Central Bank of Liberia

Working Paper Series

Working Paper No. 01/2016

The Impact of Foreign Exchange Intervention on Liberian Dollar Money Supply (2006-2015): An Autoregressive Distributed Lag (ARDL) Modeling Approach

Dr. Mounir Siaplay*†, Jefferson S.N. Kambo*†† and John M. Collins*††† [1]

November 2016

This Working Paper findings, interpretations, conclusion, and recommendations expressed are entirely that of the authors. They do not represent the views of the Central Bank of Liberia or its management. Working Papers describe research in progress by the author (s) and are published to elicit comments and to further debate.

[1] *The authors are, respectively, the Deputy Governor for Economic Policy, Director for Research, Policy and Planning, and Research Analyst at the Central Bank of Liberia.

†Email: msiaplay@cbl.org.lr. Address: Ashmun & Lynch Streets, P.O. Box 2048, Monrovia, Liberia.

†† Corresponding author Email: jkambo@cbl.org.lr**.** Address: Ashmun & Lynch Streets, P.O. Box 2048, Monrovia, Liberia.

††† Email: jmcollins@cbl.org.lr. Address Ashmun & Lynch Streets, P.O. Box 2048, Monrovia, Liberia.

Abstract

The paper examines the impact of the Central Bank of Liberia's (CBL) foreign exchange intervention on the growth of Liberian dollar money supply and whether or not the intervention is sterilized. We estimate these effects using Autoregressive Distributed Lag (ARDL) modeling approach employing monthly time series data spanning the period 2006 to 2015. To determine the stationarity of the data, an Augmented Dickey-Fuller and Phillips-Perron tests were conducted at level and 1st difference. Next, we perform co-integration test using Bound Test technique. The existence of co-integration allows us to estimate the error correction model for broad money.

This paper finds evidence that the CBL's intervention in the foreign exchange market is sterilized and that the intervention variable is rightly signed but statistically insignificant, reflecting the low levels of intervention through the CBL's auction. Thus, we proffer the following recommendations. First, in the short run, the CBL foreign exchange intervention strategy should be directed to major actors such as importers, businesses, and forex bureaux. The level of foreign exchange intervention should be informed by the level of CBL's international reserves. Second, macroeconomic policy harmonization and coordination between the fiscal and monetary authorities should be strengthened to promote long term sustainable and inclusive growth and development. Third, the CBL should institute measures that would deter speculation and rent seeking behavior in the foreign exchange market and ensure that its intervention strategies are properly targeted at enhancing appropriate monetary policy stance, inflation control and exchange rate stability, among others. Fourth, there is a need to convert portion of the remittance inflows to Liberian dollar to promote Liberian dollar monetary growth.

JEL Classification: *E58, F31*

***Keywords**:* Foreign Exchange Intervention, Money Supply, Exchange Rate, Autoregressive Distributed Lag, Co-Integration.

To cite this article,

Siaplay, M., Kambo, J.S.N., and Collins, J.M. (2016), "The Impact of Foreign Exchange Intervention on Liberian Dollar Money Supply (2006-2015): An Autoregressive Distributed Lag (ARDL) Modeling Approach." Central Bank of Liberia, Working Paper No. 01/2016.

1. Introduction

Over the years, the Liberian monetary authorities have used foreign exchange intervention as a monetary policy instrument to help smooth exchange rate volatility. The importance of this monetary instrument cannot be understated as its pass through effect on inflation has a significant impact on the primary objective of most central bank that is price stability in the wider economy. Since 2009, the Central Bank of Liberia (CBL) has intervened in the foreign exchange market in order to support and stabilize the value of the Liberia dollar. In 2012, the CBL intervention in the foreign exchange market was further strengthened as the Government of Liberia through the Ministry of Finance signed on the International Monetary Fund Extended Credit Facility (ECF) program. As part of the ECF program, the CBL purchases foreign exchange from the Government to intervene in the foreign exchange market as well as use a targeted amount for reserve accretion. However, the existing dual currency regime[2] characterized by the high level of dollarization[3] presents a major challenge to the CBL in conducting effective monetary policy. Moreover, Liberia's growth model which has relied over the years on the extractive industry, particularly iron ore and rubber coupled with high importation regime for its staple commodities, has exposed the economy to exogenous shocks. This condition has led to a large reduction in the Government revenue intake denominated in foreign currency thereby placing enormous pressure on the CBL to intervene more frequently to meet the demand of importers, businesses, and forex bureaux among others, to facilitate their operations.

Although foreign exchange intervention as a monetary instrument has been used to mitigate exchange rate volatility, its effectiveness has been a subject of debate amongst central bank policymakers and researchers (Simatele, 2003; Guimarães, and Karacadağ, 2004; Bank of International Settlement, 2005, 2013; Menkhoff's, 2010; Alder and Tovar, 2011; Newman et al, 2011; Omojolaibi and Gbadebo, 2014). Furthermore, it is important to distinguish between sterilized and non-sterilized interventions as there is a general agreement that non-sterilized intervention impacts exchange rate via money supply while sterilized interventions have mixed results (Danker et al., 1996; Lewis, 1988b; Humpage, 1989; and Dominguez, 1998).

[2] The Liberian and United States (US) dollars are both legal tenders in Liberia.
[3] The US dollar share of broad money at end-August, 2016 stood at 70.2 percent, an indication of the high degree of dollarization of the Liberian economy.

The purpose of this paper is to determine the impact of foreign exchange intervention on the growth of money supply and whether or not the intervention is sterilized. Liberia's dual currency regime and the nature of foreign exchange intervention through which the CBL purchases US dollar from Government and in turn provide Liberian dollar equivalent does have implication on the growth of money supply. Thus, if the intervention is not sterilized, then it would impact the growth of money supply which affects the exchange rate and by extension inflation and the economy at large (Adebiyi, 2007; Chipili, 2010; Dayyabu, Adnan, and Sulong, 2016).

The remainder of this paper is organized as follows. Section 2 discusses Liberia's dual currency regime and its history of foreign exchange market. Section 3 presents the theoretical framework on foreign exchange market intervention. Section 4 presents the data. Section 5 presents the model specification. Section 6 is the empirical analysis. Section 7 is the conclusion and policy recommendations.

2. History of Liberia's Dual Currency Regime

The dual currency regime in Liberia can be traced from the country's historical ties with the United States of America and the proximity of the British West African colonies. Since its emergence as an independent country in 1847, the economy of Liberia has been either fully or partially dollarized. During the periods 1839-1847 and 1847-1904, representing the eras of both a Commonwealth and a young Republic, the US dollar and the Liberia dollar coins circulated side-by-side in the country as medium of exchange and unit of account. However, the legality of the US dollar as legal tender currency was unclear with a conspicuous absence of a monetary authority. Liberia introduced its first notes which circulated alongside the Liberian dollar coins and US dollar between 1850s-1880s. The period between 1913 and 1942, Liberia adopted the British-West African pound, mainly used in neighboring Sierra Leone and other nearby British West African colonies. The period between 1943 and 1962, Liberia adopted the US dollar as the official and the sole legal tender currency (Erasmus, Leichter, and Menkulasi, 2009).

However, the dominance of the US dollar (though beneficial) was not without disadvantages. One of such disadvantages was massive capital outflows from the economy especially after the 1980 coup d'état. The Liberian government, therefore, introduced the five-dollar coin in 1982 to curb the capital outflows. The coin was faced with the challenge of portability. In 1989, the first Liberian bank notes, "J.J. Roberts", five-dollar banknote was introduced to replace the five-dollar coin. The "Liberty" notes were issued in 1991 to invalidate the J.J. Roberts notes looted from the National Bank of Liberia during the civil war, effectively creating two currency zones. Thus, the J.J. Roberts and Liberty banknotes were concurrently used as medium of exchange until 1999 when they were both withdrawn and replaced by the multidenominational banknotes in five, ten, twenty, fifty and hundred-dollar bills (Erasmus, Leichter, and Menkulasi, 2009).

2.1 Brief History of the Foreign Exchange Market of Liberia

The current exchange rate regime of Liberia evolved over the years shifting from fixed exchange rate system to a managed floating regime. Liberia practiced a fixed exchange rate regime with the Liberian dollar and US dollar officially trading on one-to-one parity for 37 years (1962-1999). The period between 1962 and 1982, the parallel market rate and the official rate remained almost the same. However, beyond 1982, the parallel rate deviated from the official rate. The difference widened incrementally as the political crisis escalated with attendant slowdown in economic activities. The CBL's Act of 1999 expunged the one-to-one parity between the Liberian dollar and US dollar. However, it maintained the legal tender status of the US dollar.

3. Theoretical Framework on Foreign Exchange Market Intervention

Exchange rate is affected by reversible factors, namely: fundamental and transitory. Thus, exchange rate volatility would depend on the extent to which the causes underlying the latter is influenced by the former (Chipili, 2014). Volatility in the exchange rate is triggered by volatility in market fundamentals such as the growth of money supply, income, and interest rate. In addition, the formulation of market expectation due to new information and speculative bandwagons further impact exchange rate volatility (Bonsear-Neal and Tanner, 1996).

Dominguez (1998) argues that to model exchange rate as a forward-looking process is efficient with respect to public information. Thus, the current spot exchange rate can be represented as:

$$s_{t=}(1-\delta)\sum_{k=0}^{\infty}\delta^{k}E_{t}(z_{t+k}|\Omega_{t}), \qquad (1)$$

where s_t is the logarithm of the current exchange rate; δ is the discount factor such that $\delta\,\frac{\beta}{1+\beta}$ where β is the interest semi-elasticity of money demand in the monetary model; z is a vector of exogenous driving variables; E_t is the expectations operator; and Ω_t is the information set in period *t*. If intervention operations, denoted I_t, provide relevant information to the market, the market information set will enlarge such that ($\Omega_t < \Omega_t + I_t$) and the spot exchange rate will be influenced. For instance, if the central bank intervention in the market intended to support the domestic currency signals future contractionary domestic monetary policy, the domestic currency is expected to appreciate relative to the foreign currency such that:

$$s_t = (1-\delta)\sum_{k=0}^{\infty}\delta^k E_t(z_{t+k}|\Omega_t) > \; s_t = (1-\delta)\sum_{k=0}^{\infty}\delta^k\, E_t((z_t|\Omega_t + I_t), \qquad (2)$$

where I_t represents an official purchase of domestic assets[4]. In general, foreign exchange market intervention is any transaction or announcement by an official agent of the government intended to influence the value of the exchange rate (Dominguez, 1998). The intervention can be classified as sterilized or unsterilized. Sterilized intervention occurs when the monetary authority offsets the domestic asset such that the monetary base is unchanged and prices or interest rates are not affected directly. On the other hand, unsterilized interventions leads to a change in the monetary base where the interest rates differentials as well as the exchange rate are affected. Thus, monetary model of exchange rate determination states that unsterilized intervention impacts the exchange rate such that the impact is proportional to change in the relative supplies of domestic and foreign money.

According to Neil and Fillion (1999), sterilized intervention might affect exchange rate at least through four mechanisms, namely: signaling, portfolio-balance, noise-trading and liquidity approaches. Aguilar and Nydahl (1998) explained that intervention can affect the exchange rate through these various channels such that the exchange rate can be specified as follow:

$$s_{t=}f_t + \alpha[E_t(s_{t+1}|\Omega_t) - s_t] \qquad (3)$$

where f_t is current period fundamentals; other variables in the equation (3) were previously defined. Thus, equation (3) indicates that the exchange rate at time *t* is determined by the current period fundamental factors as well as the expected capital gain of holding the currency until the next period.

[4] Empirical evidences in support of the hypothesis that intervention serves as a signal for future monetary policy are found in studies such as Dominguez (1993); Ghosh (1992), Lewis (1995) and Kaminsky and Lewis (1996).

Equation (3) can further be reduced to:

$$s_{t=}\frac{1}{1+\alpha}\sum_{j=0}^{\infty}\left[\frac{1}{1+\alpha}\right]^{j} E\left(f_{t+j}\ |\Omega_t\right)+\left[\frac{1}{1+\alpha}\right]E(b_{t+1}|\Omega_t) \quad (4)$$

where b_{t+1} represents a rational bubble. The expected present value of future fundamentals are expressed as $\frac{1}{1+\alpha}\sum_{j=0}^{\infty}\left[\frac{1}{1+\alpha}\right]^{j} E\left(f_{t+j}\ |\Omega_t\right)$ while a bubble is expressed as $\left[\frac{1}{1+\alpha}\right]E(b_{t+1}|\Omega_t)$. Therefore, the intervention affects the exchange rate through various channels as follows.

3.1 Signaling Approach

Under the signaling approach, the assumption is that there is information asymmetry in that the central bank has more information than the market agents in regards to future monetary policy. By intervening in the foreign exchange market, the central bank changes the expectation of market agents about future monetary policy fundamentals. The signal of future monetary policy is observed as a result of central bank purchase of domestic currency which leads to contractionary monetary policy, thereby revising the market agents' expectations which result in an appreciation of the domestic currency (Kaminsky and Lewis, 1996). Hence, signaling theory posits that exchange rate will depreciate if the central bank purchase of foreign currency is assumed to signal a more expansionary domestic monetary policy. The resulting depreciation effect is attributed to the action of the central bank that does not alter the domestic monetary base to avoid the agents misinterpreting it as a change in the monetary policy position. The only way that this action by the central bank in term of its intervention in the foreign exchange market becomes effective is that the signal about future monetary policy must be credible. Over the years, studies have found that intervention has been effective through this channel (Galati and Melick, 1999; Neely, 2000).

3.2 Portfolio-Balance Approach

The basic premise of this approach is that investors would balance their portfolio between domestic and foreign assets on the basis of their expected returns and the risk associated with those returns (Sarno and Taylor, 2001). The important feature of this approach is that investors are assumed to be rational and risk-averse. Therefore, intervention would affect the level of exchange rate through the portfolio-balance channel by altering the relative supply of foreign and domestic securities, thus compensating investors by a risk premium for holding securities that are imperfect substitutes. Such action creates a portfolio disequilibrium in investors' portfolio and equilibrium can be restored through a change in risk premium. But, if the securities are perfect substitutes, then intervention would not have any effect on the exchange rate (Chipili, 2014; Dayyabu, Adnan, and Sulong, 2016). Several studies also allude to the effectiveness of this intervention (Dominguez and Frankel, 1993; Catte et al., 1994; Neely, 2000).

3.3 Noise-Trading Approach

This approach allows for the movement of the exchange rate from its fundamental value due to the rational bubble assumption which take into account the behavior of "noise traders." The actions of the noise-traders in term of the movement of asset prices away from the fundamental equilibrium is captured through the buying and selling of currency as a result of the central bank intervention. Thus, the noise-traders actions affect their perception of the trend in the exchange rate. Therefore, central bank intervention can either increase or decrease exchange rate volatility when the noise-traders move the exchange rate away or toward the fundamental value. Hence, it is important to note that the theory regarding the effectiveness of central bank intervention on exchange rate volatility is ambiguous (Chipili, 2014).

3.4 Liquidity Approach

Under this approach, the assumption is that intervention does impact exchange rate volatility but not its levels. Short-term effect on exchange rate is determined by the size of the central bank intervention in the foreign exchange market. The size of the intervention influences behavior of the market and by extension impact the current exchange rate. This creates additional liquidity to dealers and reduce market risk. Overall, the size of the intervention affects market fundamentals and provides a window in which the impact on the exchange rate is realized as a result of the size of the intervention relative to the market turnover within a given period of time (Chipili, 2014). However, there have been little empirical evidence to support this approach due to the fact that the size of intervention by the central bank is usually smaller relative to the total market liquidity (Rogoff, 1984; Humpage, 1988; Obstfeld, 1989; Klein and Rosengren, 1991; Ghosh, 1992).

4. Data

For the empirical analyses, we employed monthly secondary time series data spanning from January 2006 to December 2015. The variables used in this analysis included: broad money, exchange rate, Liberia price index, remittance inflow, and U.S. interest rate. In this paper, we created a dummy variable to represent the intervention time series which assigns a value of one when the central bank intervenes and zero otherwise. The data were mainly sourced from the Central Bank of Liberia Quarterly Economic Bulletin, Liberia Financial Statistics and the International Financial Statistics, International Monetary Fund. Broad money is defined as currency outside bank plus demand deposits and quasi money (saving and time deposits). Exchange rate is the price of one US dollar in terms of Liberian dollar in nominal term. Liberia price index measures Liberia's consumer price index which comprises 235 items. Remittance inflow is migrant remittances into Liberia. US interest rate is the Federal Funds Rate which banks charge each other for overnight lending.

5. Model Specification

Similar to Adebiyi (2007), this paper seeks to determine the extent to which the Central Bank of Liberia foreign exchange intervention is sterilized through its effect on the growth of broad money. We employed the Auto-regressive Distributed Lag (ARDL) approach that was popularized by Pesaran and Pesaran (1997), Pesaran and Smith (1998), Pesaran and Shin (1999), and Pesaran et al. (2001) given its numerous advantages. One of the main advantage of the ARDL approach is that it can be applied irrespective of whether the variables are I(0) or I(1) (Pesaran and Pesaran (1997). Also, the ARDL approach allows for sufficient number of lags to capture the data generating in a general to specific modeling framework (Laurenceson and Chai, 2003). Additionally, a dynamic error correction model (ECM) can be derived from ARDL approach through a simple linear transformation (Banerjee et al., 1993). Finally, the ARDL approach avoids problems resulting from non-stationary time series data (Laurenceson and Chai, 2003). Thus, we illustrate the ARDL modeling approach as follows:

$$M_{2(t)=}\gamma_0 + \gamma_1 ER_t + \gamma_2 LPI_t + \gamma_3 INF_t + \gamma_4 USR_t + \gamma_5 INV_t + \varepsilon_t \quad (5)$$

where $M_{2(t)}$ represents Liberian dollar broad money at time *t*; ER_t is the nominal exchange rate at time *t*; LPI_t represents Liberia price index at time *t*; INF_t is the remittance inflow at time *t*; USR_t is the U.S. interest rate at time *t*; INV_t is a dummy variable representing the intervention time series which assigns a value of one when the central bank intervenes and zero otherwise; ε_t is a vector of stochastic error terms; andγ_0, γ_1, γ_2, γ_3, γ_4, γ_5 are the parameters. Using equation (5), the ARDL error correction model can be expressed as:

$$\Delta M_{2(t)}{=}\varphi_0 + \sum_{i=0}^{p} \varphi_{1i}\,\Delta ER_{t-i} + \sum_{i=0}^{p} \varphi_{2i}\,\Delta LPI_{2t-i} + \sum_{i=0}^{p} \varphi_{3i}\,\Delta INF_{3t-i} + \sum_{i=0}^{p} \varphi_{4i}\,\Delta USR_{4t-i} + \sum_{i=0}^{p} \varphi_{5i}\,\Delta INV_{5t-i} + \varphi_6 ER_{t-1} + \varphi_7 LPI_{t-1} + \varphi_8 INF_{t-1} + \varphi_9 USR_{t-1} + \varphi_{10} INV_{t-1} + \varphi_{11} ECM_{t-1} + \varepsilon_t \quad (6)$$

where in equation (6), φ_1,φ_2,φ_3, φ_4, φ_5 represents the short-run dynamics of the model while φ_6,φ_7,φ_8, φ_9, φ_{10} represents the long-run relationship. The null hypothesis is φ_6=φ_7=φ_8=φ_9= φ_{10}=0, that is there is no long-run relationship that exist amongst these variables. ECM_{t-1} is the error correction model in time *t -1* which represents the speed of adjustment in the growth of money supply.

5.1 ARDL Model Testing Procedure

Under this approach, the first step is to conduct a bound test with a null hypothesis that there is no co-integration. To verify the null hypothesis, the F-statistic is compared with the critical value (Pesaran and Pesaran, 1997; Pesaran et al., 2001). The null hypothesis states that no long-run relationship is rejected if the test statistic exceeds the upper bound or if the test statistic falls below the lower bound regarding the order of integration. Also, if the test statistic is within the upper and lower bounds, then the results are inconclusive. However, if the variables are I(1), then the test statistic is compared to upper bound critical value while if the variables are I(0), then the test statistic is compared to the lower bound critical value.

To obtain the optimal lag length for each variable, we used the automatic selection in EViews 9.5. The second step is to estimate the long-run relationship using the selected ARDL model. When there exist a long-run relationship between variables, an error correction model is estimated and the results indicate the extent to which the long-run equilibrium is adjusted after a short-run shock. The third step is to conduct the goodness of fit of the ARDL model. This is done through a diagnostic and stability tests, respectively. The diagnostic test include: serial correlation, normality test, and heteroscedasticity while the structural stability test is conducted using the cumulative sum of recursive residuals (CUSUM) (Chipili, 2014).

6. Empirical Analysis

To evaluate whether or not the variables under consideration are stationary at levels, 1st difference or mixed, we conducted unit root tests, namely Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test. We verify the co-integration relationship amongst the variables by employing the bound test. Next, we estimate the short and long run relationship of the dependent variable (broad money supply) on the key independent variables. Finally, we conduct a diagnostic and stability tests to ensure that the ARDL model is robust and stable over time.

A frequent response to the problem of unit roots is to ensure that all the variables used in a regression are stationary. In checking for the unit roots, we considered the Augmented Dickey-Fuller (ADF) test which is one of the precise formal ways of testing for stationarity and confirm it by the Phillips-Perron (PP) test (Philips & Perron, 1988). The PP test is a generalization of the ADF test and is less restrictive on its assumptions about the residuals (Feridun and Adebiyi, 2007).

To test for unit root, we assume that:

$$\varphi_{\mathrm{p}}(\lambda) = (1-\lambda)\varphi_{\mathrm{p}-1}(\lambda) \quad (7)$$

where $\varphi_{p-1}(\lambda) = 1 - \varphi_1\lambda - \cdots - \varphi_{p-1}\lambda^{p-1}$ has root lying outside the unit cycle.

Therefore, the Augmented Dickey-Fuller test equation is given as:

$$\Delta Y_t = \sigma Y_{t-1} + \sum_{j=1}^{p-1} \varphi_j \Delta Y_{tj} + \theta_0 + \varepsilon_t \quad (8)$$

With the null hypothesis given as $H_0{:}\varphi = 1$ and $H_1{:}\varphi = 0$.

In order to use the ARDL approach, the data should be stationary purely at level I(0) or purely at first difference I(1) or mixture of level and first difference. For this reason, the ARDL model incorporated the logged and first difference of each variable. The series include the exchange rate (ER); growth in broad money supply (M2); remittance inflow (INF); Liberia price index (LPI); and US interest rate (USRATE). The results of the unit root tests are broadly in line with the existence of unit root at level but the first difference is stationary. All the variables are I(1) (Table1).

Table 1: Unit Root Test

		Augmented Dickey-Fuller		
Variable	**Levels**	**1st Difference**	**Critical Value**	**Integration Order**
ER	-0.76	-11.09*	-2.89	I(1)
M2	-0.81	-12.98*	-2.89	I(1)
INF	-1.52	-11.63*	-2.89	I(1)
LPI	-1.15	-10.60*	-2.89	I(1)
USRATE	-1.70	-4.87*	-2.89	I(1)
		Phillips-Perron		
Variable	**Levels**	**1st Difference**	**Critical value**	**Integration Order**
ER	-0.61	-11.48*	-2.89	I(1)
M2	-0.82	-12.92*	-2.89	I(1)
INF	-2.41	-26.08*	-2.89	I(1)
LPI	-1.23	-10.60*	-2.89	I(1)
USRATE	-1.70	-10.09*	-2.89	I(1)

Note: Parameter estimates are statistically different from zero at * 5% significance level.

6.1 Bound Test

We conduct the Bound Test to determine the long-run relationship between the independent variables and the dependent variable as stated above. According to Pesaran et. al. (2001), the Bound Test is represented as follow:

$$\Delta M_{2(t)=} - \sum_{i=1}^{p-1} \gamma_i^* \Delta M_{(2)t-1} + \sum_{j=1}^{k} \sum_{i=0}^{q_{j-1}} \Delta X_{j,t-i'}, \varphi_j , i^* - \rho M_{(2)(t-1)} - \alpha - \sum_{j=1}^{k} X_{j,t-1'}, \delta_j + \varepsilon_t \quad (9)$$

where $X_{j,t-i'}$ represent all independent variables. Thus, the test for the existence of long-run relationship is:

$$H_0: \rho = 0 \text{ and } \delta_1 = \delta_2 = \cdots \delta_k = 0.$$

$$H_1: \rho \neq 0 \text{ and } \delta_1 = \delta_2 = \cdots \delta_k \neq 0.$$

Table 2 reports the co-integrating relationships of the variables. The bound test was used to determine this relationship. The F-statistic value tells us about the co-integration among the variables. If the F-value comes less than the critical bound values then we can conclude that there is no co-integration among variables. Our F-value is above the upper and lower bound test at the different critical levels. So we can conclude that there is co-integration among variables.

Table 2 : ARDL Bounds Test

Test Statistic	Value	k
F-statistic	25.064	4
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

6.2 Model Selection

In order to determine the extent to which the CBL foreign exchange intervention is sterilized or not, the paper regressed growth in broad money supply (M2), on nominal exchange rate (ER), Liberia Consumer Price Index (LPI), remittance inflow (INF), US interest rate (USRATE), and a dummy variable for intervention (INV). The model was selected based on the ARDL estimator whose lag length was selected automatically by EViews 9.5. The maximum lag of 4 was selected based on the Akaike Information Criteria (AIC). Table 3 showed that, current change in nominal exchange rate, current and four period ago change in inflows are significant, that is, explain growth in broad money supply. Please see the automatic selection of the twenty best models in the appendix. The first of those was chosen for this paper.

Table 3 : Model Selection

Dependent Variable: D(M2)
Method: ARDL
Sample (adjusted): 2006M06:2015M12
Included Observations: 115 after adjustments
Fixed Regressors: INTERVENTION C
Selected Model: ARDL(1, 0, 0, 4, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(M2(-1))	-0.096	0.095	-1.010	0.315
D(ER)	-0.437	0.234	-1.865	0.065**
D(LPI)	-0.040	0.068	-0.583	0.561
D(INF)	0.042	0.019	2.184	0.031*
D(INF(-1))	0.012	0.022	0.560	0.577
D(INF(-2))	-0.006	0.022	-0.282	0.778
D(I NF(-3))	0.017	0.022	0.789	0.432
D(INF(-4))	-0.041	0.019	-2.115	0.036*
D(USRATE)	-0.004	0.017	-0.230	0.819
INTERVENTION	-0.005	0.009	-0.526	0.600
C	0.022	0.008	2.891	0.004*

Note: P-values and any subsequent tests do not account for model selection. Parameter estimates are statistically different from zero at * 5% and ** 10% significance levels.

6.3 Short and Long Run Regression on Broad Money Supply

The co-integrating equation (ECM) is both negative and significant, so there exist a short-run relationships. For the long-run, there is a significant and negative relationship between Liberian dollar broad money growth (M2) and nominal exchange rate (ER) (Table 4). In the short-run, current exchange rate and remittance inflow will explain growth in money supply while only exchange rate will explain the change in money supply in the long–run. The coefficient of the error correction model is statistically significant and high in magnitude. It confirms a long-run relationship between the variables. The coefficient of ECM (CointEq(-1)) term is -1.096, which suggest a fast adjustment process, nearly 110 percent of the disequilibria of the previous month's shock adjust back to the long-run equilibrium in the current month. This fast adjustment speed is largely due to the dual currency nature of the Liberian economy.

As revealed by Table 4, exchange rate appreciation is inversely related to Liberian dollar money supply (M2) in the short run, precisely, a 1 percent appreciation of the exchange rate reduces money supply (M2) by 44 percent. Conversely, remittance inflow is positively related to increases in money supply. The results also suggest that growth in remittance inflow by 1 percent increases money supply by 4.1 percent.

Table 4 : Short and Long Run Regressions on Broad Money Supply

Dependent Variable: D(M2)
Method: ARDL Co-integrating and Long Run Form
Sample: 2006M01:2015M12
Included Observations: 115
Selected Model: ARDL(1, 0, 0, 4, 0)

Co-integrating Form				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(ER, 2)	-0.437	0.234	-1.865	0.065**
D(LPI, 2)	-0.040	0.068	-0.583	0.561
D(INF, 2)	0.042	0.019	2.184	0.031*
D(INF, 2)	0.006	0.022	0.282	0.778
D(INF, 2)	-0.017	0.022	-0.789	0.432
D(INF, 2)	0.041	0.019	2.115	0.037*
D(USRATE, 2)	-0.004	0.017	-0.230	0.819
D(INTERVENTION)	-0.005	0.009	-0.526	0.600
CointEq(-1)	-1.096	0.095	-11.546	0.000*
Long Run Coefficients				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(ER)	-0.399	0.220	-1.810	0.073**
D(LPI)	-0.036	0.062	-0.584	0.561
D(INF)	0.022	0.068	0.319	0.750
D(USRATE)	-0.004	0.016	-0.230	0.818
INTERVENTION	-0.004	0.008	-0.526	0.600
C	0.020	0.007	2.933	0.004*

Note: Parameter estimates are statistically different from zero at * 5% and ** 10% significance levels.

6.4 Diagnostic Tests

To confirm the robustness of the model, the paper performs the following diagnostic tests. The result below (Table 5) indicates that there is no serial correlation and heteroscedasticity in the model since we fail to reject the null hypothesis. The normality property of the residuals was rejected, that is, the error terms are not normally distributed. The ARDL model has been shown to be robust against residuals auto-correlation.

Table 5 : Diagnostics Tests

	Breusch-Godfrey LM Test	Jarque-Bera Test	Breusch-Pagan-Godfrey Test
1. Serial Correlation	F(2,102)=0.086(0.958)		
2. Normality		268.787 (0.000)	
3. Heteroscedasticity			F(10,104)=0.539 (0.859)

Note: The parentheses represent the p-values for each test. 1) Null hypothesis: no serial correlation; 2) Null hypothesis: residuals are normally distributed; and 3) Null hypothesis: no heteroscedasticity in the data.

6.5 Plot of Stability Test (CUSUM)

The plots of the stability test result (CUSUM) of the ARDL model is given in Figure 1. The CUSUM plotted against the critical bound of the 5 percent significance level shows that the model is stable over time (see Appendix).

7. Conclusion and Policy Recommendations

Macroeconomic fundamentals are essential determinants of exchange rate. The central bank of any country cannot stop the depreciation of its domestic currency against other currencies; it can only mitigate it by taking the necessary measures that control the demand for foreign currencies. The measures may mitigate the depreciation but may result into unintended negative consequences in other sectors of the economy. This is due to the partial equilibrium analysis often pursued in developing countries against the general equilibrium analysis pursued by advanced economies which identifies vulnerabilities and discontinuities. It must be stated that the exchange rate usually mirrors the economy: a weak economy produces a weak or depreciated currency. Central banks decisions alone cannot cause the exchange rate to be stable or appreciate unless its policy decisions are accompanied by complementary actions of government (reduction in deficit, shunning of extra budgetary spending and provision of infrastructure, among others). Appreciation or stability of domestic currency results from stability in inflation; increased external reserves; reduced interest rates; subdued government deficit; greater accountability/transparency in governance; and dwindling import demand especially for goods that have the potential of being produced locally, among others. It is against this backdrop that the CBL has sustained its intervention in the forex market.

This paper finds evidence, among others that the Central Bank of Liberia's intervention in the foreign exchange market is sterilized. Moreover, the intervention variable is rightly signed but statistically insignificant, reflecting the low levels of intervention through the CBL's auction. The paper suggests that with a strong and negative relationship between broad money supply and exchange rate, the CBL should intervene in the foreign exchange market to mitigate exchange rate pass through into inflation.

Base on the results of the analysis, we proffer the following recommendations. First, in the short run, the CBL foreign exchange intervention strategy should be directed to major actors such as importers, businesses, and forex bureaux. The level of foreign exchange intervention should be informed by the level of CBL's international reserves. Second, macroeconomic policy harmonization and coordination between the fiscal and monetary authorities should be strengthened to promote long term sustainable and inclusive growth and development. Third, the CBL should institute measures that would deter speculation and rent seeking behavior in the foreign exchange market and ensure that its intervention strategies are properly targeted at enhancing appropriate monetary policy stance, inflation control and exchange rate stability, among others. Fourth, there is a need to convert portion of the remittance inflows to Liberian dollar to promote Liberian dollar monetary growth.

References

Adebiyi, M.A. (2007). "An Evaluation of Foreign Exchange Intervention in Nigeria (1986-2003)." *MPRA Paper (No. 3817)*, University Library of Munich, Germany.

Adler, G. and Tovar, C.E (2011). "Foreign exchange intervention: a shield against appreciation winds?" IMFWorking Paper 11/165.

Aguilar, J. and S. Nydahl. 1998. "Central bank intervention and exchange rates: The case of Sweden." Sveriges Riksbank, June.

Banerjee, A., Dolado, J. J., Galbraith, J.W. and Hendry, D.F. (1993). "Co-integration, Error Correction, and the Econometric Analysis of Nonstationary Data." Oxford, Oxford University Press.

Bank for International Settlements (2005). "Foreign exchange market intervention in emerging markets: motives, techniques and implications." BIS Papers no 24.

Bank for International Settlements (2013). "Market volatility and foreign exchange intervention in EMEs: what has changed?" BIS Papers no 73.

Bonser-Neal, C. and G. Tanner (1996). "Central bank intervention and the volatility of exchange rates: Evidence from the options market." *Journal of International Money and Finance 15*.

Chipili, J.M. (2010). "Macroeconomic effects of exchange rate volatility in Zambia." Department of Economics, University of Leicester, PhD Thesis.

Chipili, J. M. (2014). "Central Bank Intervention and Exchange Rate Volatility in Zambia." African Economic Research Consortium, Nairobi, Kenya, AERC Research Paper 268, April.

Danker, D., Haas, R. A., Henderson, D. W., Symanski, S., and Tryon R.W. (1996). "Small empirical models of exchange market intervention: Applications to Germany, Japan, and Canada." *Journal of Policy Modeling 9*.

Dayyabu, S., Adnan, A.A., Sulong, Z (2016). "Effectiveness of Foreign Exchange Market Intervention in Nigeria (1970-2013)." *International Journal of Economics and Financial Issues, 2016, 6(1)*, 279-287.

Dominguez, K. (1993). "Does central bank intervention increase the volatility of foreign exchange rates?" NBER Working Paper Series No.4532.National Bureau of Economic Research, Cambridge, MA.

Dominguez, K. (1998). "Central bank intervention and exchange rate volatility." *Journal of International Money and Finance 18*.

Dominguez, K. and Frankel, J. A (1993). "Does foreign exchange intervention matter?" The portfolio effect. *American Economic Review 83 (5).*

Erasmus, L., Leichter, J., and Menkulasi, J. (2009). "De-dollarization in Liberia-Lessons from Cross-Country Experience." IMF Working Paper WP/09/37, International Monetary Fund.

Feridun, M and Adebiyi, M. A. (2005) "Forecasting Inflation in Developing Economies: The Case of Nigeria." *International Journal of Applied Econometrics and Quantitative Studies,* Vol. 2-4.

Galati, G. and Melick, W. (1999). "Perceived central bank intervention and market expectations: An empirical study of the yen/dollar exchange rate, 1993-96." BIS Working Paper No.77, October.

Gosh, A. (1992). "Is it signaling? Exchange intervention and the Dollar Deutsche-mark rate." *Journal of International Economics 32.*

Guimarães, R. F. and Karacadağ, C (2004). "The empirics of foreign exchange intervention in emerging market Countries: the cases of Mexico and Turkey." IMF Working Paper 04/123.

Humpage, O.F. (1988). "Intervention and the dollar's decline." Federal Reserve Bank of Cleveland Economic Review, Quarter 2: 2-16.

Humpage, O., (1989). "On the effectiveness of exchange-market intervention." Federal Reserve Bank of Cleveland, unpublished paper.

Kaminsky, G., Lewis, K., (1996). "Does foreign exchange intervention signal future monetary policy?" *J. Monet. Econ. 50(1):* 1-24.

Klein, W.M. and Rosengren, E.S. (1991). "Foreign exchange intervention as policy signal." New England Economic Review, May/June.

Laurenceson, J., and Chai, J.C.H (2003). "Financial Reform and Economic Development in China." Cheltenham, UK, Edward Elgar.

Lewis, K. (1988b). "Testing the portfolio balance model: A multi-lateral approach." *Journal International Economic 24.*

Lewis, K., (1995). "Are foreign exchange intervention and monetary policy related, and does it really matter?" J. Bus. 68, 185-214.

Menkhoff, L. (2010): "High-frequency analysis of foreign exchange interventions: what do we learn?" *Journal of Economic Surveys 24(1),* 85-112.

Neely, C. (2000). "The practice of central bank intervention: Looking under the hood." *Central Banking Quarterly Journal,* X1(2).

Neil, B. and Fillion, J.F. (1999). "An intraday analysis of the effectiveness of foreign exchange Intervention." Bank of Canada, Working Paper: 99-4, February.

Newman, V., Potter, C. and Wright, M (2011): "Foreign exchange market intervention." Reserve Bank of Australia Bulletin, December, 67-76.

Obstfeld, M. 1989. "The effectiveness of foreign exchange intervention." NBER Working Paper Series No. 2796. National Bureau of Economic Research, Cambridge, MA.

Omojolaibi, J.A., Gbadebo, A.D. (2014). "Foreign exchange intervention and monetary aggregates: Nigerian evidence." *International Journal of Economics, Commerce and Management United Kingdom, 2(10*): 1-21.

Pesaran, M. H. and Pesaran, B (1997). "Working with Microfit 4.0: Interactive Econometric Analysis." Oxford, Oxford University Press.

Pesaran, M. H. and Smith, R. P. (1998). "Structural Analysis of Co-integrating VARs." *Journal of Economic Survey 12(5)*: 471-505.

Pesaran, M. H. and Shin, Y (1999). "An Autoregressive Distributed Lag Modelling Approach to Co-integration Analysis." In S. Strom, A. Holly and P. Diamond (Eds.), *Econometrics and Economic Theory in the 20thCentury: The Ranger Frisch Centennial Symposium*. Cambridge, Cambridge University Press. Available at: www.econ.cam.ac.uk/faculty/pesaran/ADL.pdf.

Pesaran, M. H., Shin, Y and Smith, R.J. (2001). "Bounds Testing Approaches to the Analysis of Level Relationships." *Journal of Applied Econometrics 16(3)*: 289-326.

Phillip, P.C.B. and Perron, P. (1988). "Testing for a Unit Root in Time Series Regression." *Biometrika, 75*:335-436

Rogoff, K. (1984). "The effects of sterilized intervention: An analysis of weekly data." *Journal of Monetary Economics 14*.

Sarno, L. and Taylor, M. P. (2001). "Official intervention in the foreign exchange market: Is it effective, and if so, how does it work?" *Journal of Economic Literature 39*.

Simatele, M. C. H. (2003). "Financial Sector Reforms and Monetary Policy in Zambia." Ph.D. Dissertation, Economic Studies, Department Of Economics School of Economics and Commercial Law, Göteborg University.

Appendix

CUSUM Test Result