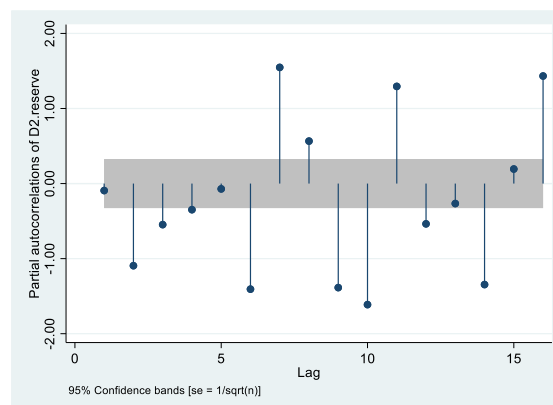


Table 4: Arima regression:

	D2.reserve	Coefficient	Pvalue
	cons	20.57042	0.898
AR	L1	-.5215139	0.000
	L2	-1.126558	0.000
	L3	-.4580869	0.025
	L4	-.3487429	0.194
	Sigma	2390.881	0.000

Source: The author’s computation using STATA 15

In table 4, the all 4 lags of autoregressive to influence reserve is significant at 5% significance level except lag 4 but p-value of lag 4 is not so high we can accept it.

Autocorrelation Test:

Null hypothesis: Residuals are white noise

Alt hypothesis: Residuals are not white noise.

Since Portmanteau test shows p-value is high (table 5), we can say residual of this model is white noise.

Table 5: Portmanteau test for white noise

Portmanteau (Q) statistic =	5.0800
Prob > chi2(16)	0.9953

Source: The author's computation using STATA 15

Stationarity of ARMA model:

The paper must also check the stationarity of estimated Arma model; hence AR roots should lie inside the unit circle. In figure 3 we can conclude all AR roots stay inside the circle which is desirable for forecasting a time series data in future. A forecast of foreign reserve which has become most concerned and discussed topic in Bangladesh for the next decade is shown in figure 4. Blue line represents the actual reserves from 1985 up to a point just after 2020. This is the observed data, showing how the reserve values have changed over time and the reserves seem to rise steadily, particularly after 2000, with a steep increase. Red line represents the forecasted reserves starting around 2022 and extending into the future until 2032. This line is a projection based on a model that likely uses past data to predict future reserve values. From 2022 onwards, the red line begins to diverge from the blue line, indicating the model's forecast for future reserve values. The forecast suggests that the reserves will continue to increase, following a similar upward trend, though slightly more volatile than the past. The close alignment of the red and blue lines before 2022 suggests that the model's forecast was well-calibrated to the historical data.

Figure 3: AR roots

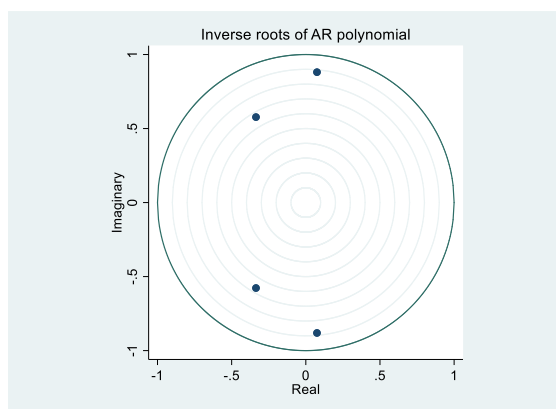
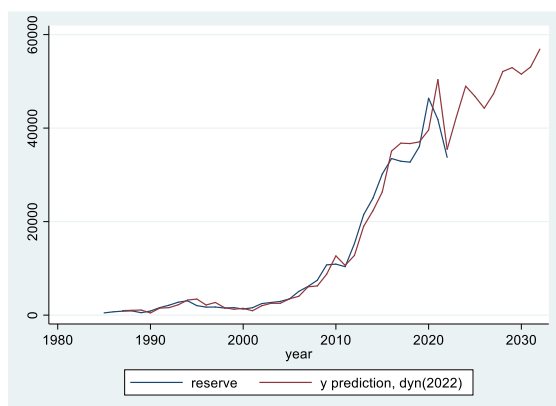


Figure 4: Forecasting for foreign reserve



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10.29322/IJSRP.14.10.2024.p15440

Volatility of Reserve:

$$\text{Mean model: } \text{reserve}_t = \delta + \delta_1 \text{Export}_t - \delta_2 \text{exch}_t + v_t$$

$$\text{Variance model: } \sigma_t^2 = \alpha_1 + \alpha_2 \sigma_{t-1}^2 + \alpha_3 v_{t-1}^2 + \alpha_4 \text{remitan}$$

Here, σ_t^2 is the variance of the residual derived from mean model which is also known as the volatility of foreign reserve. σ_{t-1}^2 is the previous year volatility of reserve and It is known as the GARCH term. $\alpha_3 v_{t-1}^2$ is the ARCH term indicating previous year's reserve information about volatility.

Table 6: LM test for ARCH

Lags (p)	Chi2	df	Prob
1	17.536	1	0.000

Source: The author's computation using STATA 15

Table 7: ARCH family regression-multiplicative heteroskedasticity

reserve		coefficient	pvalue
reserve	export	.9479382	0.000
	exch	-166.5474	0.000
	cons	4806.509	0.000
Het	remitan	.0003702	0.035
	cons	9.843972	0.000
ARCH	L1	1.57	0.029
GARCH	L1	-.0094	0.000

Source: The author's computation using STATA 15

Conclusion:

Achieving macroeconomic stability is the prerequisite for development in any economy. The economy of Bangladesh is facing several macroeconomic problems, which are obstacles to economic stability and growth. These challenges come from both domestic and international sources which have created a difficult situation not only for the policy makers but also for the government. Inflation in Bangladesh has been above 9% for 15 months. Because of this, people have been suffering a long time. Moreover, inflation negatively affects exchange rates and reserve. Importers, exporter, and also consumers are too much worried about how their movement will be in the future. To deal with the ongoing situation, central bank needs to formulate monetary policy with efficiency, transparency and accountability. This research will help them in formulating this as the objectives of this study to identify the factors that influence reserve, volatility of reserve and forecasting of reserve. It helps in understanding performance, adjusting strategies, and ensuring that the organization remains well-positioned to meet its future obligations. Regular monitoring and analysis of these reserves enable better risk management and strategic planning. this research article makes significant academic contributions by employing advanced modelling techniques, providing insights into long-run dynamics and volatility of foreign reserves, offering practical recommendations for policy, and enhancing the understanding of reserve management in emerging economies.

The government has targeted to ensure previous years growth rate of GDP and moderate inflation rate for upcoming fiscal year. To achieve these targets, the reserve has to be taken to comfortable volume. So, the recommendations are the raise export's income, remittance and foreign debt in development projects. Furthermore, under invoicing of export, over invoicing of import, non-repatriation of export earning, and Hundi should be controlled along with the increase of efficiency, sovereignty and transparency of central bank. As a result of this success, the economy that is supposed to be in a comfortable position at present has become rather complicated. Thus, the foreign exchange market is going to guarantee economic stability and give investors even more confidence.

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