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Omane-Adjepong, Maurice and Boako, Gidoen and Alagidede, Paul

University of the Witwatersrand, Kwame Nkrumah University of Science and Technology, University of the Witwatersrand

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[a]Maurice Omane-Adjepong, [b]Gideon Boako, [a]Paul Alagidede,

[a]*Wits Business School, University of the Witwatersrand, 2 St David's Place, Parktown, Johannesburg, 2193, South Africa.*
[b]*Depatment of Accounting and Finance, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

Corresponding author: Maurice Omane-Adjepong, doctoral research candidate, Wits Business School, University of the Witwatersrand, 2 St David's Place, Parktown, Johannesburg, 2193, South Africa; Email: 1766375@students.wits.ac.za/ omane.maurice@gcuc.edu.gh

Abstract
In this paper, we explore the weak form efficiency of Ghana's foreign exchange (FX) market and analyse the existence of speculative activity and correlated shocks in the market. We use high and low frequency data covering May 31, 1999 to November 30, 2017. For robustness, four robust methods are employed. Our findings are as follows: First, the efficiency of the FX market is non-homogenous. This gives very little room for speculative trading options, hence, we surmise that speculative activities cannot necessarily account for the self-driven shocks in Ghana's FX market system. Second, the cedi/dollar market inefficiency is concealed in conditional returns, and toggles between persistence and anti-persistence for the high and low data frequencies, respectively. Third, varying significant persistence is detected for the volatility returns for all market series, however, the evidence is more pronounced for daily-, absolute-, and conditional volatility returns. These data dynamics prove useful and should be considered when examining empirical behaviours of asset markets. In summing up, investors and policy makers could rely on the findings and their implications in making decisions on investment and exchange rate control systems.

Key words: correlogram, FX market returns, long-memory, speculative activity, Ghana

JEL classification codes: C22, F31, G14

1. Introduction

Historically, Ghana, like several other countries has experimented with different exchange rate regimes in a bid to maintain a stable currency. Following the Bretton Woods system in the post-World War II, Ghana joined a fixed exchange rate regime under the colonial international economic agreement. During this period, the British West African Currency Board (WACB) constituted in 1912 controlled the supply of currency to the British West African colonies. Under this framework, WACB countries (including Ghana) could not have independent monetary policy and the problem of currency depreciation was not a worry at all.

After gaining political independence in 1957, Ghana later abandoned the WACB arrangement (in 1963) and the Ghana cedi (calved from the word 'cowries') was introduced in 1965 as the domestic currency. Since then the cedi has remained the legal tender in Ghana although it has gone through demonetization (1978-79), series of reintroduction and redenomination (July 2007). Another prevalent feature (particularly in the 1970s and early-1980s) has been a predominant and perennial depreciation of the domestic currency against the major trading currencies (particularly the US dollar). This was often linked to the continuous fiscal excesses supported by monetary accommodation by the central bank, as well as negative external shock emanating from declining commodity prices which engendered adverse terms of trade. To stem the tide, therefore, the Government of Ghana in 1983 jettisoned the fixed exchange rate regime for the free floating regime as a central part of liberalization reforms under the implementation of the Financial Sector Adjustment Programme (FINSAP) – a component of the Economic Recovery Programme (ERP).

According to observations by Alagidede and Muazu (2016) and Bawumia (2014), the cedi has remained weak against the major trading currencies even following the adoption of the flexible exchange rate regime in Ghana. Nevertheless, the cedi depreciation has not been monotonic as it has recorded a modicum of stability against the US dollar between 2002 and 2007. The continuous weakness of the Ghanaian cedi against major trading currencies has engendered a self-fulfilling prophesy as most businesses in Ghana (both formal and informal) more often than not price in cedis for most transactions while thinking in dollars – see Bawumia (2014) and Boako *et al.,* (2016).

Anecdotally, analyst and governments have largely linked the volatility of the cedi to macro-economic instability. The blurrily of the situation and lack of appreciation of the main cause of such volatilities in the exchange rate market have led to the glutting of the financial press with all manner of reasons (some highly astonishing) for the sometimes free fall of the domestic currency such as, dollarization, import driven structure of the economy, redenomination, the implementation of single spine salary structure (SSSS), dwarves and 'juju men', high rise buildings, and a sign of the end of the world – see Bawumia (2014).

However, understanding the key drivers of foreign exchange rate (FX) volatility and the channels of manifestation is an empirical matter (Alagidede and Muazu, 2016). That notwithstanding, very scant empirical studies exist to examine the dynamics of the exchange rate market in Ghana. Notable studies are Tweneboah (2015) and Alagidede and Muazu (2016). While Tweneboah (2015) observes that dollarization exerts positive impact on the volatility of nominal bilateral cedi/dollar exchange rates, Alagidede and Muazu (2016) delineates that factors such as government expenditure, money supply growth, terms of trade and output shocks cause exchange rate volatility. The challenge is that all these studies attribute the boom-bust cycles in the exchange rate market to macro-economic factors. Another key finding by Alagidede and Muazu (2016) is that, about three quarters of shocks to the real exchange rate market in Ghana are self-driven. The authors however failed to account for what drives these shocks. Could it be due to speculative behaviour of market agents?

Osler (1995) postulates that normal market speculative activity could eventually become a source of random-walk exchange rate behaviour. The authors continued by arguing that, with appreciable level of speculative activity, an FX market could not distinguish itself from a random-walk process, irrespective of its principal determinants. They further showed from their findings that higher speculative activity could cause FX markets to be much predictable. Carlson and Osler (2000) corroborate this position, and specify that speculative activity affects the data generating process or microstructure of exchange rate markets. The authors then posit that such activity increases FX market volatility.

This study critically examines whether the FX market in Ghana is driven by speculative behaviour through analysis of the long-memory properties of the cedi, in relation to four major trading partners. The analysis is to help us determine whether the currency pairs exhibit persistence (long-memory) or anti-persistence (intermediate memory) behaviour that might give space for speculative agents to unfairly gain from the market. This helps to draw inferences for the efficiency of the FX market in Ghana (weak form of market efficiency), and the implications thereof for investors, governments, and market participants, in general. For instance, in efficient foreign exchange markets, the expected cost of hedging is equal to the transaction costs incurred, and thus, taking into account the low cost of hedging, investors can substantially reduce the foreign exchange risk at a relatively low cost (Soenen, 1979). Further, in an inefficient foreign exchange market, government authorities can determine the best way to influence exchange rates, reduce exchange rate volatility, reduce government intervention, evaluate the consequences of different economic policies, as well as curtail abnormal profits from foreign exchange transactions participants.

Internationally, the efficiency of FX markets has been examined by authors across different market jurisdictions. Not to mention all but few, Oh and Kim, (2006) explored relative market efficiency using global FX market indices for 17 countries. They found higher market efficiency for markets with larger liquidity than the Asian and African countries with smaller liquidity. Using 34 FXs against the US dollar, Floros (2008) recorded strong long-memory for 17 market returns, and concluded that shocks to such market persist for long time periods. Elsewhere, Cheung *et al*., (2011) examined market efficiency of the euro FX market using FX returns of 82 countries. In all, about 62 of the 82 markets displayed evidences in line with the weak form market efficiency. By employing the R/S analysis and the fractional integration method over different data frequencies, Caporale *et al*., (2017) unveiled persistence properties for two major FX markets (euro-US dollar and US dollar-yen), and partially found persistence to be higher at lower frequencies. In sharp contrast, Caporale and Gil-Alana (2013) reported lower degree of persistence for lower data frequencies, and shows that the evidence changes substantially depending on the data frequency employed. On emerging Asian and African FX markets, Oh *et al*., (2012), Kang *et al*., (2014), Salisu and Ayinde (2016), Olufemi *et al*., (2017) among others, have all provided some levels of insight on FX market efficiencies. However, the evidence is quite mixed and inconclusive.

To the best of our knowledge, studies on long-memory properties of the currency market in Ghana are virtually non-existent. That of Aidoo, *et al*., (2012) and Tweneboah *et al*., (2013) are however notable. The latter used a chain of parametric and nonparametric Variance Ratio (VR) tests to examine the efficiency of Ghana's exchange rate market. They found evidence in favour of inefficient market, and thereof concluded on the possibility of gaining excess returns through speculative activities. Similar conclusion of market inefficiency and ease of predictability was reached by Aidoo *et al*., (2012). Despite these, the following lapses in their papers are apparent. First, the exclusive use of monthly observed cedi/dollar rates by Aidoo *et al*., (2012) looks flawed, since most financial and/or economic series exhibit in the observe levels $I(d)$ properties, and shows autocorrelation structure which generally decays slowly across time lags. Another key omission of both authors is their inability to check and account for possible break effects; especially as their chosen data span spool-over major financial crises or economic cycles. A third observation is the exclusive use of cedi/dollar exchange rate data at lower frequency (monthly rates). It is often argued that most financial market series are much volatile and show dynamic properties at higher frequencies than lower periodicity. Hence, the evidences might be concealed from the exclusive use of monthly data. These notable limitations could perhaps lead to misleading long-memory detections, and subsequent pronouncement of market inefficiencies.

Our paper then rectifies these flaws and makes three major contributions to the currency market literature: firstly, the use of growth rates data on four major traded foreign currencies with a battery of rigorous long-memory detection approaches is undertaken to offer a comprehensive nature of the memory behaviour for the currency market in Ghana. Secondly, we account for structural break effects through the method of disaggregating switching regimes to obtain break-free regimes. Thirdly, the use of low (monthly) and a relatively high (daily) frequency data for examining currency market efficiencies in an emerging sub-Saharan African market is worth mentioning. Is the evidence of market inefficiencies data-frequency dependent and/or collective for the entire market system?

The remaining sections of the paper are structured as follows: Section 2 details the data and empirical methodology for the paper; Section 3 discusses the empirical results; and finally, the last section provides concluding remarks and gives policy implications.

2. Data and empirical methodology

Four major foreign currencies (namely, United States dollar, Euro, United Kingdom's pound and the Japanese yen) as against the Ghanaian cedi[1] are considered in this paper. The sampled currency pairs are expressed in the Ghanaian cedi using respective prevailing rates. The choice of the foreign currencies is backed by their high demand and volumes of trade within the local FX market. The data obtained from Bloomberg are in daily and monthly periodicities, and span from May 31, 1999 to November 30, 2017. The sampled period spans over episodic eras of substantial depreciation of the local currency – see Bawumia (2014).[2] Furthermore, the choice of the period helps to capture possible effects of major global financial/economic turmoil (9/11 US attack, 2007/8 global debt crisis, some periods of commodities price booms and busts, etc.)

[1]The local currency used in the Ghanaian economy is called the Ghanaian cedi. Its higher denominations are 50, 20, 10, 5, 2, and 1 Ghanaian cedis (GH¢) respectively. The smaller denominations are coined in pesewas which include 50, 20, 10 and 5 pesewas.

[2]Detailed information on the exchange rate market in Ghana can be sourced from Bawumia (2014), Tweneboah (2015), and Alagidede and Muazu (2016).

experienced during the past decades till Brexit, on the memory dynamics of FX markets. As reported in their findings, the memory behaviour of market variables partially swings during, before, and after major global turmoil (Omane-Adjepong and Boako, 2017). There again, the sampled data period also covers the discovery and production stages of Ghana's crude oil in commercial quantities. This period marks the opening of the local market to various investors and stakeholders in mass oil production and its allied businesses, with consequences thereof for the exchange rate market.

The observed FX market data is expressed as a continuously compounded exchange rate returns for all four foreign currency pairs using the equation:

$$returns: \ r_t = \{In(E_t) - In(E_{t-1})\} \times 100 \tag{1}$$

where, E_t and E_{t-1} are the univariate exchange rates for the markets at days *t* and *t*-1 respectively. Moreover, for each of the four FX market return series, we obtain unconditional volatility returns by simply squaring the return series at time *t* – for squared volatility returns, r_t^2; and by taking the absolute of the return series at *t* – to obtain the absolute volatility returns, $|r_t|$. Using the derived absolute-, and squared-return series, we thoroughly examine for the presence (absence) of long-memory (LM) properties with the aid of rigorous statistical methods.

2.1 Long-memory (LM) process

A stochastic process of a financial/economic variable exhibits LM properties if the autocorrelation structure of the process slowly (or gradually) decays over time lags. In such situation, the sample autocorrelation coefficients remain highly significant at lower lags, and diminish hyperbolically throughout subsequent time lags as follows:

$$\rho(k) \sim Ck^{2H-2}, \ as\, k \to \infty \tag{2}$$

where, *C* denotes a finite positive constant; *k* represents time lag and *H* is the Hurst exponent which measures the nature and degree of LM properties of the process at hand. In practice, the LM measure, *H* could be expressed in terms of a fractionally integrated measure, *d*, where $d = H - 0.5$. In the same sense, the *H* measure may also be obtained from fractional measure as $H = d + 0.5$. This signifies that the two measures are used interchangeably in detecting the nature and degree of LM in a stochastic process. The process exhibits covariance stationary and mean-reverting LM properties (persistence) given that $d \in (0, 0.5)$; intermediate memory or anti-persistence for $d \in (-0.5, 0)$; and shows stationary and short-memory properties if $d = 0$. It has a long-run mean-reverting structure and shows non-stationary properties if $d \in [0.5, 1)$; and responds to shocks with permanent effect and non-mean reverting if $d \geq 1$.

The fractional integration measure, *d* is estimated following the GPH estimator of Geweke and Porter-Hudak (1983), which uses a log-periodogram through a simple regression equation as follows:

$$\log\left[I\left(w_j\right)\right] = \beta_o + \beta_1 \log\left[4\sin^2\left(\frac{w_j}{2}\right)\right] + e_j \tag{3}$$

where, the residual $e_j = \log\left[\frac{f_z(w_j)}{f_z(0)}\right]$; $j = 1, 2, ..., m$ represents the bandwidth parameter; $w = \frac{2\pi_j}{T}$ is the j^{th} Fourier frequency specified on a sample of T observations; and $I(w_j)$ is the sample periodogram given as $I(w) = \frac{1}{2\pi T}\left|\sum_{t=1}^{T} r_t e^{-w_j t}\right|^2$, from which r_t represents a weak stationary series; and the GPH estimate of $d(\hat{d}_{GPH})$ from the regression equation is denoted by $-\hat{\beta}$. The GPH estimator is somehow sensitive to regime shifts, and sometimes tends to produce bias estimates in the presence of such switching regimes (Granger and Hyung, 2004).

To mitigate such bias detections of LM properties by the GPH test method, Smith (2005) introduced a modified version of the GPH (henceforth known as *m*GPH) which substantially minimizes such biases, and appears relatively robust even in the presence of regime shifts. The test method of Smith (2005) builds on the log-periodogram regression by introduction additional regressor, given as $-\log(p^2 + w_j^2)$ in the regression equation; where $p = k_j / n$ gives the estimate of *p* for some constant $k > 0$. To significantly mitigate the biases of the GPH, Smith (2005) recommended setting the nuisance parameter *k* to 3 (thus, $k = 3$), and uses the plug-in method by Hurvich and Deo (1999) to optimally select the bandwidth *j*. A long-memory process is favoured if the estimated *m*GPH exceeds that of the GPH with plug-in selection of *j*, recommended as a rule of thumb; else a short-memory process with level shifts is deemed viable.

2.2 ARFIMA-FIGARCH framework

Unlike the semiparametric methods, the ARFIMA-FIGARCH class of models are well-noted for dual detection of LM properties. Advanced in the seminal paper of Baillie *et al*., (1996), ARFIMA-FIGARCH is reported to possess rigorous detection powers which captures simultaneously LM dynamics in the conditional mean and conditional variance of a given market series. It's flexibility of detecting dual LM behaviour in financial and/or economic market series has made it more useful than the conventional volatility models. This dual fractionally integrated model has been found as appropriate fit for several market data, and easily captures finite persistence or long-term dependence in the returns and volatility shocks of such markets (see, Arouri *et al*., 2012; Jammazi and Chaker, 2013; Uludag and Lkhamazhapov, 2014; etc.).

Following Baillie *et al*., (1996), we specify an econometric nested equation for the ARFIMA (p_m, d_m, p_m)-FIGARCH(p_v, d_v, p_v) model as follows:

$$\begin{cases} \phi(L)(1-L)^{dm}(r_t - \mu) = \beta(L)\varepsilon_t \\ \varepsilon_t = \eta_t \sqrt[2]{h_t} \\ \alpha(L)(1-L)^{dv}\varepsilon_t^2 = w + (1-\theta(L))v_t \end{cases} \quad (4)$$

Here, the persistence behaviour in the conditional mean and conditional volatility (or variance) of the exchange rate series, r_t is respectively captured by the d_m and d_v parameters; v_t denote a scedastic innovation, measured as $v_t = \varepsilon_t^2 - h_t$; and L is a lag operator. The explanations for the d_m and d_v parameters remain the same as the d parameter under the previous section. Moreover, for the FIGARCH(p_v, d_v, q_v) component of the model, $d_v = 1$ and $d_v = 0$ reduces the fractionally integrated process to an integer integrated GARCH (ARFIMA-IGARCH) and standard GARCH (ARFIMA-GARCH) respectively.

We estimate parameters of the ARFIMA-FIGARCH process through the use of quasi-maximum likelihood approach, which is premised on asymptotic normality distribution with a log-likelihood function given by:

$$LL_t(\varepsilon_t, \theta) = -1/2\log(2\pi) - 1/2\sum_{t=1}^{T}\left[\log(h_t) + \varepsilon_t^2 / h_t\right] \qquad (5)$$

Mindful that the ARFIMA-FIGARCH model is not covariance stationary, Baillie *et al*., (1996) recommended for all the coefficients in the specified ARCH representation in (4) to be well-defined. Thus, given a FIGARCH $(1, d_v, 1)$ model, the inequality constraints defined as $\beta_1 - d_v \leq \phi_1 \leq (2 - d_v)/3$ and $d[\phi_1 - (1 - d_v)/2] \leq \beta_1(\phi_1 - \beta_1 + d_v)$ are sufficient requirements to ensure that a well-behaved model is fitted.

2.2 Structural breaks and long-memory

In order not to report unreliable LM properties and conclude on market efficiency (or otherwise) for any given financial/economic time series, several authors (see: Gil-Alana, *et al*., 2015; Arouri, *et al*., 2012, Assaf, 2007, etc.) have cautioned to account for effects of regime switching on the market series. If such switching or level shifts are allowed to exist, the properties of the series might exhibit LM properties which may not be genuine. In line with this caution, we test for possible regimes or level shifts for each of the market series using the unknown multiple break test of Zeileis *et al*., (2003). From a standard regression equation, their test specifies *m* breakpoint and *m+1* regime switching segments as follows:

$$r_t = x_t^T \beta_j + e_t, \quad for\ all\ \ t = t_{j-1} + 1, \dots, t_j \qquad (6)$$

where, the segment index which is denoted by $j = 1, 2, \dots, m+1$; $I_{mn} = \{t_1, t_2, \dots, t_n\}$, for $t_0 = 0$ and $t_{m+1} = n$ gives the collection of likely breakpoints; and e_t represent the disturbances. Also, r_t is the outcome variable at *t*; x_t represents a $k \times 1$ vector of explanatory variables at time *t*; and β_j denotes a $k \times 1$ vector of regression coefficients associated with the explanatory variables. If breaks exist, a common practice is either to demean the series or split up the series into subsamples alongside the detected breakpoints. These practices overly help to report reliable but not spurious LM properties for the data at hand.

A null hypothesis which states that the regression coefficients in (6) remain constant (absence of structural change), is tested against an alternate hypothesis that at least one coefficient varies over time. Thus, the regression coefficients toggle from a stable regression relationship to a different sort of relationship, which signifies the existence of $m+1$ segments or regimes, for which the regression coefficients become constant. In testing for structure change, Zeileis *et al*., (2003) identified two frameworks. For their first framework, *F* statistics tests are designed for a specific alternative. Tests against such alternative are determined following a sequential pattern of *F* statistics, for any change occurring at time *t*. Thus, the estimated OLS residuals, $\hat{v}(t)$, from an $m+1$ segmented regression with breakpoint at *t*, are compared to the estimated residuals, $\hat{v}$, from the unsegmented regression model using the following equation:

$$F_t = \frac{\hat{v}^T \hat{v} - \hat{v}(t)^T \hat{v}(t)}{\hat{v}(t)^T \hat{v}(t) / (n-2k)} \quad (7)$$

These sequence of *F* statistics are derived for $t = n_h, ..., n - n_h (n_h \geq k)$; where the trimming parameter $n_h = [nh]$, and h is recommended by the authors to be set at 0.1 or 0.15.

Their second framework is based on a generalized fluctuation tests that are designed to capture fluctuations in the residuals or the parameter estimates, and do not follow a specific pattern of deviation from the null hypothesis. In dating the structural change, Zeileis *et al*., (2003) further employed a dynamic programming approach in finding the breakpoints $\hat{t}_1, ..., \hat{t}_m$ that minimize the residual sum of squares (RSS) in an objective function given by:

$$\left(\hat{t}_1, ..., \hat{t}_m \right) = \arg\min_{(t_1, ..., t_m)} RSS(t_1, ..., t_m) \quad (8)$$

over the partitions $(t_1, ..., t_m)$ with $t_j - t_{j-1} \geq n_h \geq k$, of order $O(n^2)$, for *m* number of changes.

3. Empirical results and discussions

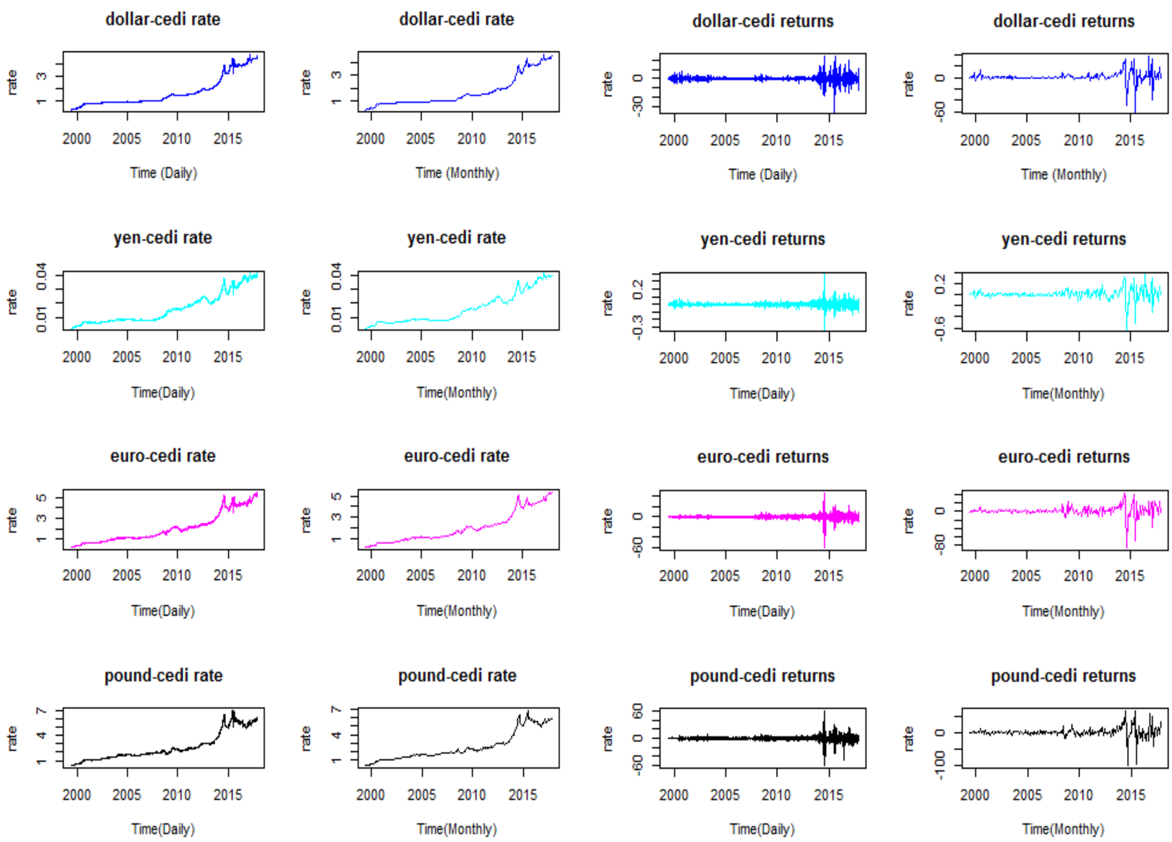
We begin the analysis of the empirical results by displaying and critically examining the time plots of each of the four FX market series. Fig.1 shows plots of daily and monthly observed exchange rate series and that of its corresponding return series. It could be noticed from label *A* of Fig.1 that, all the observed FX market series enjoyed some level of stability prior to the year 2010. However, the post-2010 era exhibits relatively sturdy increasing patterns till somewhere around 2013, and quickly changes to high peaks of movement from the early period of 2014 and beyond. This result designates that Ghana's FX market system may be described by three performance regimes.

First, a stable and well-performed FX market prior to 2010, largely underpinned by the substantial foreign exchange inflows related to the HIPC[3] debt relief, coupled with prudent fiscal and monetary policies; An abstemiously weak performance market between the epoch of 2010 and end of 2013. This seaming sloppy performance of the FX market during this era was largely a reflection of the excessive fiscal and current account deficits related to the implementation of SSSS (in 2010) and election-related expenditures in 2012; The third is a

[3]Heavily indebted Poor Country initiative.

worst-performed FX regime characterising the onset of 2014 and beyond. The latter regime simply marks a free-fall era of the Ghanaian cedi against major foreign trading currencies. Perhaps, this heightened continual depreciation could partially be attributed to the implementation foreign exchange controlled measures by the central bank (Bank of Ghana) on February 2014 to halt the then depreciating cedi. These policy measures garnered general public apprehension, resulting in subsequent withdrawal, but it adversely compounded the weak performance during the period. This assertion is also corroborated in the work of Boako *et al*., (2016).

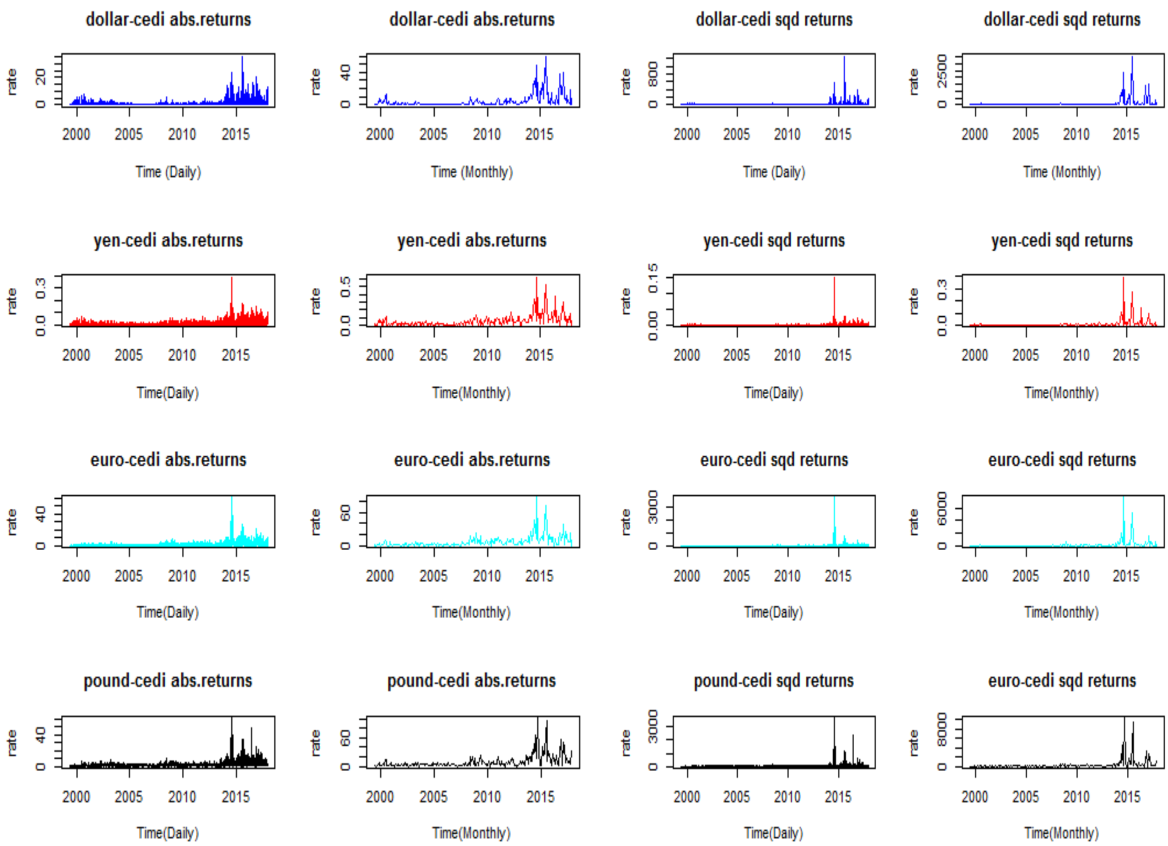
With respect to the return series shown in label *B* of Fig.1, it is visible that the realisations are fairly clustered with few isolated departures, which conspicuously stretches from 2014 onwards. Collectively, this suggests evidence of minimal fluctuations of the market system. However, the few stretches of market fluctuations in the returns are confined to the tail end of the sampled period. This doesn't pose as surprises because the period recording these notable fluctuations corresponds with significant depreciation of the local currency.



(A) observed market series **(B)** market return series

Fig.1: Time plots of observed and return series

Fig.2 displays the nature of volatility clustering patterns which characterise the absolute returns (labelled *A* of Fig.2) and squared returns (label *B* of Fig.2) for the daily and monthly FX market data. As witnessed under the return series, similar observations of smooth clustering over time, prior to 2014 can also be conferred on the volatility returns. Nonetheless, the absolute returns for the FX market series are highly volatile compared to the respective volatility patterns of the squared returns. There is evidence of highly dense clustering in the daily volatilities than could be gleaned from the monthly volatilities. This is much visible for the absolute returns. Generally, the volatility of the exchange rate returns peaked around 2014 onwards where the local currency was reported to have depreciated in large quantum to major foreign trading currencies.



(A) absolute volatility returns **(B)** squared volatility returns

Fig.2: Time plots of unconditional market volatility returns

Summary stylised characteristics of the daily and monthly FX market returns for the sampled period is presented in Table 1. From the table, the average returns are positive for all the exchange rates. Relatively higher daily average returns of 0.121% and 0.107% are recorded respectively for the cedi/pound, and cedi/euro rates, with lower daily average returns for cedi/yen. Similar trend is reported for the monthly returns. With the exception of cedi/yen, all the market returns had standard deviations (sd.) of over 1%. The cedi/pound proofs to be more volatile. Moreover, the monthly market returns with sd. ranging from 0.098% to 16.347% looks to be highly volatile than the 0.023% to 3.963% of the daily returns.

In reference to the return-to-variability ratio, as measured using the Sharpe ratio – SR, we measure the risk/return market trade-offs for investments within the FX market of Ghana. All the exchange rates showed positive SRs, with cedi/dollar recording the highest daily ratio, followed by cedi/yen. For the monthly risk/return ratios, the cedi/dollar and cedi/euro had the highest values. These results depict that investing in the cedi/dollar earns relatively higher market returns with lower risk in the FX market of Ghana. Perhaps, this could account for the de facto dollarization phenomenon in the local market.

Table 1: Summary measures

	Sample moment properties			
	cedi/dollar	cedi/yen	cedi/euro	cedi/pound
Panel A: daily market returns				
mean	0.092	0.001	0.107	0.121
std. deviation	2.307	0.023	3.228	3.963
sharpe-ratio	0.040	0.035	0.033	0.030
kurtosis	34.902	39.132	77.837	62.400
skewness	-0.220	0.752	-0.876	-0.251
JB	239870*	308780*	1207300*	777550*
$Q_r(20)$	346.0*	171.3*	492.2*	324.9*
$Q_{abs}(20)$	12395*	8186.3*	10523*	10579*
$Q_{sqd}(20)$	2898.2*	2138.4*	3621.2*	3518.6*
Panel B: monthly market returns				
mean	1.947	0.017	2.305	2.606
std. deviation	9.053	0.098	12.373	16.347
sharpe-ratio	0.215	0.177	0.186	0.159
kurtosis	16.633	13.248	18.111	14.944
skewness	-1.440	-1.456	-2.215	-1.260
JB	2692.0*	1739.4*	3282.5*	2170.5*
$Q_r(20)$	64.9*	63.2*	47.6*	49.8*
$Q_{abs}(20)$	455.9*	453.9*	412.8*	434.0*
$Q_{sqd}(20)$	128.9*	103.2*	80.6*	1235*

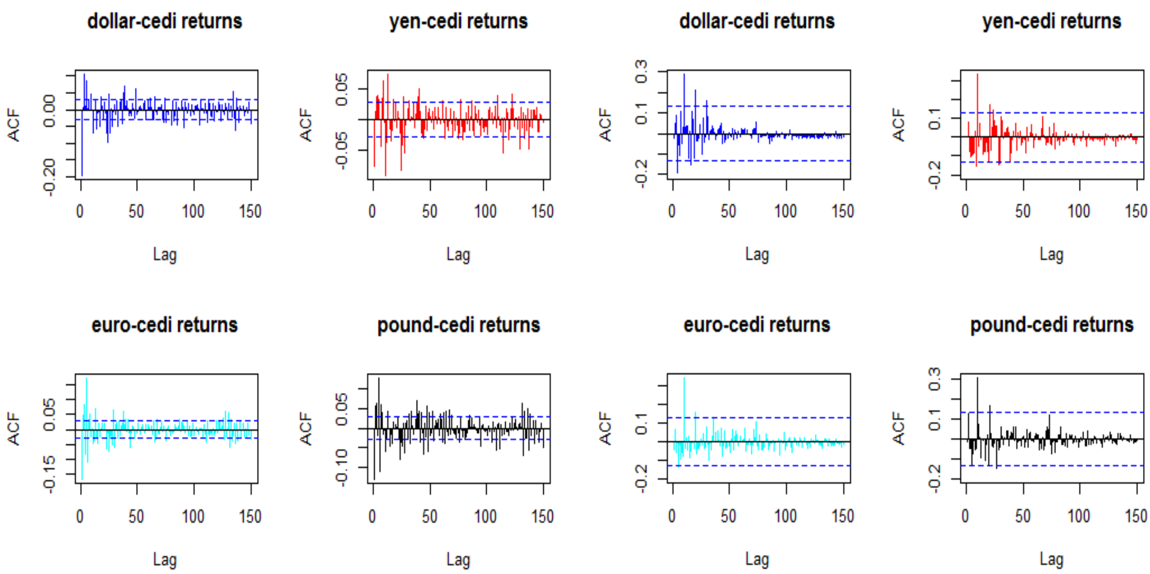
JB is the test statistic for the Jarque–Bera normality test; $Q_r(k)$, $Q_{abs}(k)$ and $Q_{sqd}(k)$ denote the Box-Ljung portmanteau test statistic based on 20-squared autocorrelations; "*" represent significance level at 1%.

From the distributional measures in Table 1, only the daily cedi/yen shows positive skewness. Negatively skewed distributions with sharp and very high peaks characterises the entire market system. Based on these measures (skewness and kurtosis), we could infer a substantial deviation from normality for the exchange rate series. This is also affirmed by the highly significant normality test results from the Jarque-Bera method. As shown by the significant Box-Ljung test measures, there is strong evidence in support of the presence of serial correlation in the returns and its volatilities for the FX market series.

3.1 Correlogram analysis

Fig. 3 graphically presents the autocorrelation behaviour of the exchange rate returns for the first 150 trading market days. Plots of respective autocorrelation coefficients against time lags, known as correlograms are shown in the figure. The blue short-dash lines in the figure represent statistical significance based on critical values at the 95% confidence band. Labels *A* and *B* of Fig. 3 respectively show the daily and monthly correlograms for the returns.

From the figure, almost all the estimated sample autocorrelations for the monthly returns are visibly found within the 95% confidence band. The autocorrelation coefficients spike high for the few beginning lags, but diminish quickly, by getting very closer to zero, and remain generally insignificant throughout the time lags. These properties of the monthly return series do conform to a series which follows a white noise process. Meaning, the returns are much likely to conform to the weak form of the efficient market hypothesis (EMH), where speculative gains cannot be achieved. Similar conclusions could be made for the daily returns, which show few isolated coefficients departing from the confidence bands. Nonetheless, the diminishing rate for the monthly returns are faster, mostly insignificant, and nearer to zero than the daily returns, which also exhibit statistical insignificance for most of its coefficients, but do not get nearer to zero.



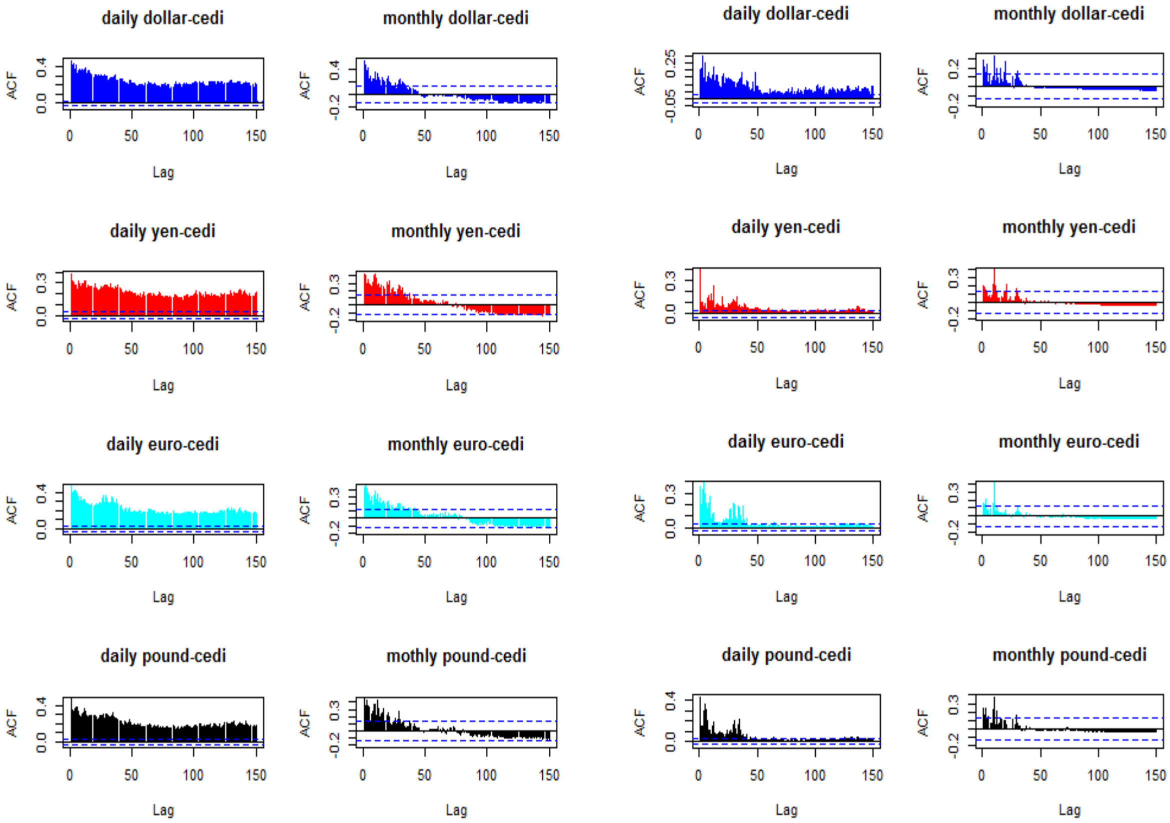
(A) daily market returns **(B)** monthly market returns

Fig.3: Correlograms of exchange rate market returns

Furthermore, we examine the dynamic nature of the autocorrelation structure for the FX market using the unconditional volatility returns. Correlograms for the absolute and squared volatility returns are displayed in Labels *A* and *B* of Fig. 4 respectively. Comparable to the squared returns, the evidence of LM or volatility persistence looks more pronounced in the absolute returns. For instance, the substantially significant autocorrelation coefficients diminish hyperbolically across the trading days for the absolute returns, but the decay rate for the squared returns looks relatively quicker.

The evidence of hyperbolic decay manifest strongly in the daily volatilities. This is much noticeable from the daily absolute returns and the squared returns for cedi/dollar, at which the autocorrelation coefficients remain significant throughout the time lags.

Generally, we could then infer from the correlogram analysis that the evidence of volatility persistence in the FX market of Ghana is more apparent in the absolute returns, and in daily periodicity. The visibly high persistence in daily periodicity (high frequency data) than seen in the monthly frequency corroborates the findings of Caporale and Gil-Alana (2013).



(A) absolute market returns **(B)** squared market returns

Fig.4: Correlograms of exchange rate unconditional volatility returns

From the collective correlogram analysis, three conclusions could be drawn: (1) visible absence of LM and its implication of market efficiency (weak form) in the entire FX market returns is noticed; (2) there exists evidence of volatility persistence in the unconditional volatility returns, which is more pronounced in the absolute returns; and (3) comparatively slower hyperbolic decays in daily periodicities for the volatility returns is recorded. This latter finding signifies the detection of momentous LM properties in a relatively higher frequency data than could be observed at the lower frequency. Nonetheless, we additionally support these initial findings with rigorous statistical methods to authenticate the claims from the correlogram analysis.

3.2 Test for stationarity

To examine whether the sampled exchange rate data follows a fractionally integrated term, the stationarity test of Kwiatkowski, Phillips, Schmidt, and Shin (1992) is employed. A test for short-memory ($d = 0$), or $I(0)$ against $I(d)$, where d could be a fractional term which gives LM alternatives has been undertaken with the KPSS test method[4]. This method possesses detection

[4]The LM test statistic for the KPSS method is computed as: $KPSS(q) = \frac{1}{n^2 \hat{\sigma}^2(q)} \sum_{k=1}^{n} S_k^2$

powers for short-memory properties as against alternatives of LM, and is equivalent to that of Lo's statistic (Lee and Schmidt, 1996). The null hypothesis of stationarity or *I*(0) is not accepted if the LM test statistic becomes greater than its corresponding critical values.

Table 2: Stationarity test for exchange rate market series

	KPSS test statistic			
	cedi/dollar	cedi/yen	cedi/euro	cedi/pound
	Panel A: daily market data			
returns				
const	0.3911*	0.1777*	0.2167*	0.1440*
const + trend	0.0594*	0.0232*	0.0290*	0.0436*
abs. returns				
const	4.5661	7.2131	6.1524	5.6854
const + trend	1.2946	1.2592	0.5891	0.7507
sqd. returns				
const	2.9360	2.6496	1.3419	1.6576
const + trend	0.5810	0.3928	0.1738	0.2313
	Panel B: monthly market data			
returns				
const	0.4680	0.2897*	0.3439*	0.1769*
const + trend	0.0897*	0.0443*	0.0523*	0.0549*
abs. returns				
const	0.8476	1.0716	1.0419	0.9294
const + trend	0.2055	0.1863	0.1188*	0.1519
sqd. returns				
const	0.7062	0.7346	0.6314	0.6512
const + trend	0.1684	0.1393*	0.1014*	0.1238*

'*'5% (0.463) denote statistical significance and its associated critical value for the constant term of the test.
'*'5% (0.146) denote statistical significance and its associated critical values for the constant and trend terms.

From the results shown in Table 2, almost all the market returns, except the monthly cedi/dollar at its intercept level followed *I*(0) processes, signifying a well-behaved FX market where speculative shocks or profits will be less likely to be recorded. This is in line with the correlograms which found no visible traces of *I*(*d*) or LM alternatives in the market returns. For the daily volatility returns, the evidence unanimously favours *I*(*d*) or long-memory processes, since none of the test statistics shows statistical significance. Moreover, substantive evidence of insignificance in the monthly periodicity is also recorded for the volatility returns. Thus, the evidence is lopsided towards LM alternatives, *I*(*d*), rather than short-memory, *I*(0), for the volatility returns; and looks very stronger in the absolute returns. These findings also affirm the concluding deductions made with the correlograms in the previous subsection.

Although, the KPSS test and the correlograms are consistent in their collective findings for the FX market, we still advance our search to seek robust conclusive evidence using the GPH semi-parametric and ARFIMA-FIGARCH approaches.

3.3 Long-memory test results and analysis

Empirical test results of the GPH and the modified Smith's GPH (*m*GPH) methods are presented for the FX market data using plug-in bandwidth selection approach, instead of the arbitrary choice for the bandwidth. However, mindful of the GPH estimator being more sensitive to regime shift effects, we check for unknown multiple breaks in the full sampled return series for each of the four exchange rate data.

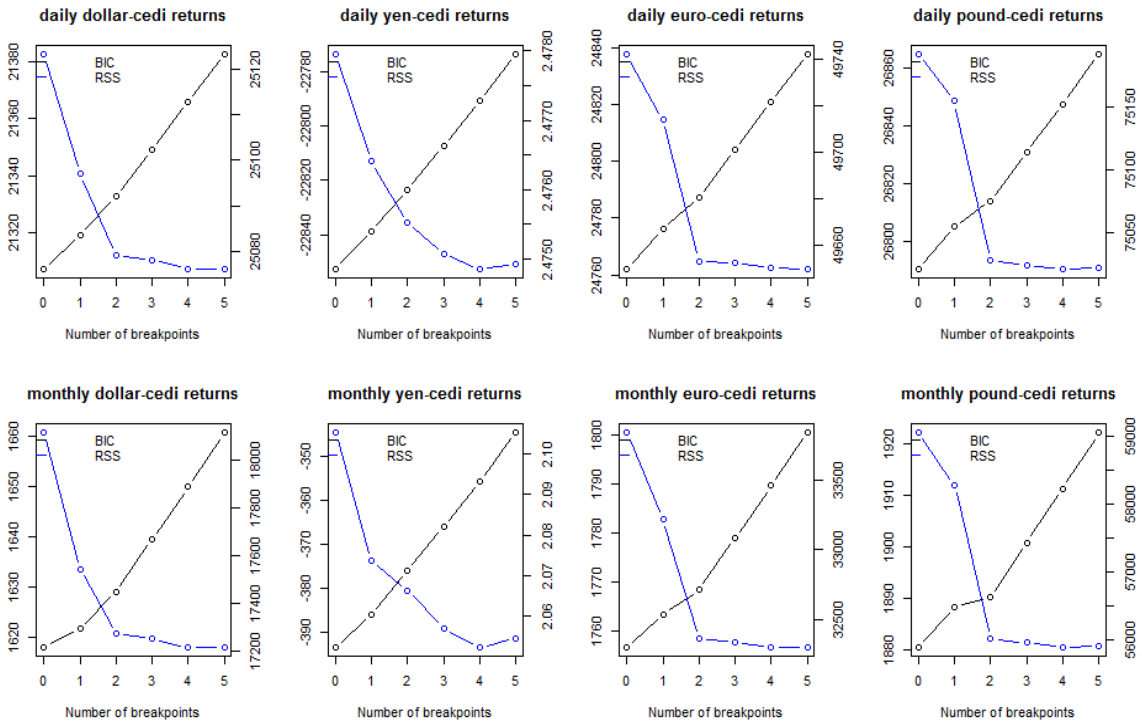


Fig.5: Detection of breaks in daily and monthly exchange rate returns with BIC

Table 3: Multiple structural breakpoints

		BIC measures				
	$m = 0$	$m = 1$	$m = 2$	$m = 3$	$m = 4$	$m = 5$
Panel A: daily returns						
cedi/dollar	***21307***	21319	21333	21349	21366	21383
cedi/yen	***-22852.7***	-22838.7	-22823.5	-22807.4	-22790.9	-22773.8
cedi/euro	***24762***	24776	24787	24804	24821	24838
cedi/pound	***26790***	26805	26814	26831	26847	26864
Panel B: monthly returns						
cedi/dollar	***1618***	1622	1629	1640	1650	1661
cedi/yen	***-393.3***	-385.9	-375.8	-366.1	-355.8	-344.7
cedi/euro	***1757***	1763	1768	1779	1790	1800
cedi/euro	***1880***	1888	1890	1901	1911	1922

"*m*" represents optimal number of detected multiple structural breakpoint(s) with the BIC measure

From Fig. 5 and Table 3, all the return series exhibit noticeable traces of single regimes (no breaks) in their respective time variations. Interestingly, the Bayesian Information Criterion (BIC) unanimously favours a break-free data structure for the daily and monthly FX market returns. Perhaps, this common stochastic property could signify a co-movement relation between the markets. However, in all cases, the RSS contradicts the BIC, but the latter's result is upheld because it has been reported as suitable competitive selection procedure for many "real" data applications (see, Bai and Perron, 2003; Zeileis *et al*., 2003, etc.).

With the absence of apparent structural breaks, we fail to split-up or disaggregate the series into switching regimes (subsample regimes), but rather choose to use the full-break-free sampled data for further analysis.

Table 4: Semiparametric test estimates for daily FX market data

	GPH *Plug-in*	*m*GPH *Plug-in*	GPH *Plug-in*	*m*GPH *Plug-in*
	cedi/dollar		***cedi/euro***	
r_t	0.136 [4.12]	0.041 [0.83]	0.058 [1.76]	-0.006 [-0.11]
$\|r_t\|$	0.374 [11.31]	0.502 [10.04]	0.412 [12.54]	0.522 [10.48]
r_t^2	0.259 [7.84]	0.344 [6.88]	0.480 [14.61]	0.406 [8.16]
	cedi/yen		***cedi/pound***	
r_t	0.037 [1.15]	-0.016 [-0.33]	0.046 [1.397]	-0.036 [-0.72]
$\|r_t\|$	0.286 [8.76]	0.454 [9.18]	0.379 [11.54]	0.586 [11.80]
r_t^2	0.235 [7.20]	0.397 [8.03]	0.442 [13.45]	0.570 [11.67]

Table 5: Semiparametric test estimates for monthly FX market data

	GPH *Plug-in*	*m*GPH *Plug-in*	GPH *Plug-in*	*m*GPH *Plug-in*
	cedi/dollar		***cedi/euro***	
r_t	0.537 [1.06]	-0.032 [-0.02]	-0.115 [-0.265]	0.462 [0.43]
$\|r_t\|$	0.534 [4.08]	0.626 [2.92]	0.574 [2.49]	0.455 [1.04]
r_t^2	0.409 [3.12]	0.474 [2.21]	0.509 [0.83]	0.390 [0.20]
	cedi/yen		***cedi/pound***	
r_t	-0.115 [-0.88]	-0.399 [-1.86]	-0.213 [-0.42]	-1.311 [-0.95]
$\|r_t\|$	0.412 [3.14]	0.549 [2.57]	0.902 [3.09]	1.256 [2.05]
r_t^2	0.741 [3.22]	0.892 [2.03]	0.595 [1.55]	0.693 [0.77]

The Tables (4 & 5) give estimated results of the GPH and its modified version (*m*GPH) for the daily and monthly market data respectively. For *A* [*B*], *A* denotes test statistic of the GPH/*m*GPH, while *B* is the associated *t*-statistic. r_t, $|r_t|$, and r_t^2 respectively represent the unconditional returns and its absolute and squared volatility returns.

The evidence of long-term dependence is clearly absent in the market returns, for the reason being that the estimated $d-values$ are statistically different from zero (see, Tables 4 and 5). Moreover, the only notable significant $d-value=0.136$ is reported by the GPH for the daily cedi/dollar returns. Yet, its corresponding *m*GPH value of 0.041 is far lesser than the GPH value, and looks highly insignificant. Hence, a significant LM or persistence detection is obviously rejected. This therefore suggests that, the FX market returns follows a Wiener process, and also is efficient in the weak form. Meaning, there would be no available spaces for speculative activities to thrive.

This initial finding contradicts the works of Tweneboah *et al*., (2013) and Aidoo *et al*., (2012), but rather affirms the conclusions made by Olufemi *et al*., (2017). The latter found market efficiencies for Ghana's (cedi/US dollar) and Burundi's (Franc/US dollar) unconditional market returns after examining 10 sub-Saharan African markets for efficiency, and accounting for break effects. However, we believe the former's results might have suffered from break effects with its consequences thereof. For instance, Aidoo *et al*., (2012) analysed and pronounced market inefficiency for Ghana's FX market using observed (or actual) cedi/dollar series, but not growth rates, and again failed to examine the sensitivity issue of break effects. In another situation, weak evidence of market inefficiency (cedi/euro) was reached by Cheung *et al*., (2011) as their study found only one of its three detection methods to have conferred inefficiency for the unconditional cedi/euro returns.

Turning our focus to the volatility returns, we report the following results. From Tables 4 and 5, all the daily FX volatility returns recorded significant positive LM parameters which are bounded from 0.286 to 0.586 for the absolute returns, and 0.235 to 0.570 for the squared returns. Except cedi/euro squared returns, the remaining *d*-parameters for the *m*GPH are greater than the associated GPHs. Also, from the perspective of the monthly periodicity, not all $d-values$ had statistical significance. As the absolute returns report of significant $d-values$ ranging from 0.412 to 1.256, the squared returns had its $d-values$ as $0.409 \le d \le 0.892$.

Inferring from the reported *d*-parameters, one could reasonably conclude that, the persistence found in the daily volatility returns is quite sturdier than for the monthly series. Also, compared to the squared returns, the absolute returns persist much strongly, as evident through its reported high-valued *t*-statistics. With respective $d-values$ from 0.235 to 0.586, and 0.409 to 1.256 for the daily and monthly volatility returns, it is fair to confer a somehow stationary and more likely mean-reverting stochastic process for the daily periodicity. There again, the significantly high $d-value$ of 1.256, suggest that volatility shocks to the cedi/pound would be non-mean reverting and has the tendency to leave traces of permanent effects.

3.4 ARFIMA-FIGARCH results and analysis

Results in Tables 6 and 7 give the estimated parameters of the ARFIMA-FIGARCH class of models. The Schwarz measure is used as our benchmark for selecting appropriate parsimonious fit. From the tables, significantly strong evidence of long-range dependence is found only for the cedi/dollar market returns. Moreover, the nature of range-dependence swings between mean-reverting persistence $(d_m = 0.2410)$ for the daily returns, and more likely long-run mean-reverting anti-persistence $(d_m = -0.8443)$ for the monthly returns. In both cases, shocks to the market would be transitory, but quicker reversions would be experienced in the daily returns. The evidence of LM properties could however not be found in the daily and monthly market returns of cedi/yen, cedi/euro and cedi/pound. With the exception of the cedi/dollar market returns, the results of the correlograms, KPSS LM test and the semi-parametric methods are much consistent with the ARFIMA-FIGARCH models.

Table 6: ARFIMA-FIGARCH estimates for daily FX data

	Parameters			
	cedi/dollar	cedi/yen	cedi/euro	cedi/pound
Cst(M)	0.0286	0.0003	0.0580*	0.0798*
d-Arfima	0.2410*	0.0413	0.0334	0.0477
AR(1)	- - - - -	- - - - -	0.2602**	0.2122**
MA(1)	-0.6607*	-0.2746*	-0.4166*	-0.4120*
Cst(V)	0.0172**	0.1695*	0.0082*	0.0188*
d-Figarch	0.3857*	0.2805*	1.0503*	1.0139*
ARCH(Phi 1)	- - - - -	-0.1353*	-0.0023	0.0285
Garch(Beta 1)	0.1783*	- - - - -	0.9193*	0.9141*
Schwarz	2.5572	-5.6706	3.6434	4.2016
Q(10)	7.9588	8.7307	11.2673	3.3134
ARCH(10)	0.7906	0.8910	1.1011	0.3486

Table 7: ARFIMA-FIGARCH estimates for monthly FX data

	Parameters			
	cedi/dollar	cedi/yen	cedi/euro	cedi/pound
Cst(M)	0.8057*	0.0053**	1.1956*	1.3632*
d-Arfima	-0.8443*	0.0352	-0.0433	-0.0519
AR(1)	0.9428*	-0.9907*	-0.6914*	- - - - -
MA(1)	0.1335	0.9937*	0.7011*	- - - - -
Cst(V)	-0.2236	0.1486**	4.9373	4.6709
d-Figarch	0.7793*	1.5248*	0.8427*	0.7671*
ARCH(Phi 1)	- - - - -	-0.2736	-0.5349***	-0.3500
Garch(Beta 1)	0.1867***	0.9623*	0.0059	0.1124
Schwarz	5.5550	-2.8001	6.8206	7.3061
Q(10)	2.4334	4.3734	0.4034	6.8244
ARCH(10)	0.2207	0.4047	0.7548	0.6462

Tables 6 & 7 report estimates from the ARFIMA-FIGARCH models for the daily and monthly exchange rate data respectively. Empirical statistics for conditional heteroscedasticity and Ljung-Box tests for serial correlation are respectively represented by ARCH(k) and Q(k). In all our results, the nonnegativity constraints for the FIGARCH (p_v, d_v, q_v) component of the models are strictly adhered.

*1% significance level;

**5% significance level;

***10% significance level.

For the conditional volatilities, all the exchange rate market series recorded highly significant positive $d_v - values$, signifying the presence of volatility persistence in the entire market system. The estimated value of d_v is bounded from 0.2805 to 1.0503 for the daily market series; and 0.7671 to 1.5248 for the monthly series. The respective $d_v - values$ of 0.3857 and 0.2805 for cedi/dollar and cedi/yen daily volatility returns suggest that the volatility processes are stationary and mean-reverting. However, the large significant $d_v - values$ (0.7793 and 1.5248) for the monthly data of the same latter variables indicate evidence of persistence, engulfed with apparent nonstationarity.

Nonetheless, the discrepancies of the LM dynamics in the cedi/euro and cedi/pound volatility returns of the two data frequencies (daily and monthly) are not much widened. As the daily volatility returns recorded respective $d_v - values$ of 1.0503 and 1.0139, values of 0.8427 and 0.7671 are shown for the monthly returns. In the latter situation, we conclude by favouring volatility processes that follow non-stationary and long-term mean-reversion, whereas lack of stationarity and non-mean reversion characterises the daily returns.

3.5 Brief highlights of all results

In summing up, we provide highlights from the results. Relatively higher returns with associated lower risk bearing are expected from investments in the cedi/dollar market. Also, the most volatile exchange rate market was found in the cedi/pound market returns. These characteristics of the markets could perhaps explain the explosive use of the US dollar currency for several transactions within the local Ghanaian market.

From the unconditional returns, it was realised that all the FX market series exhibited properties which conform with asset returns that follow a Wiener process (random Brownian motion). Thus, the markets favourably respond to the efficient market hypothesis, and hence, leave no spaces for speculative trading strategies. This conclusion was reached with the use of the KPSS LM test, correlograms, and the semi-parametric methods. That notwithstanding, the ARFIMA-FIGARCH approach contradicts this earlier pronouncement, and rather found market inefficiency in the conditional returns for only the cedi/dollar market. It shows respective evidence of persistence $(d_m = 0.2410)$ and anti-persistence $(d_m = -0.8443)$ for conditional returns of the daily and monthly cedi/dollar market data.

Interestingly, almost all the four methods found conspicuous evidence of varying significant volatility persistence, and non-stationary long-run mean-reverting processes across the volatility returns. The evidence is consistent for the conditional and unconditional volatility returns; and same could be concluded for the conditional $(0.2805 \leq d_v \leq 1.5248)$ and unconditional $(0.235 \leq d_v \leq 1.256)$ volatility returns. Hence, in modelling and/or forecasting Ghana's FX market, the above-mentioned dynamics should be well-captured. There again, it is important to mention that there are no breaks in all four market returns, perhaps, signifying possible stochastic co-variations (or co-movements), which needs further investigations. The lack of breaks in the series suggests to us that, the reported results are free from structural break effects, and could not suffer from spuriousness.

Holistically, the above results suggest the following. In its entirety, Ghana's FX market cannot be pronounced as inefficient; rather, the efficiency of the market looks distinctive across currency pairs. It is also evidential that speculative manipulations have no significant space to operate in three of the markets. Such manipulations or gains could only be witnessed in the cedi/dollar market. This therefore means, shocks to the market system could not necessarily be driven by speculative activities or manipulative trading strategies.

4. Concluding remarks and policy implications

This paper examines and provides empirical evidence of long-memory behaviour for Ghana's FX market returns and volatilities, using daily and monthly data frequencies of the commonly traded foreign currencies (United State dollars, euro, United Kingdom pound, and Japanese yen), as exchanged into varying quantities of the local Ghanaian cedi at respective prevailing rates. We examine for efficiency (weak form) behaviour of the market using a battery of different rigorous approaches: (1) through the use of sample correlograms; (2) using a Kwiatkowski, Phillips, Smidth and Shin (KPSS) test of $I(0)$ against a fractionally integrated term or LM alternatives of $I(d)$; (3) the use of Geweke and Porter-Hudak (1983)'s GPH test, and its modified version by Smith (2005); and (4) a dual LM detection approach from ARFIMA-FIGARCH class models – by accounting for unknown multiple breaks.

Our findings reveal interesting behaviour for the FX market. Three of the four markets show efficiencies, from which market traders or speculators cannot gain excessive profit using manipulative trading strategies. Market inefficiency was found only for the cedi/dollar market. Yet, the evidence toggles from a relatively quicker mean-reversion persistence – for daily returns, to long-run mean-reversion anti-persistence – for monthly returns. It should also be noted that such evidence was only present in the conditional returns, but got missing in the unconditional returns. Hence, such data dynamics should be considered when making holistic conclusions on market efficiency or otherwise. Also, we report of varying volatility persistence in all the market series, which are strongly observed in the daily periodicity, and for the conditional volatility returns. Our analysis of the market series is free from structural break effects.

These findings provide the risk-averse investor with an informed basis in making investment decisions over the market. Also, policy makers might base on the findings and its implications to strengthen or adopt varied exchange rate control systems, especially to target and reduce the dollarization syndrome in the local market. In modelling and/or forecasting the volatility returns of these exchange rates, the varying persistence nature of the market series needs to be duly accounted for. Additionally, since no or lesser chance exists for speculative gains or manipulations, like Alagidede and Muazu (2016), we recommend further studies to investigate what account for the three-quarters self-driven shocks to Ghana's FX market, as claimed by the former study.

References

Aidoo, E.N., Bashiru, I.I.S., Ababio, K.A., Nsowah-Nuamah, N.N.N., Munyakazi L., (2012). Analysis of Long Memory Dynamics in Exchange Rate. *The Empirical Economics Letters*, 11, 745-754.

Alagidede, P., Muazu, I., (2016). On the causes and effects of exchange rate volatility and economic growth: Evidence from Ghana. *International Growth Center Working Paper*, 1-29.

Arouri, M.E.H., Hammoudeh, S., Lahiani, A., Nguyen, D.K., (2012). Long memory and structural breaks in modelling the return and volatility dynamics of precious metals. *Quarterly Review of Economics and Finance,* 52 (2), 207-218.

Assaf, A., (2007). Fractional integration in the equity markets of MENA region, *Applied Financial Economics*, 17 (9), 709-723, DOI: 10.1080/09603100600735310.

Bawumia, M., (2014). Restoring the value of the cedi. *Distinguished Speaker Series Lecture-Central University College, Ghana*. March 25, 2014.

Bai, J., Perron, P., (2003). Computation and analysis of multiple structural change models. *Journal of Applied Econometrics*, 18(1), 1-22. DOI: 10.1002/jae.659.

Baillie, R. T., Bollerslev, T., Mikkelsen, H.O., (1996). Fractionally integrated generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, 74(1), 3-30.

Boako, G., Omane-Adjepong, M., Frimpong, J.M., (2016). Stock returns and exchange rate nexus in Ghana: A Bayesian quantile regression approach. *South Africa Journal of Economics*, 84, 149-179. DOI: 10.1111/saje.12096.

Caporale, G.M., Gil-Alana, L.A., (2013). Long memory and fractional integration in high frequency data on the US Dollar/British Pound spot exchange rate. Discussion Papers of DIW Berlin, No. 1294. http://ssrn.com/abstract=2264175.

Caporale, G.M., Gil-Alana, L., and Plastun, A., (2017). Long Memory and Data Frequency in Financial Markets. Discussion Papers of DIW Berlin, No. 1647. http://ssrn.com/abstract=2264175.

Carlson, J.A., Osler, C.L., (2000). Rational speculators and exchange rate volatility. *European Economic Review*, 44, 231-253.

Cheung, A.W.K., Su, J.J., Choo., A.K., (2011). Are Euro exchange rates markets efficient? New evidence from a large panel. Griffith Business School Discussion Papers/Finance, No. 2011-09.

Floros, C., (2008). Long memory in exchange rates: international evidence. The International *Journal of Business and Finance Research*, 2(1), 31-39.

Geweke, J., Porter-Hudak, S., (1983). The estimation and application of long memory time series models. *Journal of Time Series Analysis*, 4, 221-238.

Gil-Alana, L.A., Chang, S., Balcilar, M., Aye, G.C., Gupta, R., (2015). Persistence of precious metal prices: A fractional integration approach with structural breaks. *Resources Policy*, 44, 57-64.

Granger, C. W. J., Hyung, N., (2004). Occasional structural breaks and long memory with an application to the S&P 500 absolute stock returns. *Journal of Empirical Finance*, 11, 399-421.

Jammazi, R., Chaker, A., (2013). Cyclical components and dual long memory in the foreign exchange rate dynamics: The Tunisian case. *Journal of Economic and Financial Modelling*, 1 (2), 13-29.

Kang, S.H., Mclver, R., Park, S.Y., Seong-Min Yoon, S.M., (2014). Long memory features evolve in the time-varying process in Asia-Pacific foreign exchange markets. *Procedia Economics and Finance*, 14, 286-294. DOI: 10.1016/S2212-5671(14)00714-X.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin,Y., (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*, 54, 159-178.

Lee, D., Schmidt, P., (1996). On the power of the KPSS test of stationarity against fractionally-integrated alternatives. *Journal of Econometrics*, 73, 285-302.

Oh, G., Eom, C., Havlin, S., Jung, W.S., Wang, F., Stanley, H.E., Kim, S., (2012). A multifractal analysis of Asian foreign exchange markets. *European Phys. Journal B*., 85: 214, 1-6. DOI: 10.1140/epjb/e2012-20570-0.

Oh, G., Kim., S., (2006). Market efficiency in foreign exchange markets. http://arXiv.org/abs /physics/0608016v2.

Olufemi, A.P., Adewale, A.O, Oseko, M.S., (2017). Efficiency of foreign exchange markets in sub-Saharan Africa in the presence of structural break: A linear and non-linear testing approach. *Journal of Economics and Behavioral Studies*, 9(4), 122-131.

Omane-Adjepong, M., Boako, G., (2017). Long-range dependence in returns and volatility of global gold market amid financial crises. Physica A: Statistical Mechanics and its Applications, 472, 188-202. http://dx.doi.org/10.1016/j.physa.2016.12.013.

Osler, C.L, (1995). Short-term speculators and the origins of near-random-walk exchange rate behaviour. Staff reports: Federal Reserve Bank of New York, Number 3.

Salisu, A.A, Ayinde, T.O., (2016). Testing the Martingale Difference Hypothesis (MDH) with structural breaks: Evidence from foreign exchanges of Nigeria and South Africa. *Journal of African Business*, 17(3), 342-359. DOI: 10.1080/15228916.2016.1183274.

Smith, A (2005). Level shifts and the illusion of long memory in Economic Time Series. *J. Bus. Econom. Statist*. 23(3), 321–335. http://dx.doi.org/10.1198/073500104000000 280.

Soenen, L.A., (1979). Efficient market implications for foreign exchange exposure management. *De Economist,* 127(2), 330–339.

Tweneboah, G., (2015). Financial dollarization and exchange rate volatility in Ghana. *Ghana Journal of Economics*, 3, 28-44.

Tweneboah, G., Amanfo, A.N., Kumah, S.P., (2013). Evidence of market inefficiency and exchange rate predictability in Ghana. *Ghanaian Journal of Economics*, 1, 52-66.

Uludag, B.K., Lkhamazhapov, Z., (2014). Long memory and structural breaks in the returns and volatility of gold: Evidence from Turkey. *Applied Economics*, 46:31, 3777-3787. DOI: 10.1080/00036846.2014.929627.

Zeileis, A., Kleiber, C., Kramer, W., Hornik, K., (2003). Testing and dating of structural changes in practice. *Computational Statistics and Data Analysis*, 44, 109-123.