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Monetary Policy and Foreign Exchange Fluctuations in Cambodia

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Abstract

In this study, the ARMAX model, a univariate time series model, was utilized to assess the impact of broad money supply on the exchange rate between the Khmer Riel and the US Dollar. The maximum likelihood estimation method was employed to estimate the sample parameter using monthly data from January 2011 to March 2023. The findings indicated that the monthly exchange rate and money supply series were integrated at order one or I(1), as demonstrated by the ADF unit root test. The Engle and Granger cointegration test revealed a long-run relationship between EXC and M2. Notably, among the top four ARMAX models, ARMA(1,1) was deemed the best model due to the lowest value of Schwarz Bayesian Information Criteria and was therefore selected. Consequently, an increase or decrease of KHR 100 million in money supply would cause the nominal exchange rate to depreciate or appreciate by approximately KHR 41.8 per US Dollar. The empirical results of this study suggest that the US Dollar Auction, a traditional monetary policy conducted by the central bank, is the most effective tool in controlling fluctuations in the domestic foreign exchange rate.

Keywords: *Exchange Rate, Broad Money, ADF test, Engle and Granger Cointegration test, SBIC, ARMAX Model*

1. Introduction

Over the course of nearly two decades, spanning from 1998 to 2019, Cambodia experienced an average annual economic growth rate of approximately 7.7%. The country's economy is typically segmented into three primary sectors, namely agriculture (24.4%), industry (37%), and services (38.6%). Despite the presence of these three sectors, it was the garment industry and tourism within the service sector that played a pivotal role in driving the Cambodian economy's recovery during this period. However, the COVID-19 pandemic had a significant impact on the country's economic growth, resulting in a negative growth rate of 3.1% in 2020. Nevertheless, the economy has since rebounded, with a growth rate of 3% in 2021, largely due to an increase in export demand from foreign markets, particularly for garment products (World Bank, 2023). According to the April 2023 Asian Development Outlook (ADO) published by the Asian Development Bank (ADB) in 2021, the real GDP growth rate for the year 2022 was recorded at 5.2 percent. It is anticipated that this growth rate will increase to 5.5 percent in 2023 and further to 6 percent in 2024, primarily due to the recovery of the tourism and other service sectors. The sustained economic growth that Cambodia has been experiencing for over two decades is attributed to the stable price level maintained by the macroeconomic policies of the Royal Government of Cambodia (RGC), which includes both monetary and fiscal policies (Asian Development Bank, 2023). Cambodia is categorized as a highly dollarized economy due to the extensive use of the US dollar in the daily transactions of Cambodian citizens, particularly in the urban regions of Phnom Penh and other provinces with significant economic and commercial activities. Furthermore, approximately 90% of commercial banks' loans are denominated in US dollars (Lim, 2018). In such an economy, the National Bank of Cambodia (NBC), as the monetary authority, has consistently maintained that price stability can be achieved through a stable exchange rate between the Khmer Riel and the US dollar. The NBC manages exchange rate fluctuations in the domestic foreign exchange market by regulating the money supply in the economy, particularly the domestic circulating currency, the Riel. Cambodia employs two definitions of the monetary aggregate, namely narrow base (M1) and broad money (M2). The narrow base money supply is derived from the combination of currency in circulation and demand deposits, while the broad money supply is calculated by adding M1 to time and savings deposits, as well as foreign currency deposits. The extent of dollarization has constrained the central bank's capacity to execute monetary policy. The

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RGC has released government bonds that are offered to the general public, albeit their trading value remains relatively low. Consequently, open market operations are not deemed the most effective means of regulating the money supply within the economy. The lender-of-last-resort mechanism is also applicable in the banking system, whereby banks may obtain funds from the central bank. However, this avenue is not a favored source of financing for banks, given that the majority of lending and borrowing in the banking system is denominated in US dollars. Additionally, the central bank has established the reserve requirement ratio to manage money deposits in banks and the money supply. The policymakers at the central bank assert that the maintenance of exchange rate stability is imperative in achieving price stability. In pursuit of this objective, the central bank strives to regulate the fluctuation of exchange rates between the Khmer Riel and the US Dollar in the domestic foreign exchange market. This is accomplished through the implementation of a mechanism referred to as the US Dollar Auction, which entails the purchase or sale of US Dollars in the domestic market from money exchangers, with the intention of managing the quantity of Riel in circulation. It is imperative to conduct an empirical investigation into the fluctuations of the exchange rate between the Khmer Riel and the US Dollar, at varying levels of monetary supply, in order to provide pertinent information to policymakers in relevant institutions. This information will aid in the formulation of efficacious strategies for stabilizing the exchange rate and the overall price level. The primary objective of this study is to devise the optimal Autoregressive Moving Average model of the exchange rate, by incorporating the exogenous variable of monetary aggregate, M2, known as the ARMAX model. This model possesses the ability to make dynamic forecasts.

2. Literature Reviews

The majority of research pertaining to fluctuations in exchange rates has been conducted utilizing univariate models, such as Autoregressive Regressive Integrated Moving Average (ARIMA) or Seasonal ARIMA (SARIMA). A comparative analysis was undertaken to assess the predictive efficacy of linear regression and ARIMA models in forecasting the exchange rate between the United States dollar and the Renminbi. The study utilized daily data spanning from February 23, 2022, to February 23, 2023. The primary aim of this research was to forecast short-term trends and variations in the data, while also examining the policies that give rise to abrupt fluctuations in the data over brief intervals. The research presented in this article provides novice statisticians with additional insight into problem-solving techniques. In particular, prediction problems that are beyond the scope of simple linear regression and conventional elementary models can be effectively analyzed by applying specific time series models. In addition, plausible justifications for data fluctuations can be attributed to existing policy factors, such as the inevitable effects of inflation and the United States' response to the Federal Reserve's interest rate hike (Wang, 2023). The Box-Jenkins SARIMA (1, 0, 1)(1, 0, 0)12 model was applied with monthly exchange rate to forecast the exchange rate between the Jordanian Dinar versus US Dollar. In the present application, it has been demonstrated that the Box-Jenkins methodology is well-suited for the purpose of modeling and forecasting exchange rate data pertaining to the Jordanian Dinar vis-à-vis the US Dollar (Shaher and Tahir, 2020). This model was also applied in predicting the foreign exchange between Indonesian Rupiah (INR) and US Dollar by using weekly data covering from December 1, 2003, to June 15, 2023. Based on Schwarz Bayesian Information Criteria (SBIC), the optimal model of exchange rate of INR was SARIMA(2,1,0,52). The empirical result of this research concluded that the SARIMA model is a statistical model that effectively captures seasonal trends in historical data to forecast future discounts. Its application is instrumental in facilitating informed decision-making in areas such as currency trading, financial planning, and international business operations (Amrullah, 2023). The determination of exchange rates using the MPT is closely linked to the international gold standard, as noted by Brown (2008). During the period of the Bretton Woods System from 1955 to 1970, exchange rates were fixed to gold, and currencies in the market were either made of gold or convertible to gold at a predetermined rate. The value of currency was pegged to the weight of gold, and it was the responsibility of the central bank of each country to be prepared to buy and sell gold at a certain price. The Quantity Theory of Money (QTM), which is based on the monetarist school of thought, is the simplest model for determining the long-run equilibrium exchange rate. According to Nyoni (2018), the monetarists asserted that any change in the quantity of money affects only the price level, leaving the real sector of the economy unaffected. In the context of international economics, or the international form of QTM, an increase in the money supply is also reflected in a proportional increase in the exchange rate. As demonstrated by Oleka, Sabina & Mgbodile (2014), the exchange rate can be seen as determined by the demand for money, which is positively affected by the growth rate of the real economy and negatively affected by the inflation rate. Therefore, it is impossible to ignore the significant impact of real economic growth on a country's currency value. However, Ude (1999) argued that the international QTM has a limitation in that it cannot account for fluctuations in the real exchange rate, as opposed to the nominal exchange rate. On the contrary, the TMPT asserts that an increase in the actual interest rate resulting from the implementation of a restrictive monetary policy leads to a greater appreciation of the currency in the short run as opposed to the long run. This is due to the fact that the tightening of monetary policy can enhance the yield on domestic assets, thereby prompting foreign investors to consider holding foreign assets, particularly if they anticipate a future depreciation of domestic currencies. In the meantime, the Central Bank of Nigeria (CBN) employs the Purchasing Power Parity Theory (PPPT) as an economic theory to ascertain the relative value of currencies. This is achieved by estimating the sum of the adjustments required in the exchange rate between countries, in order to equate the purchasing power of each currency. According to Scott (2008), the PPPT identifies inflation levels and trends as

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significant determinants of the exchange rate for both emerging and developed economies. The PPPT asserts that the value of a currency will depreciate if inflation is high or perceived to be increasing. This is due to the fact that inflation erodes purchasing power parity and consequently, demand for that particular currency. As concluded by Obadan (2006), the equilibrium exchange rate between two convertible paper currencies is determined by the equality of their purchasing power. Extensive research has been conducted to forecast the exchange rate of various currencies in different regions. Typically, the models adopted utilize time series data, which is known to be dynamic. Therefore, Dos (2018) and Dos & Diz (2019) have suggested that forecasting models may need to be adjusted according to the behavior, trends, or main goals of the study. For example, certain determinants of exchange rates cannot be controlled, such as government interference, surplus, or deficit in the balance of payments or trades. Consequently, forecasting exchange rates and other time series data remains of great interest among researchers. Many researchers have attempted to forecast exchange rates using various methodologies. For instance, Ishfaq (2018) utilized time series methodology to study the exchange rate of the Chinese Yuan (CNY) and concluded that the VIX index is applicable in providing a fair prediction of the direction of the CNY exchange rate movement. Meanwhile, Prado et al. (2020) suggested a new model that incorporates several individual models, including autoregressive integrated moving average, genetic algorithm, extreme machine learning, ANN models, SVR techniques, adaptive neuro-fuzzy inference system, and fuzzy inference system models. The study concluded that the incorporation of these models enhances the accuracy of the model. Other researchers, such as Mance et al. (2015), applied the causality test to find the relationship between exchange rate movement, inflation, and other macroeconomic variables. Lastly, several other studies have also adopted the ARMA/ARIMA methodology and suggested a more accurate response, i.e., close to actual. In 2020, Joshi et al. utilized the ARIMA method with the Box-Jenkins approach to forecast the time series of the exchange rate between the Indian Rupee and the US Dollar. The study determined that ARIMA(1,1,5) produced a more precise result, closely resembling actual observations. Additionally, Deka et al. (2019) utilized the ARIMA method to predict the consumer price index and the exchange rate of the Turkish Lira and Turkish inflation rate. The study suggested that ARIMA(3,1,3) and ARIMA(1,1,4) provided more accurate results in predicting the exchange rate and inflation rate, respectively. Furthermore, Abreu et al. (2019) tested the forecasting accuracy of the ARIMA and Singular Spectrum Analysis (SSA) models in predicting the exchange rate between the EUO/US Dollar. The study concluded that ARIMA was highly accurate in forecasting the exchange rate between the EUO/US Dollar compared to the SSA model. Similarly, Umar et al. (2019) demonstrated the vital role of ARIMA in his study and concluded that ARIMA(2,1,1) was highly efficient in forecasting the exchange rate of Naira against the UK Pound.

Finally, Farhan et al. (2019) employed the aforementioned method to analyze the exchange rate of the Iraqi Dinar against the US Dollar. The results indicated that ARIMA(1,1,1) generated the most reliable forecasting compared to other models. Furthermore, Dhankar (2019) employed the ARIMA model to forecast four exchange rate time series, namely the US Dollar, Sterling Pound, Euro, and Yen against the Indian Rupee. The out-of-sample forecasting results indicated that the exchange rate of the pound, dollar, and euro would experience slight appreciation in the following year. Conversely, the behavior of the exchange rate of the Japanese Yen remained constant.

Additionally, Tran (2016) utilized three years of data to predict the exchange rate of the Vietnam Dong and US Dollar for the next year. The results revealed that the ARIMA model is more suitable for short-term forecasting than long-term forecasting, as evidenced by the comparison of the forecasting data with the actual data. Humphry et al. (2015) investigated the exchange rate of the Zambian Kwacha to the US Dollar using the autoregressive-integrated model with data spanning from 1964 to 2014. Kadilar et al. (2009) determined that the ARIMA model is appropriate for determining the week-by-week rates of USDTRY, utilizing data from January 3, 2005, to January 28, 2008, with 160 observations.

Cenk et al. (2017) utilized 3,069 observations of USDTRY from January 3, 2005, to March 8, 2017, to produce short and long-term models for determining. They concluded that the ARIMA(2,1,0) and ARIMA(0,1,1) models are suitable for short-term and long-term estimating, respectively. Bircan et al. (2003) assessed the monthly mean exchange rate of USD/TRY using 132 observations from January 1, 1991, to December 31, 2002. The analysts determined that the appropriate model is ARIMA(2,1,1). In conclusion, the ARIMA method is a suitable approach for forecasting the USDTRY exchange rate. Other analysts have also utilized the ARIMA model to forecast various variables, such as the KIBOR rate (Ahmed et al., 2017) and the gold price (Massarrat, 2017). Moreover, the ARIMA model can predict macroeconomic trends.

The ARIMA and SARIMA models are statistical models that effectively capture trends in exchange rate series, spanning daily, weekly, monthly, quarterly, semiannual, or annual periods, between two currencies. These models utilize past data values to forecast future fluctuations in exchange rates. However, a notable drawback of the ARIMA and SARIMA models is their failure to account for exogenous shocks that may arise from other macroeconomic indicators. To address this research gap, the present study will employ the ARMAX model to investigate fluctuations in the exchange rate between the Khmer Riel and the US Dollar. This model will incorporate a control variable, namely broad money supply (M2), which can be influenced by the central bank.

3. Research Methodology

The ensuing equations delineate the structural equation of exchange rate, denoted as equation (1), and the autoregressive moving average, ARMA(p,q), equation (2).

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$$EXC_t = \beta M2_t + \mu_t \quad (1)$$

$$\mu_t = \sum_{i=1}^{p} \rho_i \mu_{t-i} + \sum_{i=1}^{q} \theta_j \epsilon_{t-i} + \epsilon_t \quad (2)$$

The variable EXC represents the nominal exchange rate, Riel per US Dollar, while M2 is the exogenous variable denoting broad money supply. The slope coefficient of the money supply variable is denoted by β, and the unconditional residual terms of the structural equation and ARMA equation are represented by μ and ϵ, respectively. The disturbance term ϵ_t is assumed to be a white-noise process with zero mean and constant variance, or independently and identically distributed as $\epsilon_t \sim i.i.d.N(0, \sigma^2)$. The parameters ρ and ϵ denote the autocorrelation and moving-average parameters, respectively. The time period covered in this study is from January 2011 to March 2023, denoted by $t = 1, \cdots T$. The average monthly exchange rate and broad money supply for this period are extracted from the International Financial Statistics (IFS) of the International Monetary Fund (IMF).

The parameters to be estimated in this study are β, ρ, θ, and σ^2, and the Maximum Likelihood (ML) method is used for estimation. The likelihood function under the assumption of Gaussian innovation of the ARMA model is given by:

$$log\ L(\beta, \rho, \theta, \sigma^2) = -\frac{T}{2} log(2\pi) - \frac{1}{2} log|\Omega| - \frac{1}{2} \mu' \Omega^{-1} \mu \quad (3)$$

$$= -\frac{T}{2} log(2\pi) - \frac{1}{2} log|\Omega| - S(\beta, \rho, \theta)$$

The symmetric Toeplitz variance-covariance matrix Ω is derived from the unconditional residual of the ARMAX model (Doornik & Ooms, 2003). The Schwarz Bayesian Information Criteria (SBIC) ascertains the optimal lengths of lags p and q.

4. Empirical Results

This section has been partitioned into three primary components, namely graphical analysis and descriptive statistics, unit root test, cointegration test, and the estimated outcome of the ARMAX model.

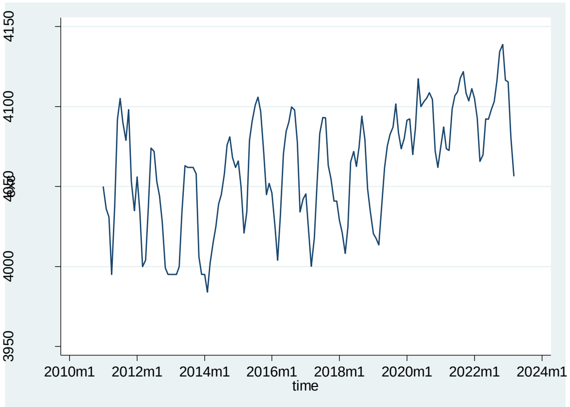
During the study period spanning from January 2011 to March 2023, the exchange rate series between the Khmer Riel and the US Dollar displayed a cyclical pattern, characterized by fluctuations around the mean value of KHR 4062.059 per US Dollar. The minimum, maximum, and standard deviation values were KHR 3984.000, KHR 4138.717, and KHR 36.085, respectively. Based on the probability of the Jarque-Bera test, which exceeded the 5 percent significant level, it can be concluded that the exchange rate series followed a normal distribution, as the null hypothesis of the test was not normal. Therefore, with 95 percent confidence, the exchange rate between the Khmer Riel and the US Dollar fluctuated within the range of KHR 4025.974 and KHR 4098.144 per USD.

Table 1. Summary Statistics

	EXC	*M2*
Mean	4062.059	80576453
Median	4065.710	66122396
Maximum	4138.717	1.76E+08
Minimum	3984.000	19793549
Std. Dev.	36.08550	49322808
Skewness	-0.262662	0.481097
Kurtosis	2.186859	1.873312
Jarque-Bera	5.740119	13.44587
Probability	0.056696	0.001203
Sum	597122.7	1.18E+10
Sum Sq. Dev.	190115.8	3.55E+17
Observations	147	147

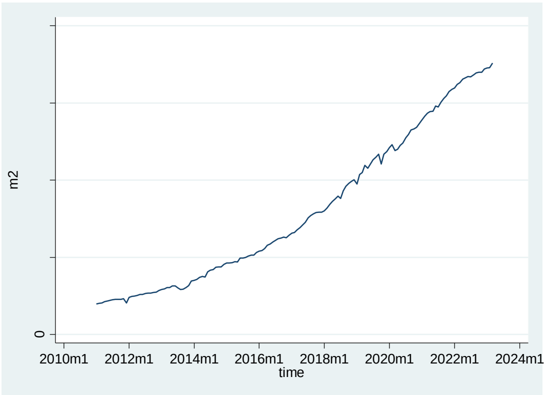
Simultaneously, the broad money supply series exhibited a positive trend, with an average value of KHR 80,576,453 million. The minimum and maximum levels were KHR 1.76E+08 million and KHR 19,793,549 million, respectively, and the standard deviation was KHR 19,793,549 million. The probability of the Jarque-Bera test was lower than the 5 percent significant level, indicating that the broad money supply series did not follow a normal distribution, as the null hypothesis of the test was not normal.

Figure 1. Nominal Exchange Rate, *EXC*, KHR/USD



Based on the two models, namely the model with constant and the model without constant and trend, of the Augmented Dickey-Fuller (ADF) test, it can be inferred that the exchange rate series under investigation is non-stationary or possesses a unit root at the level. This is because the null hypothesis of each model cannot be rejected at the 5 percent significance level. However, in the case of the model with constant and trend, the series is stationary as the null hypothesis of a unit root is rejected. Subsequently, all models are re-run for the first difference in exchange rate variables, and the null hypothesis of each model is rejected at 1% and 5% significant levels.

Figure 2. Broad Money Supply, M2



The estimated results of the ADF test for all models for *M2* indicate that the null hypothesis of the unit root is rejected for each model at a significant level of 5%.

Table 2. Unit Root Test Results Table (ADF)

		At Level	
		EXC	*M2*
With Constant	t-Statistic	-1.1400	3.5469
	Prob.	***0.6987***	***1.0000***
		n0	n0
With Constant & Trend	t-Statistic	-3.2857	-1.9680
	Prob.	***0.0731***	***0.6134***
		*	n0
Without Constant & Trend	t-Statistic	0.3972	8.8626
	Prob.	***0.7969***	***1.0000***
		n0	n0
		At First Difference	
		d(EXC)	*d(M2)*
With Constant	t-Statistic	-3.9157	-13.9617
	Prob.	***0.0025***	***0.0000***
		***	***
With Constant & Trend	t-Statistic	-3.9900	-15.2685
	Prob.	***0.0112***	***0.0000***
		**	***
Without Constant & Trend	t-Statistic	-3.9122	-1.3843
	Prob.	***0.0001***	***0.1540***
		***	n0

Notes:

a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant

b: Lag Length based on SIC

c: Probability based on MacKinnon (1996) one-sided p-values.

Moreover, when applying the model with constant and the model with constant and trend of the ADF test to the first difference in broad money, the null hypothesis of each model is rejected to a high degree at a significant level of 1%.To further ensure the accuracy of the results and avoid spurious regression outcomes, an Engle and Granger cointegration test is conducted. This test aims to determine whether there exists a long-run relationship between the two variables, given that both exchange rate and money supply variables are integrated, with order one or *I(1)*.

The Engle-Granger cointegration test's null hypothesis posits that the series of exchange rate and broad money supply variables are not cointegrated. However, this hypothesis is strongly refuted by the Engle-Granger tau-statistic, which is -6.869, and its probability is close to zero, falling below the 1 percent level of significance. Based on this outcome, it can be asserted that the two variables are cointegrated or possess a long-term relationship. Consequently, a regression analysis between broad money and exchange rate at the level will not yield spurious results.

Table 3. SBIC of ARMAX Model

Model	SBIC
ARMAX(1,1)	8.507
ARMAX(2,1)	8.530
ARMAX(1,2)	8.531
ARMAX(2,2)	8.532

The Schwarz Bayesian Information Criteria (SBIC) is utilized to ascertain the optimal lag length of the ARMAX model. A lower SBIC value indicates a superior model. As evidenced in Table 3, there exist four distinct ARMAX models with corresponding SBIC values. Among these models, the ARMAX(1,1) model yields the lowest SBIC value. The estimated outcome of this model is presented in Table 4.

The empirical results of ARMAX(1,1) has indicated that the estimated parameter of *M2* variable is positive and statistically significant at 1 percent level, which mean that the exchange rate between Khmer Riel and US Dollar will depreciate when broad money supply is increased and vice versa. The sample parameters of *AR(1)* and *MA(1)* are 0.612150 and 0.637508, respectively and all are statistically significant at 1 percent level. In addition, the coefficient of σ^2 which measure the volatility is also statistically significant at 1 percent level.

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Moreover, the calculated *F*-statistic is 154.4286 and its probability is 0.0000 which is lower than 1 percent level. Based on this result, it can be concluded that all slope coefficients are jointly explained nominal exchange rate. More interestingly, the adjust R^2 is 0.807 which is high, and can be interpreted that the model fit the data well. The empirical findings of the ARMAX(1,1) model have demonstrated that the estimated parameter of the *M2* variable is positive and statistically significant at the 1 percent level. This implies that an increase in broad money supply will result in a depreciation of the exchange rate between the Khmer Riel and the US Dollar, and vice versa. The sample parameters of the *AR(1)* and *MA(1)* models are 0.612150 and 0.637508, respectively, and all are statistically significant at the 1 percent level. Furthermore, the coefficient of σ^2, which measures volatility, is also statistically significant at the 1 percent level. Additionally, the calculated *F*-statistic is 154.4286, with a probability of 0.0000, which is lower than the 1 percent level. Based on these results, it can be concluded that all slope coefficients jointly explain the nominal exchange rate. Notably, the adjusted R^2 is 0.807, which is high and indicates that the model fits the data well.

Table 4. ARMAX(1,1) Model

Dependent Variable: EXC

Method: ARMA Maximum Likelihood (OPG - BHHH)

Sample: 2011M01 2023M03

Included observations: 147

Convergence achieved after 11 iterations

Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4028.221	9.330216	431.7393	0.0000
M2	4.18E-07	1.13E-07	3.702175	0.0003
AR(1)	0.612150	0.071109	8.608632	0.0000
MA(1)	0.637508	0.071134	8.962119	0.0000
SIGMASQ	241.7346	29.36368	8.232437	0.0000

R-squared	0.813088	Mean dependent var	4062.059
Adjusted R-squared	0.807823	S.D. dependent var	36.08550
S.E. of regression	15.81918	Akaike info criterion	8.404970
Sum squared resid	35534.99	Schwarz criterion	8.506685
Log-likelihood	-612.7653	Hannan-Quinn criter.	8.446298
F-statistic	154.4286	Durbin-Watson stat	1.928139
Prob(F-statistic)	0.000000		
Inverted AR Roots	.61		
Inverted MA Roots	-.64		

5. Conclusions and Policy Recommendation

This research used univariate regression model, ARMAX model in order to study the fluctuation of exchange rate between Khmer Riel and US Dollar. The ADF test revealed that the exchange rate and broad money data series were non-stationary or possessed a unit root during the study period. However, the series became stationary after being transformed to first difference. Given that both data series are I(1), the Engle and Granger cointegration test was conducted, which indicated a long-run relationship between the two variables. This ensured that spurious regression results were avoided when using level variables to run the model. The optimal lag length of the model was determined to be ARMAX(1,1) based on SBIC. The empirical findings of this study suggest that controlling the amount of money supply in the economy is crucial for maintaining exchange rate stability. Specifically, increasing or decreasing broad money would cause the nominal exchange rate between the Khmer Riel and the US Dollar to depreciate or appreciate. The estimated results of the ARMAX(1,1) model indicate that an increase or decrease of KHR 100 million in the money supply would cause the nominal exchange rate to depreciate or appreciate by approximately KHR 41.8 per US Dollar, holding other variables constant. Therefore, the traditional monetary policy of conducting US Dollar auctions by the central bank is deemed the most effective tool for controlling the fluctuations in the domestic foreign exchange rate.

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