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Johnson, Leroy and Osabuohien, Evans

Bank Of Sierra Leone, Covenant University

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Return and Volatility Connectedness in Foreign Exchange Markets of Sierra Leone

By

Leroy N. Johnson

Research & Statistics Department, Central Bank of Sierra Leone

Manager, Financial Stability Research Section

(ljohnson@bsl.gov.sl; johnson.leroy@hotmail.com)

&

Evans Osabuohien

Professor of at Covenant University, Ota, Nigeria

Chair & Lead Economist, DePECOS Institutions & Development Research Centre
(DIaDeRC), Nigeria

(pecos4eva@gmail.com; diaderc.centre@gmail.com)

Abstract

The study explores the return and volatility nexus in Sierra Leone Foreign Exchange (Forex) Markets. The exchange rate excessive volatilities have been a serious concern as it translates to propel inflationary pressures and erodes the strength of the currency. The methodology of Diebold and Yilmaz (2012, 2014) indicator of connectedness was employed to unravel the intensity of connectedness among the selected forex markets in Sierra Leone (January 2011- December 2021). The study then uses, Leone/USD, Le/ Euro and Le/Pound sterling official exchange rate from the central bank to measure exchange rate dynamics in the market. The study finds connectedness among the forex markets in Sierra Leone to be highly time-varying and appear to be higher during the period of high depreciation of the Leone which coincides with the period of falling iron-ore and oil prices and domestic economic meltdown of 2014 and 2016, respectively. This shows that, relative to external shocks, connectedness among financial markets is likely to get amplified during the time of domestic turbulence. The paper, therefore portends the build-up of reserves by the Central Bank of Sierra Leone which serves as buffers to contain and assuage internal and external shocks in a timely and efficient manner.

JEL Codes: C58; F31; G11; G12

Keywords: Connectedness, Foreign Exchange, Return Spillover, Volatility

1. Introduction

Interconnectedness of domestic financial markets that are interlocked with global financial markets spurs trade amongst countries is documented. For instance, Herring (1994) portends that the inception of computer hardware and software have largely dampened the costs of collecting and analyzing data, commencing and firming transactions, clearing and settlement payment; and tracking financial flows. However, the associated vicissitude has created an albatross. The ramifications of these materialized dynamics are onerous to financial markets. These transmitting spillovers sometimes compound an already challenged conditions in financial markets including pricing and portfolio diversification dynamics. A correction to these vicissitudes is noted by Agenor (2003) that financial integration should be well crafted and redressed to elicit benefits outweigh the short run risks. A corollary to minimizing risks is sharing information about likely spillover effects among markets (with financial flows) in order to guide both investors and policy makers in decision making.

In this context, a better comprehension of the interconnectedness amongst markets (with financial flows) by market participants, policy makers, and investors amongst others is crucial. The main forex markets (with financial flows) in Sierra Leone are the USD pair and Euro pair, and pounds pair. As such, these variants of forex markets are the significant and catalytic in the financial markets space. The interconnectedness or pass-through amongst these markets are vital for policy-makers, investors and market participants but also to identify vulnerabilities (weaknesses) and take appropriate actions to handle them. For instance, when the USD market experiences tight liquidity situation, the leones depreciates further and these dynamics are permeated across the pounds and euro markets. This reflects that the USD dollar is leading the way as the prime mover. Consequently, this study attempts to provide evidence-based research on the direction and magnitude of connectedness amongst these main market (especially the forex market) in Sierra Leone. This translates in providing insights on asset diversification and maximization of returns.

The 2007/2008 Global Financial Crises (GFC) revealed that financial markets can easily permeate risks across economies and this dampened the world economy over that period. A myriad of studies have been conducted on the nexus of these markets in developed countries in particular, Diebold and Yilmaz (2012) for the United States; Sensoy and Sobaci (2014) for Turkey; Liow (2015) for G7; and Kal et al. (2015) for Australia, Canada, Japan and United Kingdom, , Kakinuma,(2021);

Singhal et al.(2021); Sheku et al(2020); Sawar et al.(2020); Nyugen et al.(2020); Rastogi et al.(2021).

Sierra Leone is a small developing economy that is import driven reflecting it is highly vulnerable to exogenous shocks (such as dramatic price decrease in commodity prices and fossil fuels compounded by the lingering impact of the GFC). The study is further motivated by the need to provide insights on the hedging capability of these financial markets, revealing diversification benefits to investors, market participants, and policymakers. In other words, it serves as bedrock for ‘evidence-based policy-making’ which has gained wide currency and acceptability. To the best knowledge, this is the first attempt that explores the links between money market and forex market. Therefore, the study fills this observed gap.

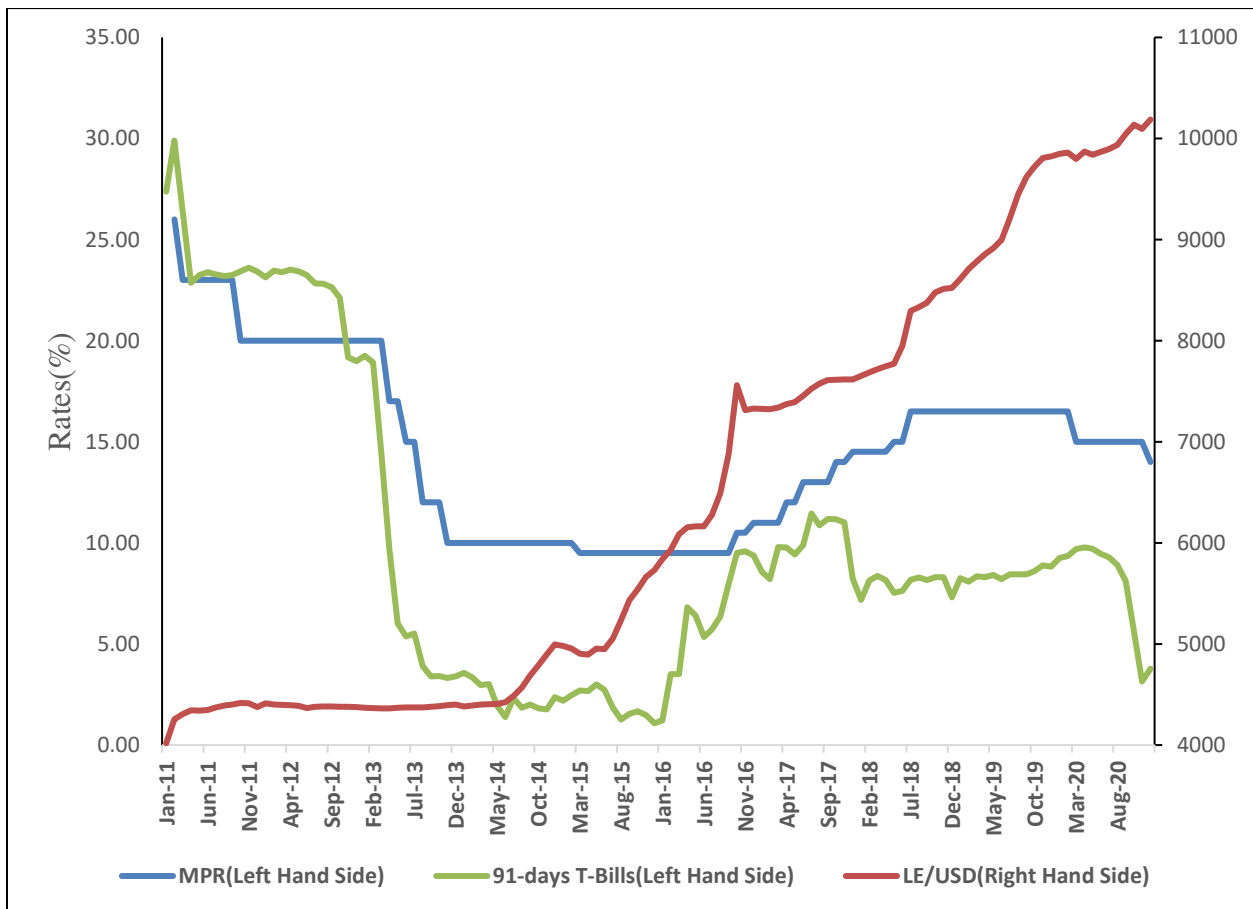
The contribution of this paper to the empirical literature is three-pronged. Primarily, the paper delves into interconnected of a low-income country using main forex markets (Le/USD, Le/Euro, Le/Pounds) as the country of interest. Subsequently, the study then encapsulates both volatility and returns spill-overs using main forex markets in Sierra Leone. Moreover, the study employs both Diebold and Yilmaz (2012, 2014) [hereafter called DY] spillover indices methodology to gauge the intensity (strength) of the nexus between these markets, and more so portray the different cyclical dynamics potentially to affect the scale of the returns and gyration of the Sierra Leone forex markets. The methodology is unique in that it is the first time it is applied for Sierra Leone and also innovative as it explores interesting insights as a potential safeguard to investors, policy-makers, market participants and academics as well on the strength and weaknesses of the Sierra Leone main forex markets. This is evident that it serves as early warning signs for any untoward event in these markets.

The rest of the study is structured as follows, Section 2 presents some stylized facts, Section 3 analyses the methodology and empirical results. Section 4 discusses the analysis of rolling sample analysis whilst section 5 concludes with some policy implications.

2.0 Stylized Facts

91-day T-bills, foreign exchange rate (Le/USD) are the indicators of the main financial markets and monetary policy rate as the key signal rate for all other market rates to follow. By visual inspection the 91-day rates trended downwards and monetary policy rate (mpr) was on averaged loosened reflective that liquidity conditions spur interbank market activities. However, the trend of forex indicates on average depreciation.

Figure 1: 91-Day Treasury Bills, Monetary Policy Rate & foreign exchange rate (Le/US\$) over the review period

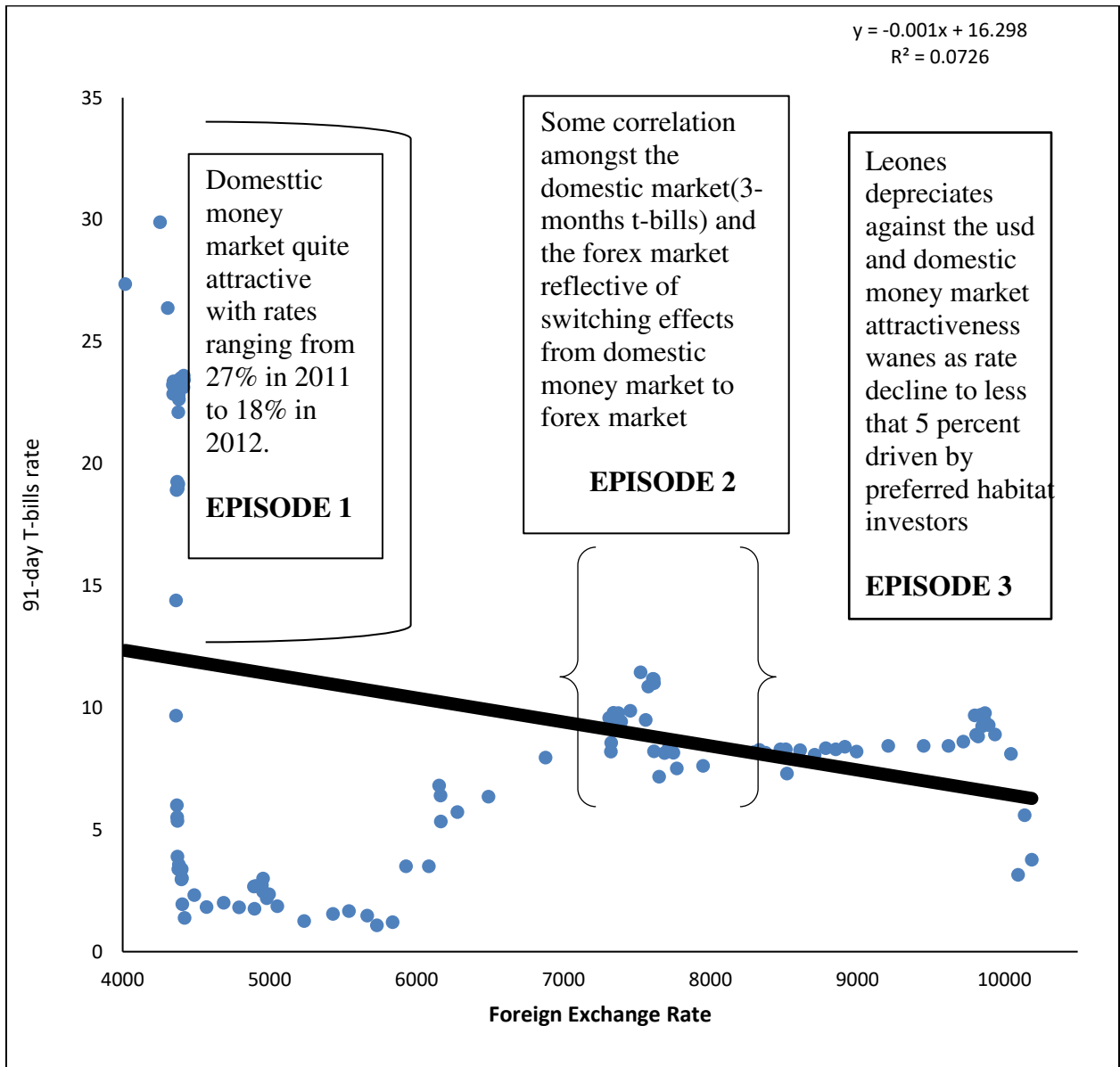


Source: Bank of Sierra Leone

Over the period under review, 91-day T-bills rate moved largely in tandem with the monetary policy rate reflecting some degree of mimicking at least in terms of direction. In the same vein, the exchange rate depreciated largely over the review period driven by largely by supply-side dynamics and minimally by demand-side play-out.

With regards to assessing the dynamics between the domestic market (3-months T-bills) and the foreign exchange market (exchange rate), the key point is that the forex market is leading the way in terms of attractiveness and profitability for investors relative to the 3-months T-bills market.

Figure 2: FOREX VS 91-DAY T-BILLS



Source: Bank of Sierra Leone

Figure 2 reflects the scattered diagram of the two main markets namely, money market (91-day treasury-bills rate) and the foreign exchange market (Le/USD), super-imposed with a line of best fit to show the degree of association between the two markets during the review period

3. Data, Methodology and Descriptive Analysis

3.1 Data

The study does a rendition of statistical analysis of returns and volatilities of the three main currencies (namely, LE/USD, LE/POUND and LE/EURO) driving the foreign exchange market (using the BSL official mid-rate) in order to reveal their statistical characteristics. Monthly data spanning 2001 to 2021 is employed and sourced from the BSL website. The coverage of this analysis is driven by the operationalization of foreign exchange policies which came into existence during this vintage and the availability of monthly data over the period.

3.2 Methodology and Model Specifications

Diebold –Yilmaz (DY) Approach was employed. The underlying framework for the DY spillover indexes is the generalized vector autoregressive (VAR) model of KPPS. Specifically, the study leverages on the DY (2012, 2014) approach to set up a directional spillover indexes in a generalized VAR framework that is invariant to ordering (i.e., it eradicates the possible dependence of the outcomes on ordering) of the variables. Setting up the spillover indexes starting from equation (1), a covariance stationary N-variable VAR(p) was considered.

In setting up the spillover indexes, a stationary VAR is considered :

$$\mathbf{r}_t = \Phi \mathbf{r}_{t-1} + \varepsilon_t; \quad \varepsilon_t \sim (\mathbf{0}, \Sigma) \quad \text{.....(1)}$$

Where: $\mathbf{r}_t = (r_{1t}, r_{2t}, \dots, r_{Nt})'$ is an $N \times 1$ of vector of return/volatility series, Φ is an $N \times N$ matrix of parameters, ε_t is a vector of independently and identically distributed disturbances & Σ is the variance matrix for the error vector ε_t .

The moving average representation can be written as:
$$\mathbf{r}_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \quad \text{.....(2)}$$

Where: $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \dots + \Phi_p A_{i-p}$; A_0 is an identity matrix with an $N \times N$ dimension and $A_i = 0$ for $i < 0$. Equation (2) forms the basis for the derivation of variance decompositions required to determine the spillover indexes.

Prior to providing the representations for the various indexes, the following preliminary considerations are important:

- Own variance shares are defined as the fractions of the H-step-ahead error variances in forecasting r_i that are due to shocks to r_i , for $i = 1, 2, \dots, N$.
- Cross variance shares or spillovers are defined as the fractions of the H-step-ahead error variances in forecasting r_i that are due to shocks to r_j , for $i, j = 1, 2, \dots, N$, such that $i \neq j$.
- Based on the generalized VAR framework of KPPS, the H-step-ahead forecast error variance decompositions denoted by θ_{ij}^s is written as:

$$\theta_{ij}^s (H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)} \quad (3)$$

Since the sum of the elements in each of the variance decompositions as defined in (3) is not equal to 1: $\sum_{j=1}^N \theta_{ij}^s (H) \neq 1$; DY (2012) normalized each entry of the variance decomposition matrix by the row sum in order to use the full information of the matrix.

The normalized KPPS H-step-ahead forecast error variance decompositions represented by $\tilde{\theta}_{ij}^s (H)$ is expressed as:

$$\tilde{\theta}_{ij}^s (H) = \frac{\theta_{ij}^s (H)}{\sum_{j=1}^N \theta_{ij}^s (H)} \quad (4)$$

where $\sum_{j=1}^N \tilde{\theta}_{ij}^s (H) = 1$ and $\sum_{i,j=1}^N \tilde{\theta}_{ij}^s (H) = N$ by construction. Given these preliminaries, the total spillover index is written as:

$$S^g(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^N \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} \times 100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^N \tilde{\theta}_{ij}^g(H)}{N} \times 100 \quad (5)$$

Essentially, equation (5) measures the contribution of spillovers of return/volatility shocks across the assets under consideration. Also, it is possible to assess quantitatively the direction of spillovers across the assets.

These directional spillovers are classified into two :

- ‘Directional Spillover To’ $(S_{.i}^g)$
- ‘Directional Spillover From’ $(S_{i.}^g)$

‘Directional Spillover To’ measures the spillovers transmitted by i market to all other markets j .

$$S_{.i}^g(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ji}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ji}^g(H)} \times 100 = \frac{\sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ji}^g(H)}{N} \times 100 \quad (6)$$

‘Directional Spillover From’ measures the spillovers received by market i from all other markets j .

$$S_{i.}^g(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^g(H)} \times 100 = \frac{\sum_{\substack{j=1 \\ j \neq i}}^N \tilde{\theta}_{ij}^g(H)}{N} \times 100 \quad (7)$$

Net Spillover Index: It is the difference between (6) and (7). $S_i^g(H) = S_i^g(H) - S_{i.}^g(H)$. (8)

3.3 Descriptive Results

The returns of the series (r_t) are computed as the first difference of the natural logarithm of the level series (P_t); this is expressed in equation (1a):

$$r_t = 100 * \log [P_t / P_{t-1}] \text{-----(1a)}$$

Where: r_t = represents the calculated treasury bill/exchange rate returns, P_t is the level t-bills rate/exchange rate, and expression in the braces is the first difference lag operator. Hence the positive/negative returns will mimic the direction of depreciation or appreciation of the exchange rate (Le/USD, Le/Pound, Le/Euro).

Consequently, the volatility series, is derived by the estimation of GARCH (1, 1) model

($\sigma_t^2 = \omega + \alpha \nu_{t-1}^2 + \beta \sigma_{t-1}^2$) indicative of all variables in their estimated forms. Table 1 and 2 present the summary statistics for the three series.

Table 1: Summary Statistics for log of returns of three main trading currency pairs (full sample)

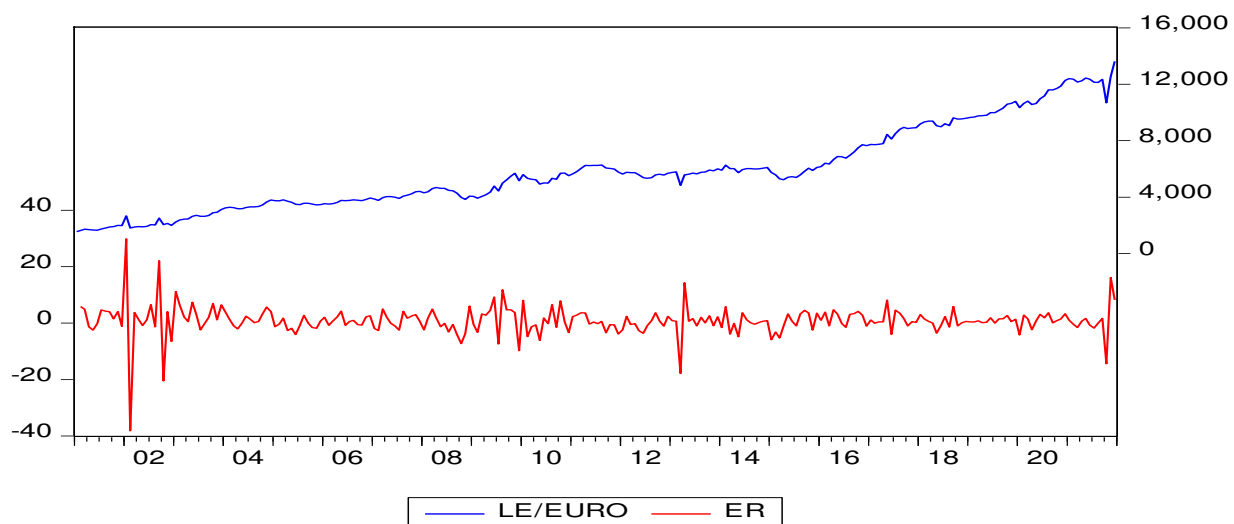
STATS	ER	PR	UR
Mean	0.865	0.719	0.762
Median	0.676	0.610	0.378
Maximum	29.814	33.479	7.449
Minimum	-38.161	-31.010	-6.162
Std. Dev.	5.156	3.949	1.379
Skewness	-1.110	0.212	1.076
Kurtosis	21.533	36.720	10.423
Jarque-Bera	3643.788	11893.500	624.760
Probability	0.000	0.000	0.000
Sum	217.354	180.601	191.419
Sum Sq. Dev.	6646.184	3900.586	475.621
Observations	252.000	252.000	252.000

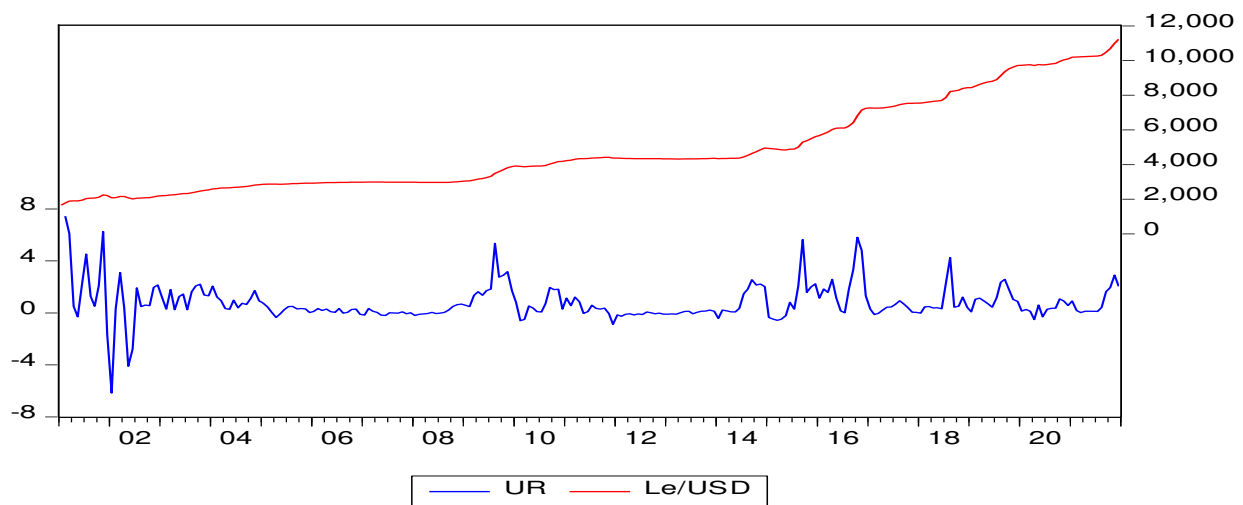
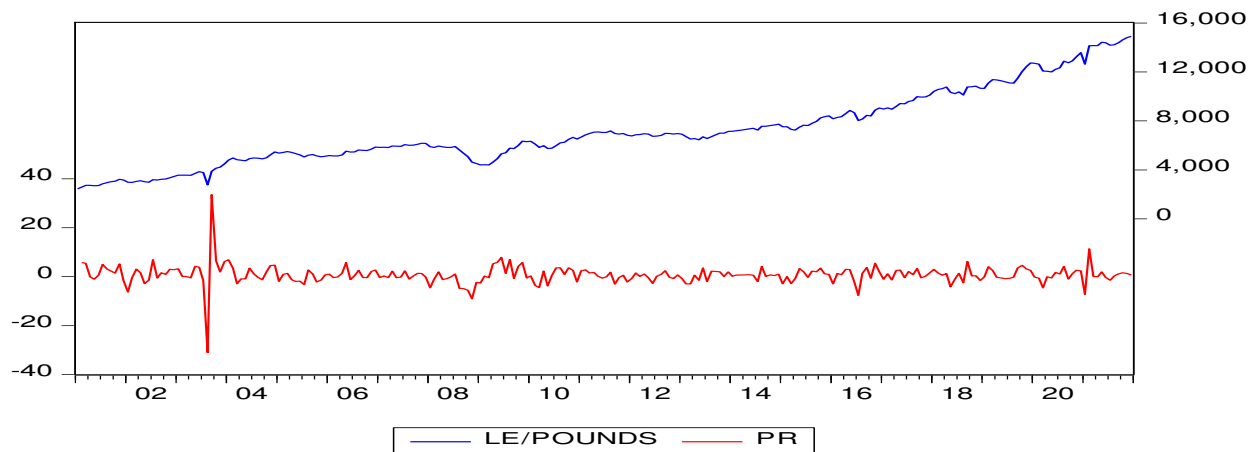
*Note: ER is the returns from the Le/Euro, PR is the returns from the Le/Pounds and UR is the returns from the Le/USD

Source: Compiled by authors

Table 1 shows the descriptive statistics for the return series of the three (3) foremost currency pairs in the foreign exchange market over the coverage period. Inference from the table indicates that the mean represents the average returns in these currencies transacted in the forex market. Inference from the three currency pairs in terms of returns show that all three of the currencies in the forex market elicits positive average returns implying that the leones depreciated against the Euro, Pounds and the USD with the mean statistic showing euro yielding the highest returns. This behavior of the return series is further analyzed using visualizations (See figure 3). Figure 3 reflects that the leones depreciated against the euro pounds and the USD consistently over the period under consideration indicating an upward sloping trend. The observations are consistent with the computed summary statistics.

Figure 3: Combined Graph for currency pairs and their returns





The maximum and minimum values including the skewness and kurtosis statistics of the returns from the three main currencies are also illustrated. The return series of the pounds and dollar are positively skewed whilst the euro returns negative skewness. The kurtosis statistics also revealed that the return series of all three currency pairs are highly peaked or leptokurtic.

Table 2 shows the descriptive statistics for the volatility series of all the three currency pairs under the whole sample period. Drawing from figure 4, all the three currency pairs are volatile (though some are more volatile than others).

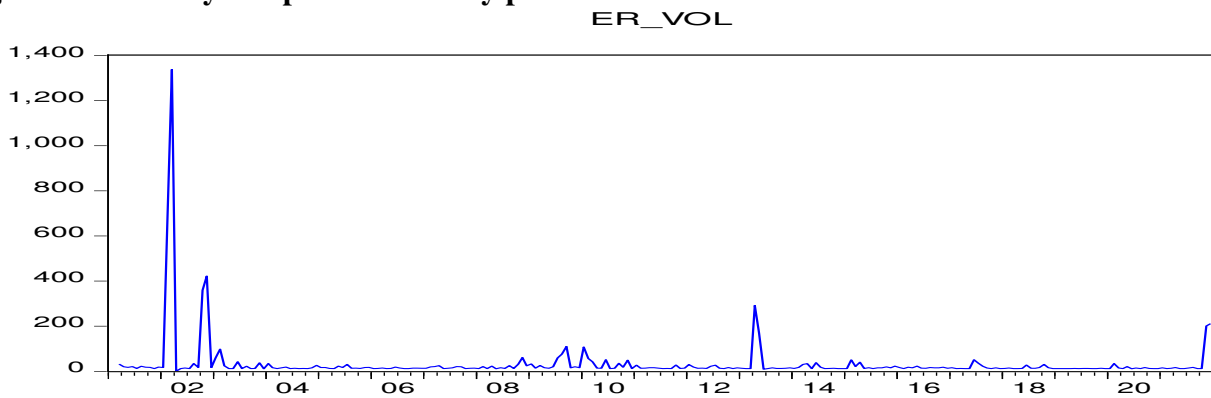
Table 2: Summary Statistics for volatility series three main trading currency pairs (full sample)

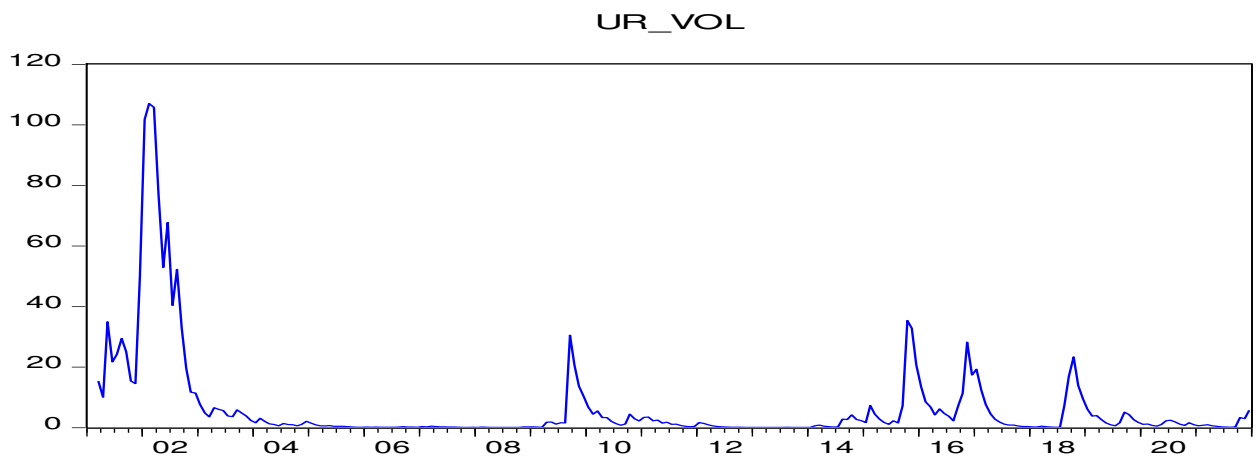
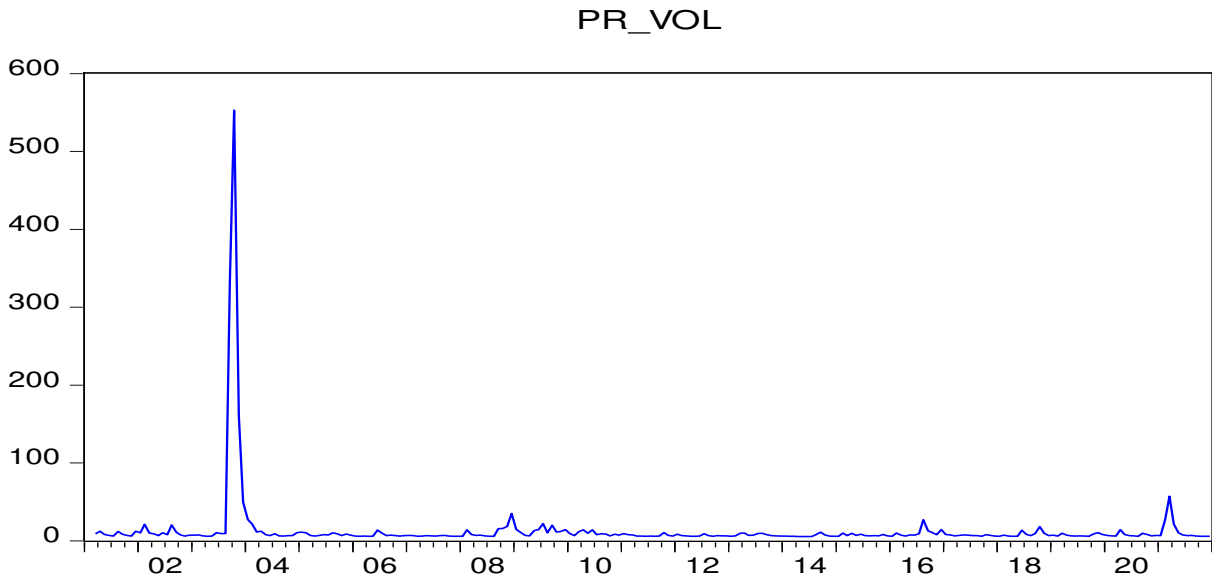
STATS	ER_VOL	PR_VOL	UR_VOL
Mean	33.26	13.02	6.41
Median	14.71	7.09	1.17
Maximum	1337.82	552.75	107.00
Minimum	0.00	5.52	0.07
Std. Dev.	102.11	41.36	15.28
Skewness	9.80	10.94	4.40
Kurtosis	114.74	131.44	25.16
Jarque-Bera	134079.80	176849.9	5925.81
Probability	0.00	0.00	0.00
Sum	8315.08	3257.37	1603.95
Sum Sq. Dev.	2596507.00	426156.50	58155.66
Observations	252.00	252.00	252.00

Source: Compiled by authors

with indication of volatility clustering, i.e., periods of high volatility are tracked by periods of relatively low volatility. Also, virtually all these currency pairs exhibit notable spikes. The average unpredictability nature of each currency pair is captured by in the mean or average in table 2. The LE/USD_VOL has the least mean value while the ER/ USD-VOL has the highest mean value. For deviation from the mean, the UR_VOL has the least value subsequent to PR_VOL and ER_VOL in ascending order. Thus, the ER_VOL is more volatile than others judging by the standard deviation. In addition, all the volatility series are skewed positively and have fat tails.

Figure 4: Volatility Graph for currency pairs





4. Discussion of Empirical Results

4. 1 Analysis of Spillover Tables

The DY methodology is a double machine learning technic that can help move beyond prediction to understand causation, in the context of an effort to estimate connectedness using proxies for Sierra Leone’s forex markets (that account for over 90% of the transactions in foreign exchange). These are the Leones/USD, Leones/pounds and the Leones/Euro. DY methodology is commonly divided into the Spillover Tables and the Rolling Window Analysis. The Spillover Tables produces a single fixed (scalar) value reflecting the indices during the period of interest. This is insightful where the focus is to gauge aggregate spillovers during a given period. Yet, a profound and innate meaning can be elicited wherein unexpected episodes mimicking the behavior of the spillovers are

embedded by the analysis. This brings to the fore the importance of rolling window analysis which complements the spillover tables as it mirrors cyclical and secular dynamics depicting these features of spillovers per period.

Consequently, the study depicts the spillover tables for both returns and volatilities of the three main currency pairs in the foreign exchange market in Sierra Leone (see Table 3&4). Table 3 illustrates the return spillovers estimated for the entire sample enshrined on second order 3-variable VAR with 10-step ahead forecasts. The off-diagonal column aggregates compute the “contribution to others” while the off-diagonal row sums provide the “contribution from others”. Both are directional spillovers where “Directional spillovers to” is represented by “contribution to others” while “Directional spillovers from” is denoted by “contribution from others” in both Tables.

Table 3: Return Spillover of 3 main foreign exchange market from Jan 2001-Dec 2021 with insignificant

TO	FROM			Contribution From Others	Net Spillover
	er	pr	ur		
er	93.2	1.8	4.9	6.8	5.9
pr	9.5	81.9	8.6	18.1	-13.6
ur	3.2	2.7	94.2	5.8	7.7
Contribution to others	12.7	4.5	13.5	30.7	
Contribution including own	105.9	86.4	107.7	Spillover index: 10.2%	

Note: The *ij*th entry gives the *ij*th pairwise directional connectedness

Source: Compiled by the authors

Table 4: Volatility Spillover of three main foreign exchange market from Jan 2001-Dec 2021

TO	FROM			Contribution From Others	Net Spillover
	er_vol	pr_vol	ur_vol		
er_vol	74.9	0.1	25	25.1	-21.9
pr_vol	0.1	99.9	0	0.1	0
ur_vol	3.1	0.1	96.8	3.2	21.8
Contribution to others	3.2	0.1	25	28.3	
Contribution including own	78.1	100	121.9	Spillover index 9.4%	

Note: The ij th entry gives the ij th pairwise directional connectedness

Source: Compiled by the authors

Thus, each element in each column, other than the main diagonal elements, captures individual market's contribution to the forecast error variance of other markets. Similarly, each component in each row, excluding the main diagonal components, gauges the contributions of other markets to the forecast error variance of a specific market under consideration. Technically, "contribution to others" measures the total contribution of shocks to a particular market to the forecast error variance of other markets while "contribution from others" measures the total contribution of shocks to other markets to the forecast error variance of a particular market. In essence, the spillover table is similar to the input-output table as it shows how shocks are immersed and propagated within the system of interest.

The net spillovers are obtained by deducting the "contribution from others" from "contributions to others" or *vice versa*. This means that the net spillovers reflect the subtraction between the contribution a market gives to and receives from others. Using the former definition, a positive magnitude is an indication that the market under consideration has a greater influence in other markets than the influence it receives from them. This endears the market under consideration

mildly inimical to external shocks. Conversely, a negative magnitude means the market under scrutiny is more inimical to shocks to other markets. Furthermore, the total spillover index is illustrated in the lower right corner of the spillover table and it is computed by expressing the aggregate “contributions to others” (or total “contributions from others”) as a percentage of sum of “contributions including own”. This condenses the various directional spillovers into a single index; therefore, it effectively captures the aggregate spillovers conveyed among the markets under consideration.

In terms of interpretation, the spillover Table for the return series reflects that in connection with the individual directional spillovers from others. Starting with return connectedness, the empirical estimates in Table 3 with the total spillover index at 10.2% is an indication of low level of return connectedness among the three main currency pairs (Euro, Pounds and the US Dollar) in Sierra Leone. A deeper analysis of the total spillover index reveals that the calculated value of 10.2% mirrors that marginally over 10% of the total variance of the forecast errors over the sample is elucidated by shocks across the currency pairs, whilst the residual 89.8% is expounded by idiosyncratic shocks. For instance, the examination of the gross directional return spillover suggests that only 6.8% of the variations in euro returns might be due to spillover of shocks from other currency pairs. For pounds and euro currency pairs in the foreign exchange market, the magnitude of spillover effect from other markets is 18.1% and 5.8%, respectively. However, the net spillovers reveal returns on US dollar with 7.7% net spillovers as highest net transmitter of shocks followed closely by the euro with 5.9%, however the net spillover of the pounds was negative 13.6%.

On volatility spillover, the empirical estimates in Table 4 indicates the total spillover index at 9.4% is an indication of low level of return connectedness among the three main currency pairs (Euro, Pounds and the US Dollar) in Sierra Leone. A deeper and more intuitive perusal of total spillover index, the calculated value is 9.4%, which is reflective that slightly under 10% of the total variance of the forecast errors during the sample is explained by shocks across the currency pairs, whilst the remaining 90.6% is explained by idiosyncratic shocks. In particular, the examination of the gross directional volatilities spillover suggests that 25.1% of the variations in euro volatilities might be due to spillover of shocks from other currency pairs. For pounds and euro currency pairs

in the foreign exchange market, the magnitude of spillover effect from other markets is 0.1% and 3.2%, respectively.

However, the net spillovers reveal volatilities on US dollar with 21.7% net spillovers as highest net transmitter of shocks followed by the euro and the pounds with insignificant impact. The USD appears the least transmitter of shocks in euro and pounds volatilities and yet stands out as the net receiver of volatility permeation from other markets currency pairs. This however, is expected of a country practicing managed float exchange rate regime. Therefore, the overall connectedness among the USD currency pairs appears to be more pronounced for spillovers due to volatility in currency pairs relative to connectedness due to return spillovers.

4.2 Rolling-Sample and Spillover Analyses

4.2.1 Rolling-Sample Analysis

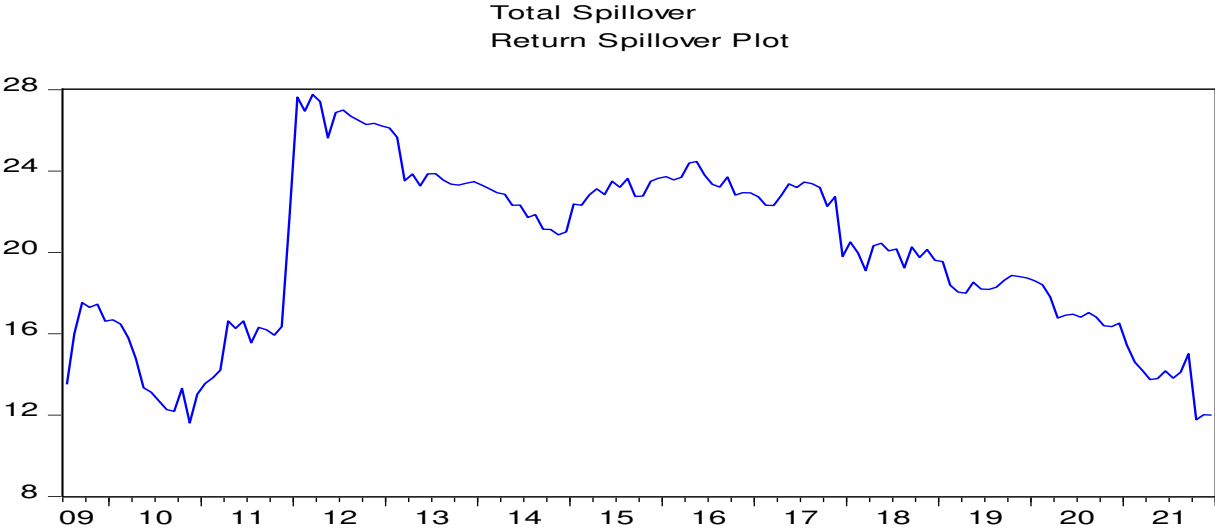
While the spillover table and index buttressed with other relevant analysis has given a background of the “average” spillover features amongst the three main currency pair in the forex market, however Diebold and Yilmaz (2012) averred that it may not reveal passably, the significance of some notable episodes of financial gyrations and or economic slumps. Consequently, the study leverages on the rolling sample framework using 200-month sub sample rolling windows in order to ameliorate these inadequacies and correctly encapsulate events or crises episodes that may have ensued over the period reviewed. The resultant plots for total spillover indexes for both returns and volatilities are visualized in figures 3 and 4 respectively. Both total spillovers commence at a value above 12 percent with return spillover marginally greater than volatility spillover in the first window. Precisely, the total return spillover plot mostly fluctuates between 11.6% and 27.8% during the review period.

For the total volatility spillover plot in figure 5, it was observed that the most pronounced of them is in 2012 march where the total volatility spillover appears to be at its peak at 27.8% wherein FDI inflows emanated from the inception of African minerals, London mining and Sugar Magbass industries being operational. A synopsis of this period shows that 2012 saw a propulsion in economic growth recording annual GDP Growth of 15.18%. This translated into prompting an accretion in reserves and relative stability in the foreign exchange market. Thereafter, the spate of

volatilities declined till it tailed away at 12 percent in 2021. This was driven by a cocktail of elements comprising the rolling out of forex policies endearing domestic currency (leone) usage and de-dollarize the domestic economy dynamics. Importantly, Sierra Leone experienced Covid-19 shock in 2020 the disruptive economic activities ensuing in a recession of 2.2% over this period. The smart economic recovery package (quick action) implemented during this period assuaged the inimical impact of these dynamics. This driven by cross market volatility transmission during or in the reverberation of a turbulent economic period.

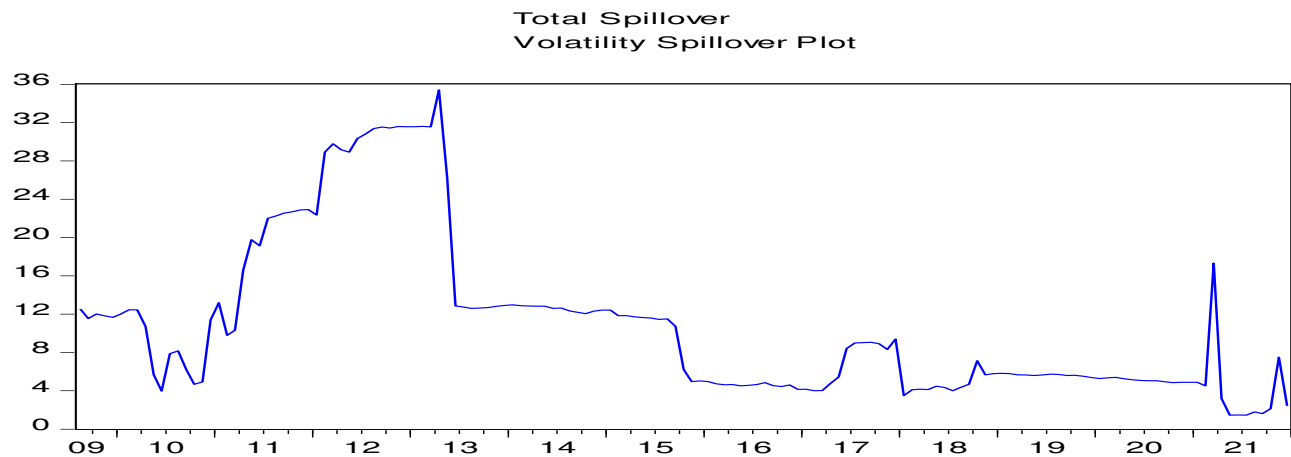
In sum, a cursory look at the two graphs depicts that return spillovers exhibit both trends and bursts during the period reviewed while volatility spillovers show significant bursts but no trends.

Figure 4



Source: Author’s estimation from research data

Figure 5



Source: The Authors'

4.2.2 Directional Spillovers

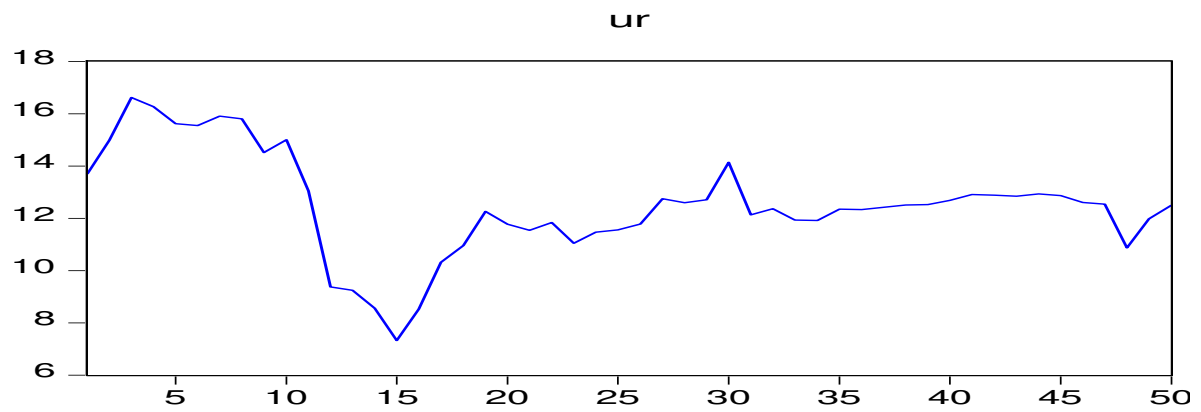
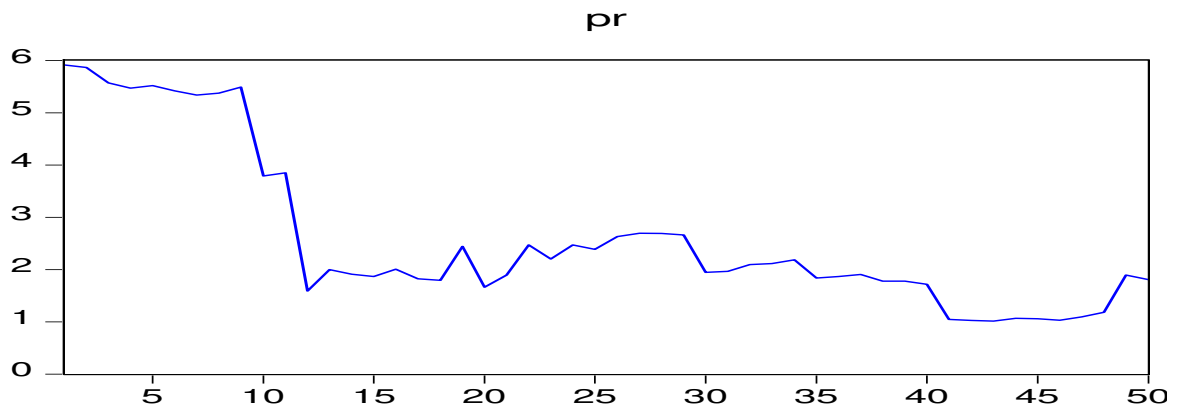
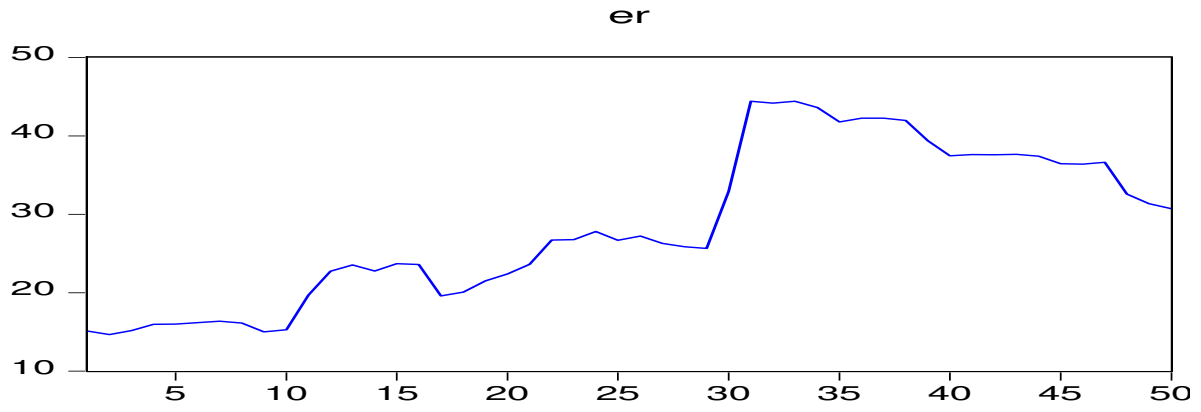
This section assesses directional spillovers from and to others amongst the main currency pairs for both returns and volatilities. In this context, directional spillovers provide information on how spillover is being transmitted from one currency pair to others and from other currency pairs to a specific currency pair (in Sierra Leone forex market). An examination of directional return spillovers are illustrated by figures 6 and 7, respectively. In Figure 6, are the directional return spillovers to each of the main currency pairs from others (corresponding to the “directional spillovers from others”) in Table 4. Among the three currency pairs, the return spillover from other currency pairs to foreign exchange market seems generally exceed other market irrespective of the period. The Figure 6 reveals the following: Directional return spillovers to others seem to follow dissimilar patterns. It depicts currency pairs that witnessed somewhat increasing trends for the euro returns, dollar returns but somewhat, but the returns on the pounds followed a declining trend thereafter, there was a smaller and unsteady surge in the spillovers. The second group-directional spillovers from in reflected in figure 7 shows what appears as a steep trend. The spillovers recorded somewhat main increases especially for the returns on the euro and the dollar, however, with a somewhat downward trend afterwards.

Despite the groupings, the two figures indicate substantial directional return spillovers among the currency pairs. The directional return spillovers display both trends and bursts over the rolling

window. Giving a laser focus to the direction volatility spillovers (see figures 7 and 8), we find a pattern that is similar to the total volatility spillovers. This means that, the directional volatility spillovers also display significant bursts like the total volatility spillovers. All the currency pairs recorded significant volatility spillovers implying that they are all vulnerable to volatility shocks in international FX markets.

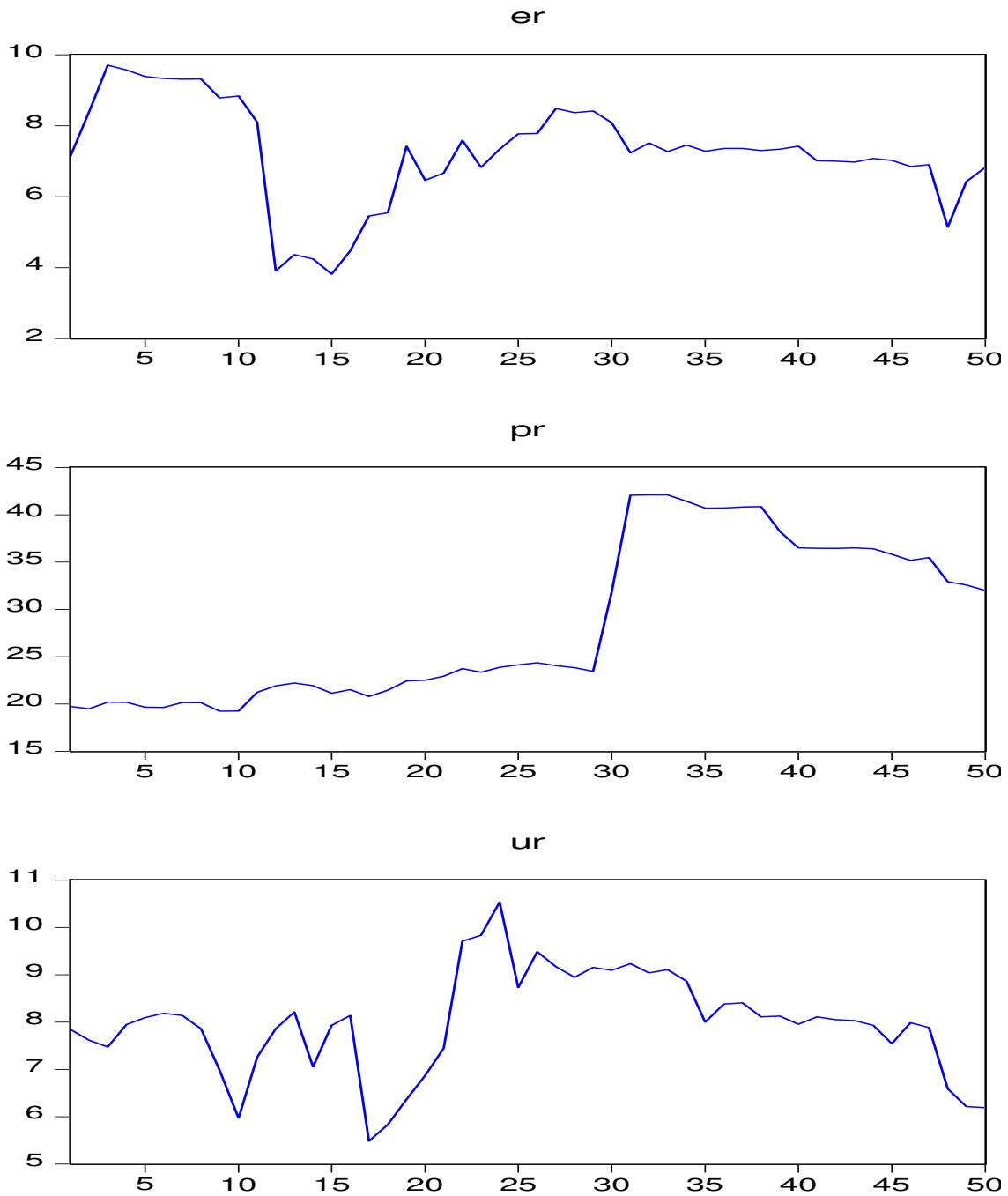
Taken in one breath, the rolling window analyses signal large return and volatility spillovers for some periods than the others due to some cyclical events as emphasized. These variations are usually not readily visible in the spillover tables. This clarifies why it is vital support⁵⁴ spillover indexes with rolling window analyses.

Figure 6: Directional Spillovers to the individual return series



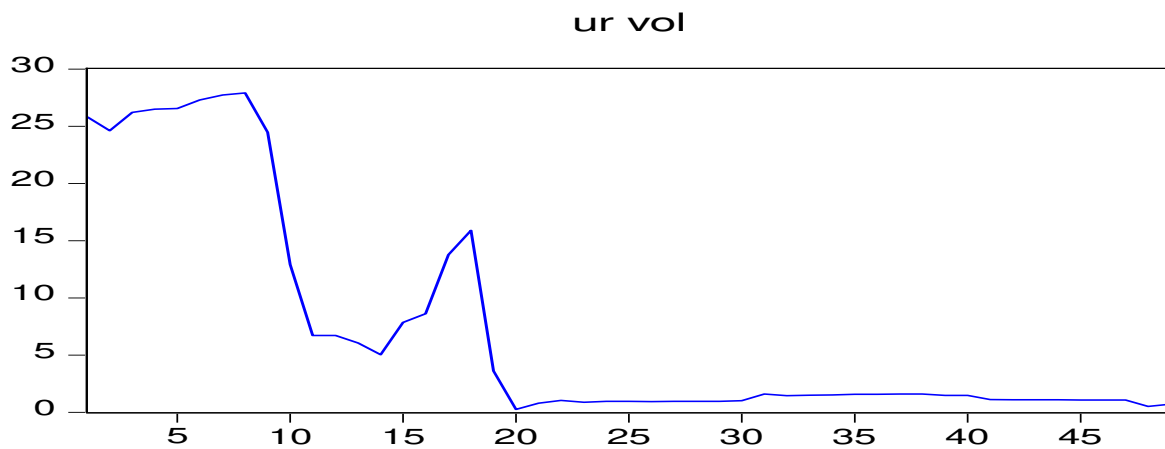
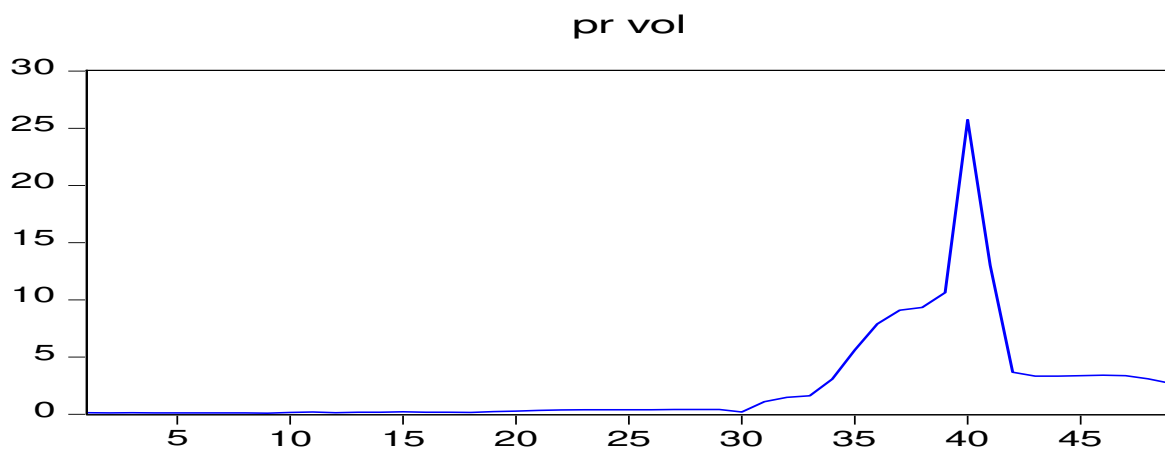
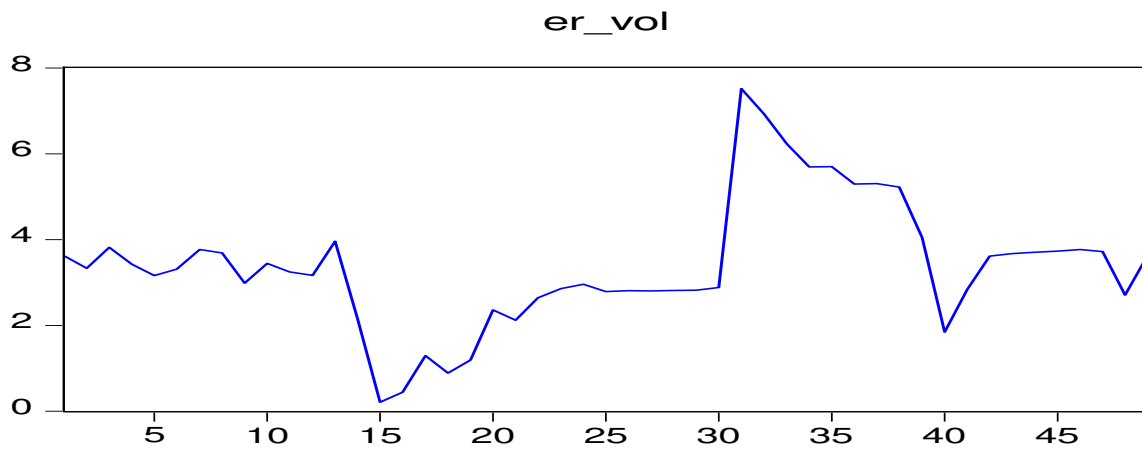
Source: The Authors'

Figure 7: Directional Spillovers from the individual return series



Source: The Authors

Figure 8: Directional Spillovers to the individual volatility series



Source: The Authors'

5. Conclusion and Recommendations

This paper assessed and modelled the intensity of connectedness among forex markets in Sierra Leone. It leveraged on the novel DY (2012) approach which is measure of connectedness index, and it was observed that for an emerging economy such as Sierra Leone, its forex markets are likely to be more responsive to external shocks and domestic economic turbulence.

The striking findings of the study can be classified into two-pronged strata. First, we find evidence of cross-market spillovers among the selected forex currency pairs, feeding through from the US dollar to the euro and then to the pounds sterling. This pass-through mechanism may also follow the reverse order.

Second, the paper implied that the US dollar market in Sierra Leone has the highest transmitter of volatility spillovers when compared to euro and pound sterling forex markets. This means that the US Dollar market in Sierra Leone appear to exert more influence on the behavior of returns of the of the other selected FX markets. In this regard, the Central Bank of Sierra Leone (BSL) mandated with pursuing financial stability would be expected to manage the volatilities of the selected forex markets which are the drivers.

Based on the findings, it is recommended that policymakers in Sierra Leone should look both inward and outward whenever policy discussion gyrate around the increasing integration of forex markets so as to soften the inimical impact on the economy from exacerbations of contagion. This recommendation is in line with our findings, coupled with the structure of the Sierra Leone economy and its high reliance on iron-ore. Thus, in its pursuit of price and exchange rate stability BSL needs to capture not only the inherent contagions associated with the internal connectedness of the country's forex markets, but also their vulnerability to external shocks. This means that BSL should leverage on the accretion of reserve buffers to contain these risks through the timely intervention in the forex market and this reinforces confidence and trust.

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