UNIVERSITY OF CAPE COAST

EXCHANGE RATE BEHAVIOUR IN GHANA

LORETTA AKU YAYRA ATEPOR

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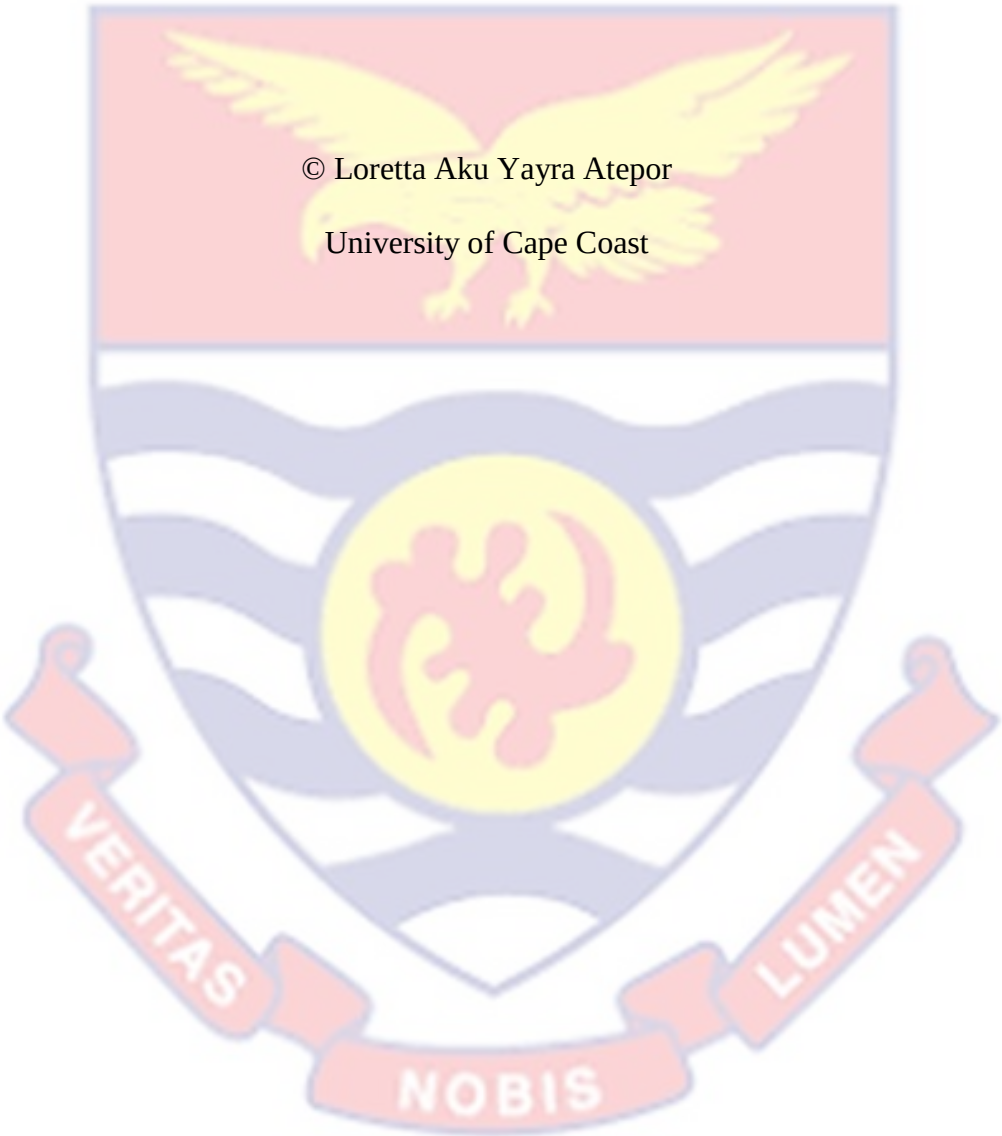

UNIVERSITY OF CAPE COAST

EXCHANGE RATE BEHAVIOUR IN GHANA

BY

LORETTA AKU YAYRA ATEPOR

Thesis submitted to the Department of Finance of the School of Business, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfilment of the requirement for the award of Master of Commerce Degree in Finance

DECEMBER 2021

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature …… Date ……..

Name: Loretta Aku Yayra Atepor

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature …… Date ……..

Name: Prof. Anokye Mohammed Adam

ABSTRACT

Exchange rate is a key economic variable all around the world due to its multi-faceted nature and its effect on the lives of every individual in many ways. However, the non-linear and the non-stationary characteristics of exchange rates make them difficult to understand their dynamics as well as factors that drive exchange rates. Therefore, the behaviour of the GHS/USD exchange rate from 2000 to 2019 was examined in this research work. The study adopted the heterogeneous market hypothesis (HMH) to explain the intrinsic characteristics of the GHS/USD exchange rate. To achieve the objectives of the study, the ensemble empirical mode decomposition (EEMD) technique was employed to determine the factors influencing the GHS/USD exchange rate. Using the EEMD, the GHS/USD exchange rate was decomposed into intrinsic mode functions (IMFs) and a residue. Secondly, the IMFs and the residue were classified into high-frequency, medium-frequency, low-frequency and trend components. These were then analysed and it was found that the macroeconomic fundamentals were the main drivers of GHS/USD exchange rates. Finally, the rescaled range analysis (R/S analysis) and the autoregressive fractionally integrated moving average (ARFIMA) were used to also investigate and analyse the existence of long memory in GHS/USD exchange rates. It was observed that the GHS/USD exchange rates possessed long memory characteristics. It is, therefore, recommended that policymakers, as well as investors, should closely monitor the movement of the exchange rates and macroeconomic fundamentals when formulating exchange rate policies and adopting investment strategies.

KEYWORDS

Autoregressive fractionally integrated moving average

Denoising

Ensemble empirical mode decomposition

Exchange rate

Long Memory

Macroeconomic fundamental

Rescaled Range Analysis

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DEDICATION

To my parents and siblings

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LIST OF ACRONYMS

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ARFIMA	Autoregressive Fractionally Integrated Moving Average
DFA	Detrended Fluctuation Analysis
EMD	Empirical Mode Decomposition
EEMD	Ensemble Empirical Mode Decomposition
GHS	Ghana Cedi
HMH	Heterogeneous Market Hypothesis
IMFs	Intrinsic Mode Functions
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
LM	Lagrangian Multiplier
PP	Phillips-Perron
USD	United State Dollar
WACB	West African Currency Board.

CHAPTER ONE

INTRODUCTION

Exchange rate is one of the most important economic variables for policymakers due to its pass-through effects. The exchange rate market is known to exhibit intrinsic complexities which are caused by activities of the participants (government, financial institutions, businesses, speculators and long-term investors) of the exchange rate market (Mouton, 2014). These participants have different goals, intentions and different time horizons. In addition to these heterogeneous behaviours of the participants of the exchange rates markets, macroeconomic factors and invisible factors such as speculative behaviour also increase the complexities of the exchange rate behaviour (Datta, 2019; Doganay, 2014; Omane-Adjepong, 2018). Cheong, Cherng and Yap (2016) submit that the combination of these factors creates a unique volatility in the exchange rate market making exchange non-linear, non-stationary and exhibit long-memory. These intrinsic characteristics make it difficult to explain the movement of exchange rates. Therefore, these intrinsic features are the motivation for this study. The study is grounded on the heterogeneous market hypothesis (HMH) theory.

Background to the Study

The exchange rate is among the most important economic fundamental variables in the world because of its unique and complex nature as well as its effect on the lives of every individual in many ways. Exchange rate is simply the price at which one currency can be exchanged for another. The exchange rate is important in personal investment, government economic policies, corporate financial decision making and international trade and commerce.

Because of the importance of exchange rate in the world's economy, the movements of exchange rates need more attention; but its non-linear and non-stationary nature makes them difficult to understand their dynamics as well as determine factors that drive exchange rate movement. For several years, a significant number of research works have sought to explain the unexpected movements in exchange rates. But there have been inconclusive results on what mainly drive exchange rate movements. Some previous studies concluded that exchange rate movements are caused by some fundamental factors such as interest rate, money supply, inflation, real GDP, total external debt, FDI flow, government expenditure etc. (Agyemang-Adjei, 2019; Alagidede & Ibrahim, 2017; Arko, 2016).

The exchange rate of Ghana is a notable example for a study of exchange rate behaviour because the Ghana cedi has been repeatedly viewed among the worst currencies on numerous instances (Owusu Junior, Tweneboah & Adam, 2019) and also it has been difficult to predict the stability of Ghana's exchange rate market for a long period in the current structure of the economy. The frequent depreciation of the cedi, more especially against the dollar and fluctuations in the prices of commodities are critical and worrying issues to the Ghanaian economy and policymakers in general (Bank of Ghana, 2019). The continuous depreciation of the Ghana cedi has created a dwindling degree of confidence together with the increased rate of inflation and unstable macroeconomic fundamentals making Ghana an interesting case for the study. The unprecedented levels of movements in the Ghana cedi are the motivation to undertake this study. The study concentrated on the Ghana cedi/ US dollar exchange rate. This is because, in the economy

of Ghana, transactions in foreign currencies are largely done in the US dollar because the US dollar is the most commonly traded currency in international trade (Sarpong, 2019).

According to Omane-Adjepong, Boako, and Alagidede (2018), most studies attribute the unexpected movement in the exchange rate market to macroeconomic factors (fundamental factors). In the opinion of Datta (2019), a significant portion of the time series exchange rate stays unexplained by the fundamental factors of an economy. Datta (2019) explained that changes in the behaviour of exchange rates are influenced by the combination of macroeconomic factors and the heterogeneous behaviour of market participants in the exchange rate market. Doganay (2014) also stated that exchange rates are associated with complex interactions with the fundamental factors and invisible factors such as speculative behaviour in the exchange rate market.

Among the biggest and most active financial markets in the world is the foreign exchange market. The foreign exchange market is deemed the largest and busiest market because of its large volume of transactions. Mouton (2014) explained that there are a lot of market participants in the exchange rate market. These market participants include the government, financial institutions, businesses, intra-day traders (speculators) and long term investors. Each participant operates with distinct goals, intentions and different time horizons. According to Muller et al. (1993), the market participants of a market may differ in their perception of the market, interests, time horizon, degree of disclosure of information, risk profiles, constraints, motivations of investing or trading as well as reaction and response time to

news. Now, these participants in the foreign exchange market interpret the same information or news differently by using different strategies taking into consideration their trading opportunities and preferences.

Similarly, Cheong, Cherng and Yap (2016) submit that the combination of these different strategies has created unique volatility or additive volatility in the market. Therefore, the interactions of these market participants with different motivations influence exchange rate movement and cause exchange rate volatility, thus, making exchange rates non-linear and non-stationary. Due to these characteristics, the movements of the exchange rate become difficult to explain. These intrinsic complexities of the exchange rates are the motivation to study the exchange rate behaviour. According to Cheong, Cherng and Yap (2016), a financial market is made up of market participants with numerous investment strategies ranging from short term duration to long term duration. They stated that the combination of all the different duration volatilities has created long memory in the financial markets. Long memory property is another important aspect of exchange rate behaviour. A number of observations exhibit long memory behaviour when the values of the observations are correlated among themselves or when they show significant autocorrelation among observations at long lag length.

Based on the efficient market hypothesis, the behaviour of exchange rates should follow the martingale process (Malkiel & Fama, 1970). Hence future exchange rates cannot be predicted using past exchange rate data or available information to the public. This theory has been affirmed by some research works by (Chiang, Lee, Su & Tzou, 2010; Chortareas, Jiang & Nankervis, 2011; Nakamura and Small, 2007; Uthayakumar & Prabha, 2012).

Some studies by (Aidoo, Saeed, Ababio, Nsowah-Nuamah & Louis, 2012; Cheung, 1993; Cheung & Lai, 2001; Gil-Alana, 2000; Han, 2005; Souza, Shittu & Yaya, 2009; Tabak & Cajueiro, 2007) have also hypothesized that exchange rates possess long memory behaviour. In other words, future exchange rates can be predicted using their past information or available information to the public.

Understanding the long memory properties of exchange rates will assist policymakers in formulating appropriate monetary policies in Ghana. Hence, this study also considered the long memory behaviour of the GHS/USD exchange rates. The study employed two long memory techniques (for robustness purposes); the rescaled range analysis (R/S analysis) and the autoregressive fractionally integrated moving average (ARFIMA) to determine whether the exchange rates in Ghana have long memory behaviour or not.

Exchange rates are deemed to be highly non-linear and non-stationary. These exchange rate features contain valuable information which is unobservable or invisible; thus making the movement of the exchange rate volatile. When these hidden characteristics are revealed, it will help in the determination of the actual factors that drive exchange rates. These invisible or hidden features associated with exchange rates can be unravelled by a data analysis technique called the empirical mode decomposition (EMD) which Huang et al. (1998) introduced. The presence of mode mixing after decomposition is a major limitation of EMD. To alleviate this mode mixing problem, Wu and Huang (2009) introduced the ensemble empirical mode decomposition (EEMD). Therefore, this research study applied the EEMD to

the exchange rates in Ghana to help reveal the main characteristics and drivers of the exchange rates in Ghana.

The theory underpinning this study is the heterogeneous market hypothesis (HMH). The HMH, introduced by Muller et al. (1993) suggested that a financial market is made up of non-homogeneous participants in the market. The HMH states that the heterogeneous market participants interpret similar news or information differently taking into consideration their investment opportunities and preferences. As stated by Muller et al. (1993), the participants of a market may differ from their perception of the market, time horizon, interest, risk profiles, motivation for trading and reaction to news. Thus, this study focuses on the variety of time scales of market participants in the exchange rate market.

The time scales of investments according to Cheong (2013) can be categorized into the short-term horizon, medium-term horizon and long-term horizon. Muller et al. (1997) claimed that short-term market participants assessed the market more frequently and have a shorter memory than long-term market participants. Consistent with the HMH, the short-term durations are assumed to correspond with speculative activity (Tittle, 2008). According to Donati and Donati (2008), the medium-term duration is consistent with the business cycle of an economy. However, longer durations are associated with the investment activities of large organisations and are influenced by economic fundamental strategies (Lynch & Zumback, 2003). Based on these evidences, this study decomposed the exchange rate data by using the ensemble empirical mode decomposition (EEMD) technique into intrinsic mode functions (IMFs). These IMFs were then classified into generation

frequencies. These generation frequencies include; high-frequency components which represent the speculative behaviour of market participants, medium-frequency components which represent the business cycles of organisations and low-frequency component which represents the effect of significant events and the trend components.

Exchange rate movements affect the decisions made by the governments, businesses, market participants as well as individuals, thus, making the exchange rate an extremely important economic fundamental. The movement of the exchange rates is extremely important for policymaking, especially in monetary policies. Exchange rate policies help to protect the value of the home currency and to save enough money in the foreign exchange reserve (Nyoni, 2018). Also, Bawumia (2014) posited that the exchange rate is a significant factor when it comes to the pricing of utilities and petroleum products. This indicates that all other factors being equal, if there is depreciation in the exchange rate, prices for utilities and petroleum products will increase as well as all other commodities.

Likewise, exchange rates have been generally agreed upon to play a fundamental role in a country's trade volume and trade performance. The impact of the exchange rate movements on trade performance may either lead to a trade surplus or a trade deficit Amoah (2017). Amoah (2017) made it clear that a trade deficit will create problems for the economy if the government is not able to fund the deficit. Collectively, exchange rate behaviour has a great impact on macroeconomic fundamentals like inflation, interest rates, balance of payment, prices of oil, economic activities or economic growth among others. Exchange rate behaviour directly affects the prices of goods and

services. Given the importance of exchange rate behaviour in an economy, it is necessary to examine the behaviour of exchange rate by determining the primary drivers of exchange rate behaviour.

Statement of the Problem

The behaviour of exchange rates is undeniably important because of the relevant roles it plays in the Ghanaian economy. According to Adu, Karimu and Mensah (2015), the GHS/USD exchange rate has been depreciating consistently from the time when it was liberalized in the 1980s. Adu et al. (2015) mentioned that in the first quarter of 1986, approximately 0.01 cedis could be exchanged for 1 dollar, however, the rate increased to 3.84 cedis per dollar at the end of April 2015, representing a 98.7 percent depreciation during the period.

As reported by Amoah (2017), the instability in the exchange rate market in Ghana just about three (3) years after the redenomination exercise in July 2007, sparked a lot of heated debate because the Ghana cedi lost over 80% of its value. Amoah (2017) claimed that monetary authorities established several actions which were harshly condemned in attempts to resolve the free fall of the Ghana cedi. Some measures put in place included the abolition of the foreign exchange account of Ghanaians as well as the imposition of limits on foreign exchange withdrawals for particular purposes. As a result of the detrimental effects these measures had on the financial system, they were abolished.

The probable cause of the unexpected fluctuations in the exchange rates continues to be the topic of discussion. Amoah (2017) mentions that the unexpected movement in the exchange rate may influence interest rates,

prices, wages, employment opportunities, money supply, investments and/or other macroeconomic variables positively or negatively.

The GHS/USD exchange rate has been depreciating at an abnormally fast rate, thus increasing the cost of living and the cost of doing business in Ghana (Bawumia, 2014). The exchange rate fluctuations have created uncertainty in business (trade) and changes in consumer prices which led to a reduction in trade volumes (Obstfeld & Rogoff, 1998). Arko (2016) noted that managers of financial institutions are particularly interested in the movements of exchange rates because exchange rates affect the value of the assets that are denominated in the foreign currencies stated on the statement of financial position. Also, financial institutions carry out currency transactions for their own accounts and that of their customers. Therefore, instabilities in exchange rates tend to increase the riskiness of their transactions or investments.

Variability in exchange rates especially depreciation in exchange rates leads to a high production cost and this decreases the profits of firms importing goods. In order to reduce the impact of profit reduction, these firms pass on the burden to their consumers in the form of high prices leading to low demand of goods and services, then decrease in production which eventually leads to high-level unemployment. In addition to these, are reductions in exports, accumulation of trade deficits, and deterioration of the balance of payments as well as a decline in the standard living conditions of individuals (Arko, 2016).

The performance of the Ghana Cedi in the exchange rate market has received much attention in the academic and political space for some years. With all the policy interventions, the Ghana cedi continuously depreciate

against the US dollar having suffered a 31.3 percent depreciation against the US dollars in 2014, as well as a 15.7 percent in 2015 (Bank of Ghana Quarter 4 Statistical Bulletin, 2015). This compares with the depreciation rate of 9.66 percent against the US dollar in 2016 (Bank of Ghana Quarter 4 Statistical Bulletin, 2017). The Bank of Ghana Quarter 4 Statistical Bulletin (2017) also revealed that there was 4.88 percent depreciation in the Ghana Cedi in 2017 against the US dollar. The Ghana Cedi recorded an annual depreciation of 8.4 percent against the US dollar in 2018 on the interbank market (Bank of Ghana Quarter 4 Statistical Bulletin, 2018). In 2019, there was an annual depreciation of 12.9 percent against the US dollar (Bank of Ghana First Quarter Statistical Bulletin, 2020).

The exchange rate market is known to exhibit intrinsic complexities resulting from the activities of its participants (government, financial institutions, businesses, intra-day traders (speculators) and long-term investors) (Mouton, 2014). These participants operate with distinct goals, intentions and different time horizons. In addition to these heterogeneous behaviours of exchange rate markets participants, macroeconomic factors and invisible factors such as speculative behaviour also increase the complexities of exchange rate behaviour (Datta, 2019; Doganay, 2014; Omane-Adjepong, Boako & Alagidede, 2018).

Cheong, Cherng and Yap (2016) submit that the combination of these factors creates unique volatility or additive volatility in the market, thus, making exchange rates non-linear, non-stationary and exhibit long-memory. Due to these characteristics, the movement of the exchange rate becomes difficult to explain.

For policy interventions to be effective, the intrinsic characteristics of exchange rates need to be understood (Adam, Kyei, Moyo, Gill & Gyamfi, 2021). These intrinsic complexities could induce nonlinearity, nonstationarity and long-memory, thus, influencing exchange rate modelling (Cheong, Cherng & Yap, 2016). However, existing studies on exchange rate behaviour in Ghana mainly ignore these complexities which could influence the outcome and policy recommendations offered by these existing studies.

These intrinsic complexities of the exchange rates are the motivation to study the exchange rate behaviour. Understanding the behaviour of exchange rates requires an understanding of intrinsic drivers of the observed exchange rate and models which can detect and capture the non-stationary and non-linear features of the exchange rate data. Thus, this study employs EEMD with R/S analysis and ARFIMA to analyse the behaviour of exchange rates in Ghana for the first time.

Purpose of the Study

The primary objective of this study is to examine the behaviour of the GHS/USD exchange rates by identifying the factors influencing the behaviour of the GHS/USD exchange rate in Ghana as well as investigating and analysing the long memory behaviour of the GHS/USD exchange rate.

Research Objectives

The research objectives of the study are;

1. To determine which intrinsic mode functions (IMFs) influence the behaviour of the GHS/USD exchange rate.
2. To determine which generation frequency influences the behaviour of GHS/USD exchange rates.

3. To investigate the presence of long memory behaviour in the GHS/USD exchange rate time series.

Research Hypotheses

In order to address these research objectives, the following research hypotheses were formulated.

1. H0: Intrinsic mode functions (IMFs) do not significantly affect the behaviour of the GHS/USD exchange rates.

   H1: Intrinsic mode functions (IMFs) significantly affect the behaviour of the GHS/USD exchange rates.
2. H0: The generation frequencies do not significantly drive the movements of the GHS/USD exchange rates.

   H1: The generation frequencies significantly drive the movements of the GHS/USD exchange rates.
3. H0: The GHS/USD exchange rates do not significantly possess long memory properties.

   H1: The GHS/USD exchange rates significantly possess long memory properties.

Significance of the Study

Primarily, the work will make contributions to existing studies on exchange rates in Ghana by determining the key factors influencing the behaviour of the GHS/USD exchange rate by employing the ensemble empirical mode decomposition (EEMD) technique. Examining the exchange rate behaviour in Ghana will provide insight and valuable information to policymakers as well as to investors, financial managers of financial institutions and market participants in the exchange rate market to be able to

respond appropriately to the shocks associated with exchange rates movements. The findings of this study will benefit policymakers by helping them know what should be viably done to limit the unexpected movement in exchange rates. They will also know what factors mainly drive fluctuations in currency value and how the behaviour of exchange rates can be estimated and predicted.

Delimitations

The primary focus of this study is only on the behaviour of GHS/USD exchange rates. The reason for considering only the GHS/USD exchange rate is because the US Dollar accounts for approximately 80% of Ghana's foreign transactions; thus, the study was limited to GHS/USD exchange rates. The data used for this study was mainly secondary data which was sourced from Bloomberg Financial Database. Considering the purpose of this research, the research period for this study ranged from 2000 to 2019.

Limitations

The major limitation of the study is that it only focused on the Ghana Cedi/US dollar (GHS/USD) exchange rate. It did not consider other currencies such as the Ghana cedi/ Pound sterling (GHS/GBP), Ghana cedi/ Euro (GHS /EUR), Ghana cedi/Naira (GHS/NGN) etc.

Definition of Terms

The following terms are defined as used within the scope of the study.

Exchange Rate

Exchange rate is simply the price at which one currency can buy another currency. It is the value at which two different currencies can be

exchanged for one another. The exchange rate is a price that determines how much one currency is worth in comparison to another.

Exchange Rate Movement

Exchange rate movements are referred to as the changes that are; the unexpected increases and decreases in the value of one or more currencies. The upward or downward movement of a currency against another currency is referred to as exchange rate movement. Exchange rate movement is measured in this study using the GHS/USD exchange rate.

Long Memory

The correlation structure of a set of observations with long-lag length is described as long memory. A series of observations is said to possess long memory properties when the observed values are correlated with each other or when they show significant autocorrelation among observations widely separated in time.

Denoising

Denoising is referred to as the reduction of the influence of noise in time series data. Denoising is basically the extraction of a signal from a signal-noise mixture. When data is analysed in the presence of noise, it mostly results in misinterpretation of the data. As a result, denoising enables us to focus on the important parts of the time series.

Organisation of the Study

This research consists of five (5) chapters, which include chapter one (introduction), chapter two (literature review), chapter three (research methods), chapter four (results and discussion) and chapter five (summary, conclusion and recommendations). The first chapter is the introduction. It

includes the background of the study, statement of the problem, the purpose of the study, the research objectives, the research hypotheses, significance of the study, delimitation, limitations and finally the organisation of the study. The second chapter focuses on the theoretical framework and the empirical reviews underpinning the study. Chapter three deals with the methods used in the study. It involves the various methods and techniques used in the study as well as details of the data. Chapter four is the results and discussion chapter which considers the presentation, analysis and discussion of results. Finally, chapter five presents the summary, conclusions drawn from the findings of the study, recommendations as well as suggestions for further studies. It gives a detailed summary of the entire study and summarizes the results of the study.

CHAPTER TWO

LITERATURE REVIEW

Introduction

Chapter two provides an overview of previous studies concerning the topic of this study. The chapter presents both the theoretical review and empirical review on issues relating to the behaviour of exchange rates. The factors influencing exchange rate movement in Ghana has been studied extensively but the findings of these studies seem to be inconsistent. This paper adds to literature by identifying the main drivers of the GHS/USD exchange rate movements by introducing the ensemble empirical mode decomposition (EEMD) method. This chapter discusses the theory underpinning this study; the Heterogeneous Market Hypothesis (HMH) and presents empirical literature on factors influencing exchange rates, long memory behaviour of exchange rates, ensemble empirical mode decomposition (EEMD), the rescaled range statistic (R/S analysis), the autoregressive fractional integrated moving average (ARFIMA) and heterogeneous market hypothesis (HMH).

Theoretical Review

The heterogeneous market hypothesis (HMH)

The heterogeneous market hypothesis is a concept that was suggested by Muller et al. (1993) in their study regarding foreign exchange markets. The heterogeneous market hypothesis proposed that there are heterogeneous (non-homogeneous) market participants in a financial market (Cheong, Cherng & Yap, 2016). As explained by Rambaratsingh (2017), heterogeneous means that there are different agents or participants in a market with different trading

strategies. According to Cheong (2013), the heterogeneity that exists in a specific financial market may result from the response of the participants in the market to new information or news entering the market. The HMH asserts that heterogeneous market participants interpret the same information or news in different ways taking into consideration their trading preferences and opportunities. Muller et al. (1993) stated that the participants of a market may differ in their perception of their market, interests, time horizon, risk profile, degree of disclosure of information, motivation for investing or trading, constraints as well as reaction to news.

This study focused on the time horizon of the market participants. The time horizon was chosen because Mahata, Bal and Nurujjaman (2019) stated that participants of the exchange rate markets are classified into groups based on the different time horizons.

Cheong, Cherng and Yap (2016) indicated that the heterogeneity caused by market participants has created unique and additive fluctuations across a range of different trading time scales which includes short-term investments, medium-term investments and long-term investments. This means that the financial market is made up of participants with numerous investment and trading policies varying from the short-term duration to the long-term duration and the combination of these different time scales have created the long memory properties in financial markets (Cheong, Cherng & Yap, 2016).

In the opinion of Cheong (2013), the different time duration of investments, that is; the short-term duration ranges from seconds to hours, medium-term duration ranges from days to months and the long-term duration

spans from years to decades. Cheong (2013) also illustrated that the short-term participants or investors consisted of the intra-day speculators as well as market makers who trade over short time durations. The medium-term investors are made up of hedge funds and portfolio investors while the long-term participant includes the central banks.

Cheong (2013) noted that the financial market is made up of market participants who react to news in different ways and with different response times which has created a series of fluctuations that ranges from low-frequencies to high-frequencies. Muller et al. (1997) claimed that short-term market participants assess the market more frequently and have short memory behaviour than long-term market participants. Consistent with the HMH, the short-term duration is assumed to correspond to speculative activities (Tittle, 2008). The medium-term duration corresponds to the business cycle of the economy (Donati & Donati, 2008). However, market participants with long-term duration are associated with the investment activity of large organisations and are driven by strategies based on economic fundamentals (Lynch & Zumback, 2003).

Muller et al. (1997) and Tittle (2008) illustrated that short-term traders (intra-day traders) consistently monitor the market; that is, they scrutinize the details of series of events that occur in the market before executing transactions at a high frequency. For example, a quick price increase of 0.5% accompanied by a 0.5% decrease in price is a major event for a short-term trader. A long-term trader watches the market less frequently so they have little or no information about the detailed order of activities that takes place

within a day. Therefore, long term traders are only concerned with large price fluctuations and these fluctuations mostly occur over a long period of time.

In accordance with the HMH framework, the exchange rate market is presumed to have a heterogeneous market structure that is influenced by market participants with numerous investment strategies with different time durations. These market participants respond to news or information at different points in time making the exchange rate data noisy. This makes the exchange rate data not linear and not stationary as well as exhibit long-range dependence behaviour (Owusu Junior, Adam & Tweneboah, 2020).

Empirical Review

The empirical review takes a look at the previous works of researchers on the topic or topics similar to this research work. Primarily, this section will include reviews of the study area, methodology, results and conclusions of previous works.

Empirical Reviews on Empirical Mode Decomposition (EMD)

Zhang, Lai and Wang (2008) analysed the prices of the West Texas Intermediate (WTI) crude oil using the ensemble empirical mode decomposition (EEMD). In their research, EEMD was used to break down the crude oil price into IMFs with distinct frequencies to help them identify the various features of the crude oil prices. Zhang, Lai and Wang employed the fine-to-Coarse reconstruction to group the IMFs and the residue into three components. The components consisted of the long-term trend, the impact of shocks from major events and short-term fluctuations caused by the normal supply and demand disequilibrium. They explained that the prices of the WTI crude oil, in the long run, are caused by trends that constantly change and stay

for a very long period. They postulated that the long-term trend corresponds to the economic growth or development of the world. They also discovered that the unexpected fluctuations in the prices of crude oil were influenced by significant events which are not predictable. Finally, they discovered that the small variabilities that take place in the short term are primarily caused by normal activities in the crude oil market which do not significantly affect the oil market in the long-run forecast but are significant in the short-run prediction.

Zhu, Wang, Chevallier and Wei (2013) applied the EMD technique to the European Union emission trading scheme carbon prices. Using the EMD technique, the carbon prices were broken down into IMFs and one residue to help determine the characteristics of carbon prices. Having finished that, the hierarchical clustering method was used to classify the IMFs and the residue into high-frequency components, low-frequency components and trend components. They posited that the high-frequency components are linked to short-term variabilities in the market, the low-frequency components can be identified with the impact of significant trend breaks and the trend components are connected with the long-term trend. They concluded that the trend component primarily specifies the development of carbon prices in the long run. In their conclusion, they also posited that the significant trend breaks can cause the rise and fall in the carbon prices in the medium-term and finally they asserted that the volatilities in the carbon prices are largely caused by short-term activities in the market.

Zeng and Qu (2014) conducted a study to analyse the behaviour of the Baltic dry index (BDI) using the empirical mode decomposition. According to

the research work by Zeng and Qu, the EMD technique was adopted because of the unprecedented volatility in the shipping markets. They used the EMD technique to break down the Baltic dry index (BDI) into IMFs and a residue to determine the drivers of the volatility in the Baltic dry index. The IMFs and the residue were then grouped into the short-term fluctuations which are driven by normal events that occur in the BDI market, the effect of significant events and long-term trend. Their result showed that the EMD technique accurately revealed the actual features of the bulk freight prices with various economic implications.

Due to the multifaceted nature of China's stock market, Chen and Pan (2016) used the complementary ensemble empirical mode decomposition (CEEMD) to uncover the intrinsic characteristics that are causing the prices of China's stock index futures to fluctuate. Their findings revealed three intrinsic characteristics of the prices of China's stock index futures. According to Chen and Pan, the first intrinsic characteristic is the residue. They postulated that the instabilities of the residue term are linked to the fundamental factors of the economy and the long-term expectations of investors. The next intrinsic characteristic is the low-frequency term. They asserted that the low-frequency term shows the impact of major events on China's stock index futures price fluctuations in the medium term. The high-frequency term is the last intrinsic characteristic that shows the short-term instability in China's stock market.

Tiwari, Dar, Bhanja and Gupta (2016) conducted a study on the US stock price index using the ensemble empirical mode decomposition (EEMD) technique for 1791 to 2015. In their study, the behaviour of the prices of the Standard and Poor's 500 (S&P 500) stock indices were analysed. Using the

EEMD method, the prices of the S&P 500 stock indices were broken down into distinct IMFs and a residue. They used the hierarchical clustering method to reconstruct the IMFs and the residual into high-frequency, low-frequency and trend components. Their findings showed that the low-frequency components, as well as the trend components, were the major factors influencing the S&P 500 stock price index. They concluded that the US stock prices appear to be mainly influenced by fundamental factors.

Bouoiyour, Selmi, Tiwari and Olayeni (2016) conducted a study of what drives bitcoin prices. They used the EMD technique to decompose their data into IMFs. After the decomposition, the IMFs were grouped into three categories; the long-term scales (low-frequency components), medium-term scales (medium-frequency components) and short-term scales (high-frequency components) using the mean periods. They posited that although bitcoin is mostly characterized as a purely speculative asset, after using the EMD technique, they realized that bitcoin was mainly driven by long-term fundamentals (low-frequency components) over one year.

Li, Huang and Xu (2017) conducted a study to assess the volatility mechanism in the economic growth in China using the EMD technique. In this study, the EMD technique was used to break down the quarterly data of GDP growth rate ranging from 2000 to 2010 into IMFs and a residue. Their findings showed that the fluctuations that occur in the economic growth of China are made up of short-term factors, medium-term factors and long-term factors. They found out that the long-term factors mainly influenced the volatility mechanism in the economic growth of China and are defined by the business cycle.

Adam, Kyei, Moyo, Gill and Gyamfi (2021) carried out a study to examine the behaviour of exchange rates in the Southern African Development Community (SADC) by applying the EMD method and EEMD method. The IMFs and residue generated from the EEMD analysis revealed that the exchange rates in SADC are primarily determined by macroeconomic fundamentals.

Empirical Reviews on Long Memory Behaviour

Cajueiro and Tabak (2004) conducted a study to test for long memory behaviour and efficiency in stock indices of eleven (11) emerging stocks markets as well as the stock markets of the Japan and US using Hurst's Rescaled Range Analysis. They asserted that the long memory behaviour is more significant in the Asian countries than in the Latin American countries except for Chile. They posited that the US and Japan have the most efficient markets.

Floros (2008) estimated the ARFIMA model using the conditional maximum likelihood and tested the returns of the daily exchange rate for long memory properties. Floros (2008) tested for long memory between 34 different exchange rates against the US Dollar and discovered that 17 of the 34 exchange rates exhibited long memory characteristics. Based on the findings, the results from the African and Asian countries exchange rates showed the existence of long memory behaviour. The findings from the European rates showed weak evidence of long memory while the evidence from America and Australia is mixed. Floros (2008) further stated that the long memory hypothesis is stronger in developing markets specifically, economies with low per capita income to middle per capita income. He posited that this showed

that emerging markets are unstable thus they provide opportunities to investors to exploit the market for profit.

Aidoo, Saeed, Ababio, Nsowah-Nuamah and Louis (2012) investigated the presence of long memory properties in the GHS/USD exchange rates from January 1990 to January 2012. Using the rescaled-range and modified rescaled tests, they found long memory properties in their data. Thus, their result suggested that the GHS/USD exchange rate market can be predicted with past information. In a similar way, Uthayakumar and Prabha (2012) conducted a study to assess the behaviour of the exchange rate between the Indian Rupees (INR) and the US Dollar (USD) from 2004 to 2014. However, the findings of Uthayakumar and Prabha seem to contradict the outcome of Aidoo et al. (2012). In the work of Uthayakumar and Prabha, the value obtained for the Hurst exponent was 0.5041 and they approximated it to 0.5. From their result, they found out that the INR/USD exchange rate series is a random walk series. They further stated that the current values and future values of the INR/USD exchange rates do not correlate.

Tweneboah, Adam, Dadzie and Amoako (2015) used the ARFIMA model and the FIGARCH model to investigate the long memory properties of Ghana's real interest rates. Their study revealed the existence of unit root in nominal interest rates measured by 3-month Treasury bill rates through some stationarity tests. On the other hand, they posited that the real interest rates showed unclear behaviour concerning its integration property. Further estimations of the long memory parameter implied that shocks had long memory impacts on real interest rates but it is mean-reverting in the long run.

Gyamfi, Kyei and Gill (2016) undertook a study to investigate the long memory properties in the returns and volatility of the Nigerian and Ghanaian stock markets. They employed the Hurst exponent estimated by the Local whittle estimator. Gyamfi, et al. discovered that both the returns and volatility of the Nigerian and Ghanaian stock indices possessed long memory properties. They concluded that the existence of long memory in the Nigerian and Ghanaian stock indices indicates that these stock indices are not efficient, hence, creating opportunities for profits to be made using past information.

Omekara, Okereke and Ukaegeu (2016) employed the ARFIMA model and the Hurst exponent to model and analyse the liquidity ratio of Nigerian commercial banks. The Hurst exponent was used to determine whether the liquidity ratio had long memory. They found out that the liquidity ratio series exhibited long memory properties because the Hurst exponent obtained was 0.803984. Also, the ARFIMA model and the ARIMA model was used to model the liquidity ratio of the Nigerian commercial banks to find out which technique better modelled the liquidity ratio. After comparing the results of the two models, they came to a conclusion that the ARFIMA was a better model compared to the ARIMA in this context.

Boateng (2017) employed the ARFIMA model to investigate the existence of long memory (persistence) in Ghana and South Africa's Inflation from January 1995 to December 2017. The study discovered that the Ghanaian and South African inflation time series had long memory properties. Boateng asserted that the presence of long memory in Ghana and South Africa's inflation creates an opportunity for speculative profits while casting doubt on the correctness of the efficient market hypothesis. Boateng also posited that

the existence of long memory in the inflation series provides valuable information on the possible impact of shocks on the economy over time.

Wang, Lei, Lui and Wang (2017) conducted a study to show that China's stock is not a random walk series but has long memory properties. Wang et al. (2017) used the R/S analysis to determine the Hurst exponent of 5 of China's stock in different periods. From their results, the Hurst exponent of China's stock market was greater than 0.5. Therefore, they established that the Chinese stock market possessed long memory and fractal properties.

In Ghana, Kwofie and Ansah (2018) carried out a study to explore the effect of inflation and exchange rates on stock returns. They employed monthly market returns from the Ghana Stock Exchange all-share index, monthly inflation and monthly exchange rate data. These three variables employed were assessed for long memory and the result revealed that all three variables exhibited the long memory behaviour. The long-range dependence of the exchange rate on the other hand had a negative fractional differencing parameter (d), which indicates a long-range negative dependence.

Raimundo and Okamoto-Junior (2018) applied Hurst's rescaled range analysis on five (5) pairs of currency prices (AUD-JPY, CHF-JPY, EUR-JPY, GBP-JPY and EUR-CHF). Their result showed that the historical prices for the five (5) pairs of currency prices exhibited long memory. They concluded that the five (5) pairs of currency prices are persistent processes. This suggests the identification in historical series patterns of persistence, enabling effective market risk identification policies to be developed. Observing further, Raimundo and Okamoto-Junior pointed out that market participants should

carefully consider this theme, review their bases, and promote the improvement of the methodology used to manage the risks assumed.

Omane-Adjepong, Boako and Alagidede (2018) carried out a study to analyse the influence of speculative behaviour on the foreign exchange market in Ghana by examining the long memory characteristics of the Ghana cedi with respect to four major currencies (Dollars, Yen, Euro and Pounds). Using the ARFIMA-FIGARCH and semi-parametric and high and low-frequency data, they found out that the efficiency of the foreign exchange market was heterogeneous thus giving little room for speculation in the foreign exchange market. They concluded that speculative activities could not explain the self-driven fluctuations in the foreign exchange market in Ghana.

Caporale, Gil-Alana and Plastun (2019) conducted a study to investigate the existence of long memory in financial time-series at three frequencies; namely, the daily frequency, the weekly frequency and the monthly frequency. They used the rescaled range analysis (R/S analysis) and fractional integration methods to examine the long memory features of the stock market, foreign exchange market and the commodity markets from 2000 to 2016. They discovered that persistence (long memory behaviour) was higher at lower frequencies. They indicated that this was true for both the emerging and developed stock markets and partially true for the FOREX and commodity markets they considered. They concluded that their results were against the random walk hypothesis and their results implied that the financial markets they examined were inconsistent and predictable. Based on their results, they also concluded that traders in the financial markets can use trend analysis to make abnormal profits.

Odonkor, Ababio, Amoah-Darkwah and Andoh (2019) undertook a study to investigate whether long memory behaviour was present in the daily closing prices of seven (7) stock returns on the stock market in Ghana. Using the autoregressive fractionally integrated moving average-fractionally integrated generalized autoregressive conditional heteroscedasticity (ARFIMA-FIGARCH), they found out that all the stocks used in the study possessed long memory properties.

Employing the fractional integration approach to determine whether the Sri Lankan Rupees and the Australian Dollar exchange rates exhibit a long memory behaviour, Sivarajasingham and Mustafa (2019) suggested that LKR/AUD return exhibit a short memory behaviour whiles volatility proxies; absolute squared return and conditional variance shows long memory and non-stationarity. Their data ranged from January 1, 1990, to December 12, 2017. They also estimated their ARFIMA model using the maximum likelihood method.

Alfred and Sivarajasingham (2020) used the ARFIMA model to analyse the behaviour of Sri Lankan's stock price return of the all share price index (ASPI). They employed the time-domain exact maximum likelihood to help with the estimation of the ARFIMA model parameters. According to Alfred and Sivarajasingham the absolute mean, squared return as well as conditional variance obtained from the FIGARCH model were also used to proxy the volatility of Sri Lankan's ASPI return series. According to their results, the return of the ASPI series exhibited long memory features. Their findings also revealed that the volatility of the ASPI return also possessed long memory properties. Alfred and Sivarajasingham further revealed that the

evidence of long memory properties found in the return of ASPI as well as the volatility of ASPI show that the effect of shocks on the prices of stock will last for a very long time. They concluded that the presence of long memory properties in the return of ASPI and the volatility of ASPI shows that the stock market in Sri Lanka is inefficient and not stable.

Ampofi, Tetteh, Wiah and Appiah (2020) conducted a study using the Hurst exponent Analysis to test for the presence or absence of long memory of daily returns of stock on the Ghana Stock Exchange (GSE). The objective of their study was to find out whether the GSE daily returns exhibited long memory behaviour using Hurst's Rescaled Range Analysis over the period from January 2018 to December 2018. Their findings showed that 91.7% of the stocks considered in their study exhibited long memory characteristics.

Empirical Reviews on Macroeconomic Fundamentals and Exchange Rates

Using the cointegration analysis and error-correction modelling technique, Mumuni and Owusu-Afriyie (2004) investigated the main drivers influencing the GHS/USD exchange rates after Ghana adopted the floating exchange rate regime. Mumuni and Owusu-Afriyie arrived at a conclusion that macroeconomic fundamentals contribute significantly in determining the Ghana Cedi/ US Dollar exchange rates. Also, they discovered that speculation regarding the past cedi/dollar exchange rate behaviour is a major determining factor of the future exchange rate in Ghana. According to Mumuni and Owusu-Afriyie, this may be due to the underdevelopment of the foreign exchange market and the financial institutions.

The effect of key macroeconomic indicators on the GHS/USD exchange rate was investigated by Kwakye (2015) between May 2000 and May 2014. The macroeconomic indicators used in the study were interest rate, money supply and inflation. The research discovered a long-run relationship between the GHS/USD exchange rates and macroeconomic indicators. This implied that money supply, inflation, interest rates as well as exchange rates all move together in the long run. The research also found out that past exchange rates particularly the lag of exchange rates had a significant effect on current exchange rates.

Amoa-Gyarteng (2016) carried a study to analyse and assess the dynamics of the Ghana Cedi and US dollar exchange rates. They found out that the exchange rate had a significant positive correlation with inflation and interest rate. They concluded that speculative activities only had a temporary or no influence on the movement of the GHS/USD exchange rates.

Arko (2016) conducted a study to identify and examine the drivers of the GHS/USD exchange rate behaviour in Ghana. The study aimed to assess the factors that influenced the behaviour of exchange rates by analysing the short-term effects and long-term effects of inflation, interest rate and real GDP on the nominal exchange rate. According to the study, inflation had no significant impact on exchange rate behaviour in both the short-term and the long-term. On the other hand, money supply and real GDP had a significant influence on the behaviour of the exchange rates in the long term. The interest rate was only significant in the short term.

Adusie and Gyapong (2017) employed the partial least structure equation modelling approach to determine the effect of macroeconomic

fundamentals on the GHS/USD exchange rates in Ghana for the period of 1975 to 2014. Their results indicated that economic fundamentals explained 82% of the variability in the GHS/USD exchange rate. They concluded that the economic fundamentals (annual GDP per capita growth rate, inflation, total external debt, current account balance, monetary policy rate and money and quasi money supply per GDP) contribute to the persistent depreciation of the GHS/USD exchange rates.

Alagidede and Ibrahim (2017) assessed the drivers of exchange rate fluctuations and their impact on the development of Ghana's economy. Using annual data ranging from 1980 to 2013, their result revealed that output is the main driver of fluctuations in the exchange rate in the short-run while the primary drivers of the volatility of exchange rate, in the long run, are driven by the growth of money supply, government expenditure, FDI flow, terms of trade and domestic output movement. They further decomposed the shocks in the exchange rates movements and found out that three-quarters of the volatility of the exchange rate are self-driven. They explained that the huge influence of own shocks shows that speculative noise and fads are important in the exchange rate market in Ghana. They further noted that this may be attributable to microstructure biases and uninformed activities of traders in the exchange rate market in understanding and interpreting macroeconomic news. They posited that growth of money supply, government expenditure, terms of trade and output shocks explained the remaining one-quarter of shocks

Anku (2018) also sought to determine the sources of currency depreciation in Ghana. The study's main goal was to discover the factors influencing exchange rates movement in Ghana by employing vector

autoregressive (VAR) models. The study established that the exchange rate in Ghana was influenced by inflation and interest rate differentials through the expectation medium and domestic and foreign money supplies were found to be important in the determination of exchange rate movements. Anku concluded that the fundamentals of the Ghanaian economy play a significant role in determining exchange rates. According to Anku, macroeconomic fundamentals such as inflation, interest rates and money supply are particularly important in maintaining the stability of the exchange rate in Ghana.

Agyemang-Adjei (2019) undertook a study to investigate the determinant of the Cedi/Dollar exchange rate. The study employed some selected macroeconomic fundamentals to investigate the drivers of the GHS/USD exchange rate in Ghana. They include; lending interest rate, foreign direct investment, imports, exports, inflation, gross domestic product, interest rate and balance of payment. Inflation, the balance of payment and foreign direct investment were found to have a significant and positive relationship with exchange rates.

Nor, Masron and Alabdullah (2020) carried out an investigation to analyse economic fundamentals and the exchange rate volatility. They examined the volatility associated with unregulated exchange rates in Somalia. Also, they investigated to know whether economic fundamentals had a major impact on the volatility of Somalia's unregulated exchange rates. Using the EGARCH model, they found out that the exchange rate volatility in Somalia is mainly influenced by its own shock. This means the volatility of Somalia's unregulated exchange rates are driven by past exchange rate information and

also previous volatility. They also found out that economic fundamentals have a major impact on the volatility of the unregulated exchange rates in Somalia. Subsequently, Nor, Masron and Alabdullah mentioned imports, money supply and short-term capital flows as some of the macroeconomic factors that have a strong impact on the volatility of Somalia's unregulated exchange rates.

Empirical Reviews on Speculation and Exchange Rates

According to Amoa-Gyarteng (2016), speculation is where participants in the exchange rate market buy and sell foreign currency in uncertain conditions in the hopes of making large profits. Speculators frequently buy when the currency is weak and sell when the currency is strong. Alves, Ferrari and De Paul (1999) opined that speculative attacks on local currencies can occur when macroeconomic fundamentals are expected to deteriorate in the future. They further posited that the domestic currency is susceptible to speculative attacks when the country's fiscal position is sufficiently weak. Schreber (as cited in Amoa-Gyarteng, 2016) posited that speculation could cause movements in exchange rates in developing economies like Ghana. However, Omane-Adjepong, Boako and Alagidede (2018) asserted that the heterogeneous nature of the exchange rate market in Ghana gives little room for speculation in Ghana's exchange rate market. This is because the activities of the market participants in the exchange rate market allow currencies to be priced correctly.

Empirical Reviews on other Factors of Exchange Rate

Ltaifa, Kaendera and Dixit (2009) carried out a study to examine the effect of the global financial crisis on the exchange rates of Sub-Saharan African countries. According to their study, the beginning of the 2008/2009 financial crisis led to a rapid depreciation in the currencies of Sub-Saharan

African countries as well as emerging and developing countries. According to their research, the currencies of Ghana, Kenya, Zambia, Nigeria and Uganda depreciated against the US dollar by at least 20% from June 2008 to March 2009 during the global financial crisis.

History of Exchange Rate in Ghana

According to Nyoni (2018) and Zhang and Zhang (2018), the exchange rate is the value at which one country's currency can be exchanged for another country's currency. The exchange rate is the relative price that determines the value of one currency in relation to another. Madura (2008) stated that exchange rate systems can be grouped based on the degree to which the government controls exchange rates. Madura went on to state that exchange rates systems are typically classified as fixed exchange rate regimes, flexible exchange rate regimes and pegged exchange rate regimes.

Ghana had no official exchange rate system until colonisation when she adopted the fixed exchange rate regime. Before 1912, when the West African Currency Board (WACB) was established, the Bank of British West Africa; a private bank with a branch in Ghana, distributed the British pound which did not require an exchange rate system. The WACB pound was pegged to the British pound sterling at par value after 1912 when it was first issued.

Ghana has had an independent currency and monetary policy since its independence in 1957. The fixed exchange rate system was in place for a long time before being replaced in 1983 by a more flexible exchange rate system. From 1957 to 1965, Ghana's currency was the Ghana pound, which was pegged to the British pound. Between 1966 and 1983, the value of the currency was pegged to the US dollar. During this period, the cedi was extremely stable (Anku, 2018). The managed floating exchange rate regime

began in 1983 during the PNDC regime and the economic recovery programme period.

In 1986, the auction exchange rate system was implemented and organized for importers. The auction was unified in February 1987 and the Bank of Ghana officially allowed exchange bureaus to buy and sell foreign currency. In early 1992, the auction system was phased out and replaced by an interbank exchange rate system where exchange rates were decided by the inter-bank market. The forex bureau and the inter-bank exchange rate systems are now the only providers of foreign exchange rates.

The effective exchange rate has been depreciating regularly against the main trading currency, the dollar, since the beginning of the floating exchange rate reforms in 1983 and this continues to this day. Due to the extreme fall of the Cedi, the monetary authorities and the government embarked on a redenomination of the currency in 2007 (Bank of Ghana monetary report, 2007). Asmah, Armah, Brafu-Insiadoo and Peprah (2016) posited that Ghana's currency was redenominated in July by setting ten thousand cedis to one new Ghana cedi. During the first quarter of 2008, the cedi was stable on the inter-bank market but from the second quarter, the Ghana cedi depreciated significantly against all major currencies. The significant fall of the cedi against major currencies according to the Bank of Ghana was partly due to the realignment of the major international currencies and a massive increase in the demand for foreign currency to meet higher oil prices, and food prices, as well as the servicing of external debt.

The significant depreciation of the cedi each means that more of the Ghana cedi will be required to exchange for a dollar, which is bad news for

Ghana since Ghana imports more than half of its goods and services from economically developed countries. According to the Bank of Ghana's report in 2019, the Ghanaian foreign exchange rate market experienced some volatility as a result of internal and external factors.

Chapter Summary

The theoretical and empirical review on the dynamics of exchange rates shows that understanding exchange rate behaviour is a difficult challenge to both developed and developing economies. It can be established from the theoretical and empirical review that exchange rates contain intrinsic complexities and when these intrinsic complexities are not discovered from the exchange rate data, they fail to produce consistently good results. Due to this fact, this study adopted the ensemble empirical mode decomposition (EEMD) technique to help discover the hidden characteristics of the exchange rate data.

From the empirical review above, it is clear that some studies adopted the EMD and the EEMD techniques in their studies to determine the characteristics of financial time series data but it cannot be denied that little studies have been done in Ghana using the EEMD techniques especially with exchange rate data to reveal the intrinsic characteristics and the main drivers of exchange rates in Ghana. It is also evident that there is little research in the area of long memory behaviour of exchange rates in Ghana. Thus, it is within the interest of this study to place itself in the context to reveal some shrouded truth about the behaviour of exchange rates in Ghana using the EEMD technique and Hurst's rescaled range analysis to contribute to the limited literature that exists on this topic in Ghana.

CHAPTER THREE

RESEARCH METHODS

Introduction

The methodology of this study is presented in this chapter. The main motivation of this study was to perform ensemble empirical mode decomposition (EEMD) on the GHS/USD exchange rates and to determine and interpret its drivers from a new perspective. Also, the study conducted an investigation to detect the existence of long memory behaviour of exchange rates by combining EMD and rescaled range analysis (R/S analysis), (EMD-R/S analysis) as well as EMD and autoregressive fractionally integrated moving average (ARFIMA), (EMD-ARFIMA). These approaches have the advantage of allowing me to denoise the raw GHS/USD exchange rate series and to distinguish between the exchange rate behaviour once the noise element from the original exchange rates series has been eliminated. This chapter gave a comprehensive description of the EMD and EEMD techniques including the overall steps of the proposed techniques. A brief description of the R/S analysis and ARFIMA model were provided. The light was shed on the research design used as well as the data and data source.

Research Paradigm

A research paradigm is basically how researchers understand the truth of the world and study it (Rehman & Alharthi, 2016). A research paradigm is a set of common ideologies and assumptions among researchers about their ontological concerns, epistemological and methodological positions (Johannesson & Perjons, 2014). A researcher's choice of research philosophy is mostly influenced by the researcher's basic ontological, epistemological and

methodological position. Positivism and interpretivism are the two most widely recognized research paradigms. This study adopted the positivist approach. Positivists strive to establish a causal relationship between different variables of the subject and once established, link them to a specific theory or practice with certainty in future (Rehman & Alharthi, 2016). Also, this study adopted the positivist philosophy to help determine exchange rate behaviour in Ghana. The positivism approach was adopted due to the ontological, epistemological and methodological considerations.

Ontologically, the positivism approach presumes that truth exists independently of human activities. The epistemological standpoint of the positivists is objectivism. Positivists claim that the objective of understanding a phenomenon can be obtained through observation, investigation and experimentation. Methodologically, positivists rely on experimentation. Hypotheses are proposed about the causal relationship between phenomena and allow for rigorous hypothesis testing using statistical analysis. Finally, this study adopted the positivism approach because according to Kivnga and Kuyini (2017), positivists support the fact that the findings and conclusions of a research work can be generalized to the study population or other studies of a similar nature irrespective of its been carried out in other places or a different situation.

Research Design

This study adopted explanatory research. The explanatory research design was employed by this study because it is primarily used to identify the cause of a given behaviour (Boru, 2018). Thus, the explanatory research design would help in identifying the main causes or drivers of exchange rate

behaviour in Ghana. Again, explanatory research is employed because the researcher uses theories or hypotheses to account for the factors that triggered a phenomenon to occur and also to provide deep insight into a specific subject or situation.

Research Approach

The study adopted the quantitative research approach which is mainly associated with the positivist research paradigm. The quantitative research approach suits this research because Apuke (2017) remarked that quantitative research begins with an explanation of an issue or a problem, generating hypotheses, reviewing literature and the quantitative analysis of data. Again, the quantitative approach was adopted because this study relied on time series data which lend itself to statistical analysis. Also, it allows for rigorous hypothesis testing since hypotheses have been generated.

The greatest strength associated with the quantitative research approach is that it maximizes objectivity, replicability and generalizability of the study (Boru, 2018).

Empirical Mode Decomposition (EMD)

Huang et al. (1998) proposed a non-linear and non-stationary data processing technique called empirical mode decomposition (EMD). The EMD technique helps to decompose signals into intrinsic mode functions (IMFs) without giving up the time domain. EMD helps break down time-series data into components (trends, various seasonality, various cycles and noise). In the words of Huang et al. (1998), Lin, Chiu, and Lin (2012), Yang and Lin (2016), Zhang (2018) and Nanthakumaran and Tilakaratne (2018), EMD is an adaptive approach for decomposing signals into intrinsic mode functions

(IMFs) as well as analysing signals that are not stationary and non-linear signal. The EMD technique assists in finding more detailed information that may be hidden in signals. Bouoiyour et al. (2016) explained that the EMD technique helps detect hidden information in the time-series data and intend to transform the investigated time-series data into a hierarchical structure using the scaling transformation.

Zhang, Lai and Wang (2008) posited that the EMD technique suggests that the time-series data, based on its own complexities, could have several coexisting modes of oscillations simultaneously. Thus, the core principle of the EMD technique is to break down time-series data into various intrinsic mode functions (IMFs) on the basis of the following notions according to Zeng and Qu (2014).

1. The time-series data should have a minimum of two extrema; a maximum and a minimum.
2. The characteristics time-scale of the data is only determined by the time-scale in the extrema.
3. In the event where the data does not contain any extrema but only points of inflexion, then the extrema can be obtained by differentiating the data and the results may be derived by integrating the components once or more times.

After satisfying the above assumptions, the IMF can now be extracted. An IMF is an oscillating mode of a simple function with changing amplitude and frequency. The IMFs shall meet the following requirements;

1. Throughout the whole time-series data set, the number of extrema (maxima and minima) and the number of zero crossings must be equal or may differ at most by one.
2. At each point, the mean value of the local maximum envelope and the local minimum envelope must be equal to zero.

The IMFs can be obtained through a process called the sifting process. It can be decomposed by;

1. Determining the local maxima and the local minima of the time series (x_t).
2. Use the local maxima and the local minima to generate the upper envelope (h_t) and the lower envelope (l_t) with cubic spline interpolation.
3. Measure the mean (m_t) under different points from the upper (h_t) and lower (l_t) envelopes. Thus;

$$m_{(t)} = \frac{h_{(t)} + l_{(t)}}{2} \qquad \text{Eqn (1)}$$

4. Then, we obtain a new series (C_t). Therefore,

$$C_{(t)} = X_{(t)} - m_{(t)} \qquad \text{Eqn (2)}$$

5. If (C_t) satisfies the features an IMF possesses, then (C_t) is considered as an IMF and the (X_t) in step 1 is replaced with the residual (r_t). Thus,

$$r_{(t)} = X_{(t)} - C_{(t)} \qquad \text{Eqn (3)}$$

If not, simply replace (x_t) in step 1 with (c_t). The process of extracting an IMF from a time series is repeated till the stopping criterion shows up. That is when an IMF cannot be extracted from the data because the residue $r_{(t)}$ turns into a

monotonic function or when there are only one local extrema (Huang et al. 2003).

The actual time-series data which is broken down or decomposed into numerous IMFs and a residue can be written as;

$$X_{(t)} = \sum_{i=1}^{n} C_{(t)} + r_{(t)} \quad \text{Eqn (4)}$$

Where n is the number of IMFs, r(t) is the residual and c(t) is the IMF. According to Buoiyour et al. (2016), the first component in the sifting process contains the shortest period component of the time series data and the residue corresponds to the longest period fluctuations in the data.

The major limitation of the empirical mode decomposition (EMD) technique is the presence of mode mixing after decomposition. Another major drawback of the EMD method as posited by Zeiler et al. (2010) is that the EMD method lacks theoretical backing which could help assess the performance of the algorithm in objective terms.

Ensemble Empirical Mode Decomposition (EEMD)

As already mentioned, the main problem of the EMD is the presence of mode mixing after decomposition. This phenomenon happens when an IMF originating from the EMD process is made up of different frequencies or the same frequency appears in other IMFs (Li, 2011). Wu and Huang (2009) introduced the ensemble empirical mode decomposition (EEMD) to alleviate the problem of mode mixing associated with EMD.

EEMD is a noise-assisted data analysis technique and the improved version of the EMD that prevents the mode mixing problem. EEMD involves the addition of several white noise series to the time-series or the targeted data (Tiwari, Dar, Bhanja & Gupta, 2016). This is followed by the decomposition

of the time series and the noise to produce the IMFs. As explained by Tiwari et al. (2016), this process is repeated each time by adding several series of white noise to produce the ensemble IMFs from the decomposition. According to Gaci (2016), the resulting IMFs do not show any correlation or relationship with the corresponding IMFs from one trial to a different trial because the white noise added in every trial is different. Zhang Lai and Wang (2008) stated that the white noise series can be eliminated by ensemble averaging of the extracted IMFs associated with the different trials after serving its purpose. The EEMD procedure is outlined below;

1. Add a series of white noise to the original time series signal to generate new time series data. Thus;

   $x_m(t) = x(t) + w_m(t) \qquad m = 1,2, \dots, N$ Eqn (5)

   Where; $x(t)$ is the original time-series data, $w_m(t)$ is the mth added white noise series, $x_m(t)$ is the new times series data (noisy signal) of the mth trial and N is the ensemble number of the EEMD method.

2. Decompose the data with white noise into IMFs.

   $x_m(t) = \sum_{i=1}^{L} C_{m,i} + r_{m,L}(t)$ Eqn (6)

   Where $C_{m,i}$ represents the ith IMF of the mth trial, the $r_{m,L}$ is the residue of the mth trial and L is the total number of IMFs from the decomposition of $x_m(t)$.

3. Steps 1 and 2 are repeated for N trials but in each trial, a different white noise series is added to the original time series data.

4. Obtain the ensemble means of the corresponding IMFs of the decomposition as the final results (C_m) ;

   $C_m(t) = \frac{1}{N}\sum_{i=1}^{N} C_{m,i}$ Eqn (7)

Once the EEMD is completed, the original time series data can be written as;

$$x(t) = \sum_{m=1}^{m} C_m(t) + r_m(t) \quad \text{Eqn (8)}$$

Now after the original time-series data was decomposed into IMFs, the IMFs were then reconstructed using their mean periods.

EMD Denoising

The GHS/USD exchange rates were denoised before determining the long memory properties. Denoising is simply noise reduction; that is the extraction of the noise of a signal from a signal-noise mixture. When the data is analysed in the presence of noise, it mostly results in incorrect interpretation of the data. Thus, denoising allows us to concentrate on the most important components of the time series. Exchange rates were denoised by performing the thresholding in each of the IMFs so that the low-energy IMF components that are expected to be influenced and corrupted significantly by noise are locally removed. In the EMD case, direct use of wavelet thresholding is translated into;

$$\widehat{IMF_k}(t) = \begin{cases} IMF_k(t) & IMF_k(t) \geq T_k \\ 0 & IMF_k(t) \leq T_k \end{cases} \quad \text{Eqn (9)}$$

For hard thresholding.

It also translates to;

$$\widehat{IMF_k}(t) = \begin{cases} sgn\big(IMF_k(t)\big)\big(IMF_k(t)\big) - T_k & IMF_k(t) \geq T_k \\ 0 & IMF_k(t) \leq T_k \end{cases} \quad \text{Eqn (10)}$$

For soft thresholding, where, in both thresholding cases, $\widehat{IMF_k}(t)$ indicates the kth thresholded IMF.

The reconstructed series becomes;

$$\hat{x}(t) = \sum_{K=M_1}^{M_2} IMF_k(t) + \sum_{K=M_2+1}^{L} IMF_k(t) \quad \text{Eqn (11)}$$

Where the introduction of parameters M_1 and M_2 gives us flexibility on the exclusion of the noisy low-order IMFs and on the optional thresholding of the high-order ones, which in white Gaussian noise conditions contain little noise energy.

Pearson Product-Moment Correlation and Kendall Rank Correlation Coefficient

In this thesis, the Pearson Product-Moment correlation and the Kendall Rank correlation coefficient were employed to determine and analyse the relationship between the IMFs and the original exchange rate series. The Pearson product-Moment correlation and the Kendall rank correlation coefficient showed which IMFs or components are strongly related to the original data series or influence the actual data series.

Long Memory Behaviour in Time Series

Long memory, also known as long-range dependence in time series indicates the extent of statistical dependence in between two observations in a time series. Long memory refers to the rate at which the statistical dependence between two observations decay as the distance between the observations is increased. It shows the correlational structure of time-series observations at long lag length. Long memory shows that the most recent information that is information from 'today' is not absorbed instantly by the prices in the market thus, participants of the market will respond with delay to such information. Long memory is very important in time series because it helps in determining the behaviour of time series observation.

There are numerous approaches used to investigate long memory behaviour in financial time series. They include; the rescaled range analysis

(R/S analysis), modified rescaled range analysis, generalized Hurst exponent, detrended fluctuation analysis (DFA), the autoregressive fractionally integrated moving average (ARFIMA) and many others. This study adopted the R/S analysis and the ARFIMA for robustness purposes.

Rescaled range analysis (R/S analysis)

The rescaled range analysis (R/S analysis) was first introduced by Hurst in 1951 whiles he was conducting a study on the problem of water storage on the Nile River. The R/S analysis is a statistical measure for determining and analysing the nature and extent of variability in time series data (Ampofi, Tetteh, Wiah & Appiah, 2020). The R/S analysis uses the Hurst Exponent which is denoted by (H) to measure the long memory behaviour in time series data. According to Raimundo and Okamaoto-Junior (2018), the value of the Hurst exponent ranges from 0 to 1. Omekara, Okereke and Ukaegu (2016) explained that the higher the Hurst exponent, the longer the long-memory properties and the lower the efficiency of the exchange rate market.

Interpretation of the Hurst Exponent

According to Boateng (2017), the values of the Hurst exponent has three valid interpretations. The interpretations are as follows;

- If $H = 0.5$, the process is a random walk process.

  This means that the observations are random and uncorrelated.

  This also implies that the process is an independent process.

- If $0.5 < H < 1$, the process has long memory behaviour.

  This indicates that the series is said to have persistent behaviour.

As explained by Boateng (2017), this means that what takes place today affects the future forever.

- If $0 < H < 0.5$, the time series process is anti-persistent.

  This means that the time series data is mean-reverting. This implies that large values and small values tend to switch or alternate.

Safitri, Mustafid, Ispriyanti and Sugito (2019) posited that the Hurst exponent is calculated using the R/S analysis. The following steps below show how the R/S analysis method can be used to estimate the Hurst Exponent for time series data $Z_1, Z_2, \ldots, Z_n$.

1. Calculate the mean value (M).

   Thus, $M = \frac{1}{n}\sum_{t=1}^{n} Z_t$ Eqn (12)

2. Calculate the Mean adjusted series (Y).

   $Y_t = Z_t - M$ Eqn (13)

   $t = 1, 2, \ldots, n$

3. Calculate the cumulative deviation series (Q)

   $Q_t = \sum_{t=1}^{n} Y_t$ Eqn (14)

   $t = 1, 2, \ldots, n$

4. Calculate the Range Series (R)

   $R_t = \max(Q_1, Q_2, \ldots, Q_t) - \min(Q_1, Q_2, \ldots, Q_t)$ Eqn (15)

   $t = 1, 2, \ldots, n$

5. Calculate the standard deviation series (S).

   $S_t = \sqrt{\frac{1}{t}\sum_{i=1}^{t}(Z_t - M)^2}$ Eqn (16)

   $t = 1, 2, \ldots, n$

6. Calculate the Rescaled Range series (R/S)

$$(R/S)_t = R_t/S_t \quad \text{Eqn (17)}$$

t = 1, 2, …, n

7. Determine the Hurst (H) exponent using the R/S analysis from the time series data.

$$(R/S)_t = c \cdot t^H \quad \text{Eqn (18)}$$

t = 1, 2, …, n

where c = constant

H = Hurst Exponent

The value of the Hurst exponent can be obtained by taking logarithm on both sides of the equation $(R/S)_t = c \cdot t^H$. Therefore;

$$\log(R/S)_t = H \log(t) + \log(c) + \varepsilon_t \quad \text{Eqn (19)}$$

The ordinary least square regression can be used to estimate the value of the Hurst exponent.

Mandelbrot (1971) was the first to investigate the implications of long memory on financial markets by employing the rescaled range analysis to detect long memory properties in asset return data.

Boateng (2017) asserted that one major strength of the R/S analysis is that the R/S analysis can group time-series into random or non-random components based on Hurst (H) exponent's estimated value when identifying long memory behaviour in time series.

However, the R/S analysis has some weaknesses too. Some of the weaknesses of the R/S analysis according to Boateng (2017) are;

- The R/S analysis favours the low-frequency data rather than the high-frequency data because it is understood that the high-frequency data shows a strong statistical correlation with each other.
- The R/S analysis requires longer data set as a long-term data set offers a more realistic possibility for non-periodic cycles to emerge.
- When the study period is very small or very large in terms of the total number of observations in the time series, estimation error may occur.
- The R/S analysis sometimes detects short term dependence or short memory behaviour without differing it from long memory behaviour.

The above weaknesses can lead to completely incorrect results when they occur.

Autoregressive Fractionally Integrated Moving Average (ARFIMA)

Exploiting the long memory behaviour of exchange rates require a long memory model known as the Autoregressive Fractionally Integrated Moving Average, commonly known as ARFIMA(p, d, q). The ARFIMA model was developed by Granger and Joyeux (1980) and Hosking (1981) to study the long memory behaviour of financial time-series; that is time-series where the deviations resulting from the long-run mean decays more slowly than an exponential decay. The ARFIMA model generalizes the Autoregressive Integrated Moving Average (ARIMA) by allowing non-integer values of the differencing parameter (d) to take on actual values instead of being restricted to the integer domain.

The study employed the ARFIMA (p, d, q) model to exploit the long memory behaviour of exchange rates in Ghana. The long memory characteristics of a process largely depend on the value d takes on.

Interpretation of the Fractional Differencing Parameter (*d*)

The interpretation of the values of the fractional differencing by Alfred and Sivarajasingham (2020) are as follows;

- Whenever d = 0, it means that the time series is stationary and has short memory properties. The autocorrelation function (ACF) exponentially decays to zero.
- When d = 0.5, the series is not stationary but is invertible.
- When d = -0.5, the series is stationary, however, the process is not invertible.
- When d = 1, the process has a unit root and not stationary
- For -0.5 < d < 0, the series is anti-persistent and stationary.
- A set of observations has long memory behaviour when 0 < d < 0.5. This indicates strong and positive dependency across distant observations. As explained by Alfred and Sivarajasingham (2020), there will be positive autocorrelations and the ACF will decay hyperbolically towards zero as the distance between the observations is increased.

The ARFIMA (p, d, q) model can be written as;

$$\emptyset(L)(1-L)^d r_t = \theta(L)\varepsilon_t \qquad \text{Eqn (20)}$$

Where;

- d is a fractional differencing parameter,
- L is the lag operator,
- $\emptyset(L)$ and $\theta(L)$ are lag polynomial finite orders.
- $\emptyset(L) = 1 - \emptyset L - \emptyset_2 L^2 - \ldots\ldots\ldots - \emptyset_p L^p$ is the autoregressive polynomials of finite orders.

- $\theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \ldots\ldots\ldots + \theta_q L^q$ depicts the moving average polynomial of the finite orders.
- The roots of $\emptyset(L)$ and $\theta(L)$ is located outside the unit circle, $\varepsilon_t \sim iid(0, \sigma^2)$ and (1- d)^2 is the fractional differencing operator defined as an infinite binomial series expansion in powers of the lag operator. Thus,

$$(1-L)^d = \sum_{j=0}^{\infty}(d\ j)(-L)^j = \sum_{k=0}^{\infty}\frac{\Gamma(k-d)L^k}{\Gamma(k+1)\Gamma(-d)} \quad \text{Eqn (21)}$$

Where;

- Γ is the gamma function
- r_t is both stationary and invertible if the roots $\emptyset(L)$ and $\theta(L)$ are outside the unit circle,
- d <|0.5|. The parameter d is allowed to take on any real value. This model permits the degree of differencing (d) to take fractional values.

The autocorrelation function of a long memory process decays very slowly than a short memory process. The memory behaviour of a process is determined by the value of (d). When $0 < d < 0.5$, then it means that the process is considered as a stationary process with a long memory behaviour. As noted by Hosking (1981), the autocorrelation, $\rho(k)$, of an ARFIMA process is proportional to k^{2d-1} as $k \to \infty$, $[\rho(k) \propto k^{2d-1}]$. This means that the autocorrelations of the ARFIMA processes decay hyperbolically to zero as $k \to \infty$. An autocorrelation function that decays hyperbolically in the time domain exhibits long memory behaviour. Therefore, the ARFIMA (p, d, q) model can be used to model the long memory behaviour of a series.

Data Description, Processing and Analysis

Exchange rate is simply the rate or value at which one currency can be exchanged for another currency (Buah, 2017). The study used the GHS/USD exchange rates because the US dollar is Ghana's most widely accepted and commonly traded currency in international trade (Sarpong, 2019). The study relied solely on secondary data. The data was gathered from the Bloomberg Financial Database. The data consisted of daily observations on the exchange rates of the GHS/USD exchange rate. The research is carried out using daily exchange rate data because the daily exchange rate data has the significant advantage of large samples sizes as well as high statistical significance for the findings (Muller et al., 1997). The data spans from 2000 to 2019. The data period was chosen based on the availability of adequate, accurate and consistent dataset that will allow for a thorough analysis. The data was processed using the R version 4.0.3 and Eviews version 10. Charts such as graphs and tables were used to aid in the descriptive analysis.

Unit Root Test

In the context of time-series data, it is very necessary and important to discover the properties of time series data to be used for the study to ensure that the requirements for data analysis are satisfied. To evaluate the behaviour of the GHS/USD exchange rates, an understanding of the time-series characteristics of exchange rates is a prerequisite. According to Brooks (2002), a unit root test helps to test or examine the stationarity of a time-series variable by employing an autoregressive model. A times series is stationary when its mean, variance and autocovariance do not vary when the time changes. Non-stationary data will have a changing mean, variance and autocovariance.

The Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests are some of the techniques to test for the presence of unit roots in time series data. This study adopted the Augmented Dickey-Fuller (ADF), the Phillip-Perron (PP) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests procedures to help test for unit root in exchange rate data. The primary goal of the unit root test is to make sure that the series is stationary before estimating the variable's coefficient.

Augmented Dickey-Fuller (ADF) Test

The first times series unit root testing was done by Dickey and Fuller in 1979. The basic goal of the Dickey-Fuller (DF) test is to test the null hypothesis that C=1 in $y_t = Cy_{t-1} + \varepsilon_t$ against the one-sided option of $\theta < 1$ (Adam & Owusu Junior, 2017).

The hypotheses of interest are;

HO : The series is not stationary.

H1 : The series is stationary.

According to Brooks (2002), a series has a unit root if C=1. Thus the regression model can be stated as;

$$\Delta y_t = (C-1)y_{t-1} + \varepsilon_t \quad \text{Eqn (23)}$$

Where Δ is the first difference operator. This model can be estimated and tested for a unit root is equivalent to testing μ=0 (since $C - 1 = \mu$)

Therefore;

$$\Delta y_t = \mu y_{t-1} + \varepsilon_t \quad \text{Eqn (24)}$$

One major drawback of the DF test is that; it has an assumption that the error term has no serial correlation in the error term. That is the error term

is white noise. Because of this limitation, the Augmented Dickey-Fuller (ADF) test was developed as a modification of the DF test and it involved augmenting the DF equation by lagged values of the dependent variables. It was made to ensure that the term is free from serial correlation.

The ADF equation may be expressed as:

$$\Delta y_t = B_1 + B_2 t + B_3 y_{t-1} + \sum_{i=1}^{m} a_i \Delta y_{t-i} + \varepsilon_t \quad \text{Eqn (25)}$$

Where y_t represents the times series variables, t is the time or trend variable, B_1 and B_2 are the estimated parameter, Δ is the first difference operator, a_i denotes the various estimated parameters of the differenced values of the lagged variables and ε_t is the white noise error term.

The ADF test tests the null hypothesis that a series contains unit roots against the alternative hypothesis of no unit root.

That is;

HO : The series is not stationary.

H1 : The series is stationary.

The series is stationary if the null hypothesis is rejected. If the null hypothesis is not rejected, then the series is not stationary and as such has a unit root.

Phillips and Perron (PP) Test

Phillips and Perron in 1988, developed the Phillips-Perron unit root test. According to Adam and Owusu Junior (2017), the main difference between the PP unit root test and the ADF unit root test is how the PP unit root test handles the serial correlation and heteroscedasticity in the error term.

According to Adam and Owusu Junior (2017), the Phillips-Perron test can be expressed as;

$$\Delta y_t = B_1 + B_2 t + B_3 y_{t-1} + \pi y_{t-1} + \varepsilon_t \quad \text{Eqn (26)}$$

where ε_t is $I(0)$.

The PP test rectifies heteroscedasticity and serial correlation found in the errors of the test regression by explicitly changing the t-test statistics as a function of π (Adam and Owusu Junior, 2017).

The hypothesis for the PP test is;

H0 : The series has a unit root.

H1 : The series does not have a unit root

Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Test

Despite the robustness of the ADF unit root test and the PP unit root test, these two tests have been heavily criticized. A major problem associated with the ADF unit root test and PP unit root test is that the power of the two tests is low whenever the process is stationary but has a root close to the non-stationary boundary (Adam & Owusu Junior, 2017). Again, Adam and Owusu Junior (2017) contended that the ADF unit root test and PP unit root tests are both susceptible to serious finite sample power and size problems. Both tests have a low power against the alternative hypothesis that the series is stationary with a large autoregressive root.

The KPSS unit root test was introduced to address the issues associated with the ADF and PP unit root test. The KPSS unit root test was proposed by Kwiatkowski, Phillips, Schmidt and Shin in 1992. The KPSS unit root test is a Lagrangian multiplier (LM) test statistic that is used to check for stationarity by decomposing the observable series into the sum of deterministic trends, a random walk and a stationary error (Adam & Owusu Junior, 2017). The KPSS tests the null hypothesis that the series has no unit root and the alternative hypothesis that the series has unit root.

Chapter Summary

The research methods used in conducting this study were presented in this chapter. This study is focused on the research philosophy of positivism and the quantitative research approach. This chapter presented the ensemble empirical mode decomposition (EEMD) technique; the autoregressive fractionally integrated moving average (ARFIMA) and rescaled range analysis (R/S analysis) to study the behaviour of the GHS/USD exchange rates. Even though the EEMD and the R/S analysis are robust, they are associated with some problems. Zheng, Cheng and Yang (2014) stated that when using the EEMD process, the different white noise data added to the original data generates different IMFs. Some of these IMFs may include false and irrelevant IMF components which may not meet the conditions of an IMF after the decomposition process. They explained that this problem may reduce the accuracy of the results and can lead to the misinterpretation of the results of the study.

Also, Boateng (2017) stated some of the weaknesses associated with the R/S analysis and they are; the R/S analysis requires longer data set as long-term data set offers a more realistic chance for non-periodic cycles to emerge. Also, estimation error may occur when the period is very large or very small with regard to the number of observations of the time-series data. Another problem associated with the R/S analysis is that it is sometimes susceptible to short memory behaviour. This means that the R/S analysis sometimes detects short memory behaviour without differing it from long memory behaviour.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The results and discussion of the study are presented in this chapter. The purpose of the study is to examine the behaviour of the exchange rate in Ghana by determining the main factors that influence GHS/USD exchange rates movement and the long memory properties of the GHS/USD exchange rate. First, the study discusses the descriptive statistics of the daily exchange rate used in the study. This was followed by the presentation of the results and discussion on the decomposition of the GHS/USD exchange rate by employing the ensemble empirical mode decomposition (EEMD). The last section presents the results and discussions of the estimations of the autoregressive fractionally integrated moving average (ARFIMA) model and the rescaled range analysis (R/S analysis). The EEMD, ARFIMA and the R/S analysis were the major techniques employed for analyzing the GHS/USD daily exchange rates from 2000 to 2019.

Descriptive Statistics

The purpose of this section of the chapter is to describe the basic characteristics of the GHS/USD exchange rates. Figure 1 shows the historical daily GHS/USD exchange rate from 2000 to 2019. The graphical representation of the daily exchange rates helps to identify and explain the movement and behaviour of the GHS/USD exchange rate series over the period. This graphical representation is also important because it is an alternative approach (although it is an informal approach) to check the stationarity of the series.

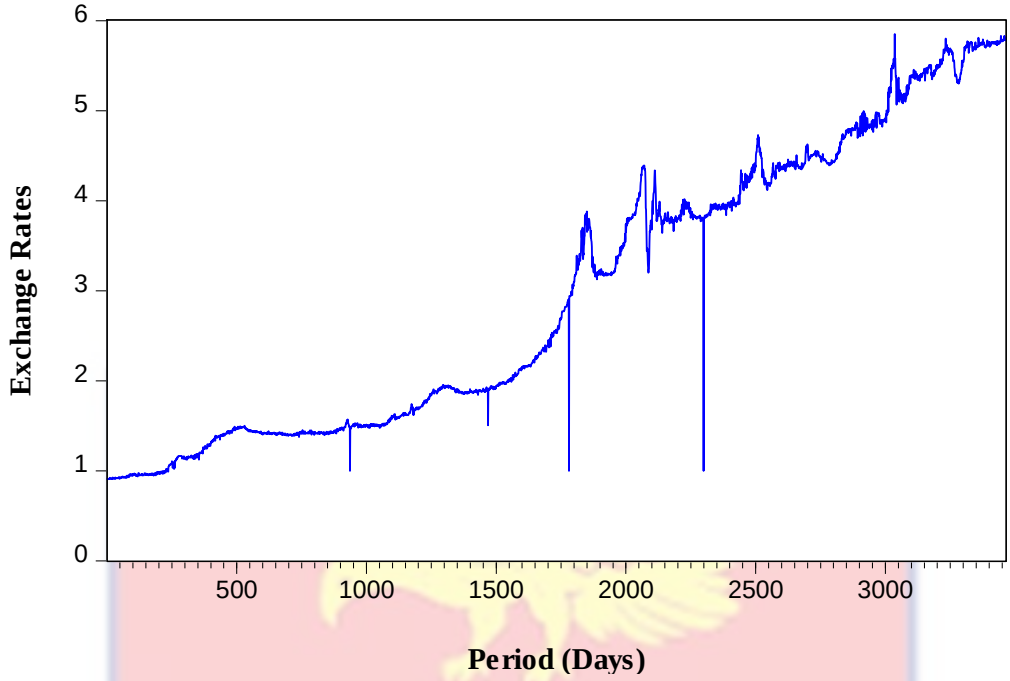

Figure 1: Historical Daily Exchange Rate between the Ghana Cedi and the US Dollar (2000 to 2019).
Source: Field survey (2021)

Figure 1 shows an upward trend of the GHS/USD exchange rates which depicts that the GHS/USD exchange rate between the Ghana Cedi and the US dollar has been increasing (depreciating) over the study period. It also shows that the GHS/USD exchange rates are non-stationary. The exchange rate in Ghana has exhibited these characteristics since the adoption of floating exchange rates in the 1980s. The observed fluctuations may be caused by visible and invisible factors such as speculative activities, macroeconomic factors among others (Arko, 2016). In 2007, the GHS/USD exchange rate showed some level of appreciation. Buah (2017) argues that the appreciation of the Ghana Cedi in 2007 was primarily due to the early stages of the redenomination of the Ghana Cedi.

Descriptive Statistics

The descriptive statistics depicts the basic characteristics of the variable used in the study. Thus, this section of the study is aimed at

explaining the key characteristics of the variable (GHS/USD Exchange rate) in this study. Specifically, this study focused on the mean which is a measure of averages, standard deviation which shows how far the observations are from the mean, maximum value shows the highest value in the current sample, minimum value also shows the minimum value in the current sample, the skewness shows the presence of symmetry or the absence of symmetry of a distribution and the kurtosis measure the peakness that is the tallness and the flatness of a distribution. Finally, the Jarque-Bera test statistics tests whether or not that the GHS/USD exchange rate series is normally distributed. The results of these test statistics are shown in Table 1 and discussed in detail.

Table 1: Descriptive Statistics for the GHS/USD Exchange Rate Series

Test-Statistics	Exchange Rate
Mean	2.980006
Median	2.546250
Maximum	5.850000
Minimum	0.902160
Standard Deviation	1.582481
Skewness	0.295006
Kurtosis	1.601934
Jarque-Bera	332.3566
Probability	0.000000*
Sum	10322.74
Sum Sq. Dev.	8672.200
Observation	3464

Note: Sum Sq. Dev. Denotes sum of squared deviation;
"*" represents significance level at 5%.
Source: Field survey (2021)

From Table 1, it is seen that GHS/USD exchange rate has a mean value of 2.98, which means that on average, with respect to the period being considered (that is, from 2000 to 2019), the exchange rate was GHS/USD

2.98. Table 1 showed that the median value of the exchange rates is GHS/USD 2.55. Table 1 also showed that the highest exchange rate recorded during the period of consideration was GHS/USD 5.85 and this occurred on 31/12/2019 whiles the lowest exchange rate was GHS/USD 0.90 and this occurred on 3/01/2000. The highest and lowest exchange rates can be seen from the maximum and minimum values in Table 1. The standard deviation of 1.58 signifies that the exchange rate deviates from the mean by GHS/USD 1.58. The skewness value of 0.29 means that the daily exchange rate data is positively skewed to the right. The kurtosis value of 1.60 suggests that the daily exchange rates data between 2000 and 2019 is platykurtic. The Jarque-Bera test statistics confirm these findings since it rejects the normality assumptions. From Table 1, the value of the Jarque-Bera test statistic is 332.3566 with a probability value of 0.000000 which rejects the null hypothesis that the data is normally distributed at a significance level of 5%. Therefore, it can be concluded that the daily GHS/USD exchange rate data is not normally distributed. From Table 1, it is evident that the total number of observations is 3464 since the datasets are daily exchange rate data ranging from 2000 to 2019.

Unit Root Test

The unit root test is a requirement for analyzing time-series data to determine and explore other intrinsic features of the data. Therefore, in this study, the stationarity status of the GHS/USD exchange rate was examined by employing the Augmented Dickey-Fuller (ADF) unit root test, the Phillips-Perron (PP) unit root test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests. The lag lengths were selected according to the Akaike

information criterion (AIC). The ADF, PP and KPSS unit root tests were employed because they are deemed to be robust. Adam and Owusu Junior (2017) explained that the ADF unit root test and the PP unit root test are similar but they differ significantly in how they deal with serial correlation. They also posited that the ADF unit root test and the PP unit root test have the same null hypothesis and alternative hypothesis. Adam and Owusu Junior also stated that the ADF unit root test and the PP unit root test normally give the same conclusion. The ADF unit root test and the PP unit root test, test the null hypothesis that the data is not stationary or the series has unit root to the alternative hypothesis that the series is stationary.

As discussed in Chapter Three, the ADF and PP unit root test has some limitations. As a result of their limitations, the study conducted the KPSS unit root test. The KPSS tests the null hypothesis that the series is stationary against the alternative hypothesis that the series is non-stationary.

The unit root test results are presented in Table 2, Table 3 and Table 4 and discussed accordingly.

Table 2: ADF Unit Root Test for the GHS/USD Exchange Rate

	|T − Statistics|	|Critical Values|	Prob.
Augmented Dickey-Fuller Test Statistics	0.023198	At levels 5% = 2.862178	0.9596
Augmented Dickey-Fuller Test Statistics	35.60879	At 1st difference 5% = 2.862178	0.0000

Source: Field survey (2021)

Table 2 shows the ADF unit root test for the daily GHS/USD exchange rates series. The Augmented Dickey-Fuller unit root test was carried out on

the GHS/USD exchange at level and the first difference to determine stationarity. The decision criteria adopted by this study to determine stationarity is that; for the series to be stationary, the critical value in absolute terms must be less than the absolute of the T-statistics. From Table 2, the result showed that the GHS/USD exchange rate series is not stationary at levels. This is because the critical value of 2.862178 is more than the T-statistics of 0.023198 and the probability value of 0.9596 is greater than the significant level of 0.05, thus, the null hypothesis is not rejected at level. But at the first difference, the GHS/USD exchange rate is stationary because the critical value of 2.862178 is less than the T-statistics of 35.60879 at a significance level of 5%. The null hypothesis is therefore rejected and it can be established that the GHS/USD exchange rate series is stationary at first difference.

Table 3: PP Unit Root Test for the GHS/USD Exchange Rate

	|T − Statistic|	|Critical Values|	Prob.
Phillips-Perron	0.054996	At level	0.9523
Test Statistic		5% = 2.862177	
Phillips-Perron	155.2631	At 1st Difference	0.0001
Test Statistic		5% = 2.862177	

Source: Field survey (2021)

Table 3 depicts the PP unit root test for the daily GHS/USD exchange rates. The Phillips-Perron unit root test was carried out on the GHS/USD exchange rate at level and at the first difference to determine stationarity. Results from Table 3 sought to test the null hypothesis that there is unit root in the series. The decision criteria to determine stationarity is that; for stationarity, the critical value in absolute terms must be less than the absolute

of the T- statistics. The result from Table 3 reveals that the GHS/USD exchange rate series is not stationary at levels. This is because the critical value of 2.862177 is greater than the T-statistics of 0.054996 and the probability value of 0.9523 is greater than 0.05, the null hypothesis is therefore not rejected. However, at the first difference, the GHS/USD exchange rate series were stationary with a critical value of 2.862177 less than the T-statistics value of 155.2631 at the significance level of 5%, hence; I reject the null hypothesis and conclude that the GHS/USD exchange rate is stationary at first difference.

Table 4: KPSS Unit Root Test for the GHS/USD Exchange Rate

	|T − Statistics|	|Critical Values|
Kwiatkowski-Phillips-Schmidt-Shin test statistic	7.458000	At level 5% = 0.463000
Kwiatkowski-Phillips-Schmidt-Shin test statistic	0.114213	At 1st difference 5% = 0.463000

Source: Field survey (2021)

Table 4 reveals the KPSS unit root test for the daily exchange rates between the Ghana cedi and the US Dollar. The KPSS unit root test was carried out on the GHS/USD exchange rate series at level and at first difference to determine stationarity. Results from Table 4 sought to test the null hypothesis that the series is stationary. The decision rule for KPSS is that; for stationarity to exist, the critical value must be more than the T-statistics in absolute terms. Table 4 reveals that the GHS/USD exchange rate series is not stationary at level since the critical value of 0.463000 is less than the value of the T-statistics of 7.458000. Thus, at level, the null hypothesis of stationarity is rejected at a 5% level of significance. However, at the first difference, the

GHS/USD exchange rate series were stationary with a critical value of 0.463000 greater than the T-statistics value of 0.114213 at a 5% significance level. Therefore, at the first difference, the null hypothesis of stationarity was accepted.

From Table 2, Table 3 and Table 4, it can be concluded that the daily GHS/USD exchange rate from 2000 to 2019 are integrated of order one [I (1)]. That is, based on ADF, PP and KPSS, the daily GHS/USD exchange rate series are not stationary at level but the GHS/USD exchange rates are stationary at first difference. According to Buah (2017), stationary time-series data have a temporary shock effect and non-stationary series have a permanent shock effect. Buah (2017) asserted that the economic meaning of unit roots is that the shocks on the time-series (daily exchange rate between the Ghana Cedi and the US Dollar) have a long-lasting effect, thus, the lack of mean reversion.

Intrinsic Mode Functions (IMFs)

The daily GHS/USD exchange rates ranging from 2000 to 2019 was used in the analysis of this study. Using the EEMD technique, the exchange rate data was decomposed into IMFs and a residual. As shown in Figure 2, the original GHS/USD exchange rate data was decomposed into ten intrinsic mode functions (IMFs) and a residue. The IMFs and the residue are presented in the manner in which they were obtained, that is, from the high frequency to the low frequency with the residual being the last mode. The IMFs amplitude and frequencies change over time. As the frequencies of the IMFs change from high frequency to low frequency, the amplitudes of the IMFs become wider.

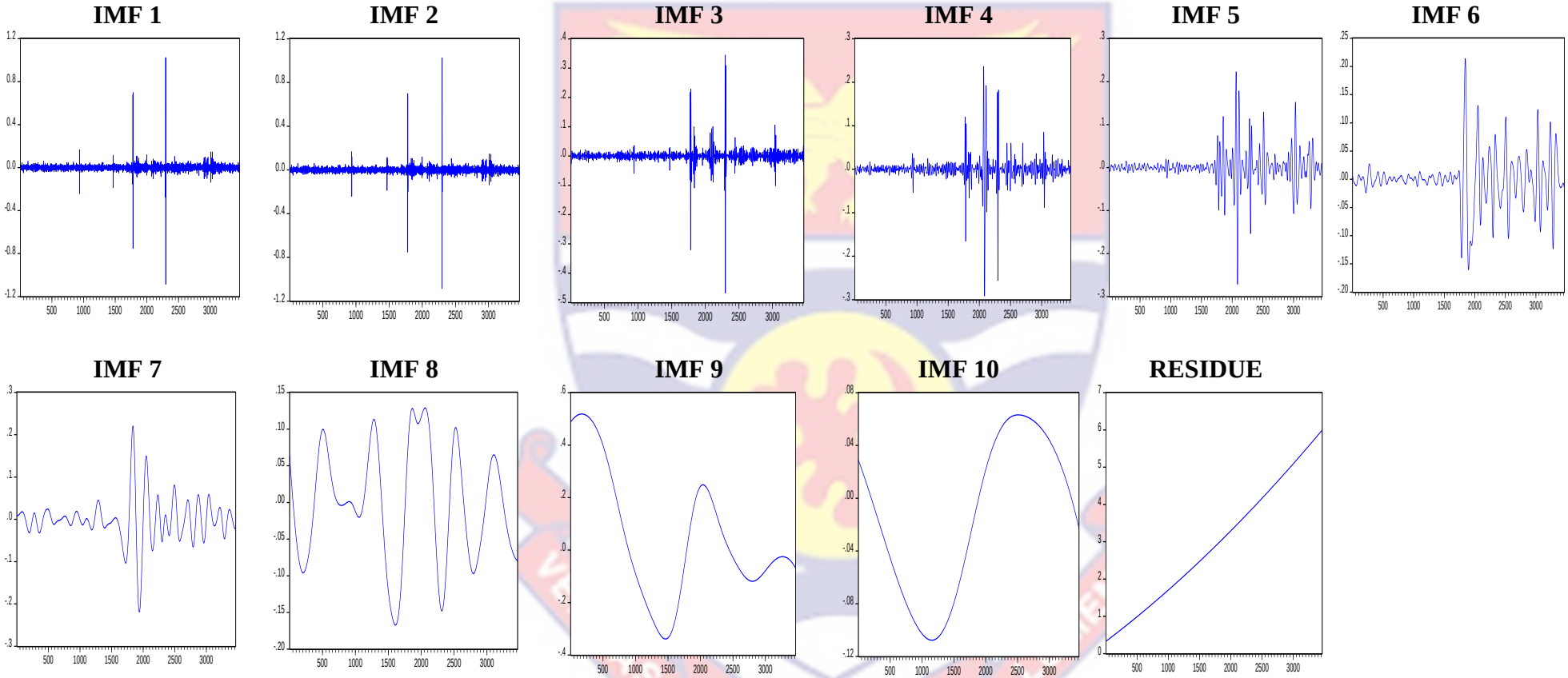

Figure 2: The IMFs and Residue of the Daily GHS/USD Exchange Rate (2000 to 2019).
Source: Field survey (2021)

Intrinsic Mode Functions and the GHS/USD Exchange Rates

Objective 1 of this study was to determine which Intrinsic Mode Functions (IMFs) influenced the GHS/USD exchange rate movement. This objective was achieved by analyzing the descriptive statistics of the IMFs. The statistics used to analyse the IMFs are; the mean period of each IMF, the correlation between the original GHS/USD exchange rate series and each of the IMFs, the variance percentage of each of the IMFs to the original GHS/USD exchange rate series and the sum of all the IMFs and the residue. The mean period of each IMF is obtained by dividing the total number of points by the number of peaks of each IMF since the frequencies of IMFs keep on changing with time continuously without constant periods. In this study, the Pearson product-moment correlation coefficient and Kendall rank correlation coefficient were used to determine and analyse the relationship between each of the IMFs and the original GHS/USD exchange rate series. When the correlation coefficient is greater, it means the IMFs have a stronger relationship or greater influence on the original exchange rate series. Also, the variance percentages of each IMF were calculated. Since these IMFs are intrinsically independent, this study used the percentage of the variance to analyse the contribution of each IMF to the fluctuations of the original GHS/USD exchange rate series. The IMFs are significant because they show the various time scales of the observed time series (Huang et al., 1998). Also, the IMFs help to better analyse and understand the market considering the nonlinearity and the non-stationarity of the observed time-series data (Owusu Junior, Tiwari, Padhan & Alagidede, 2020). The measures used to analyse the features of the IMFs are shown in Table 5.

Table 5: Measure of IMFs and the Residue for the GHS/USD Exchange Rates Derived from EEMD

	Mean Period (Days)	Pearson Correlation	Kendall Correlation	Variance as % of Observed	Variance as % of $(\sum IMFs + residual)$
IMF 1	1.40	0.027	0.014	0.08	0.073
IMF 2	2.57	0.023	0.007	0.034	0.031
IMF 3	4.91	0.024	0.009	0.029	0.026
IMF 4	9.57	0.036	0.009	0.034	0.031
IMF 5	20.14	0.036	0.004	0.058	0.053
IMF 6	45.58	0.053	0.042	0.083	0.075
IMF 7	84.49	0.073	0.008	0.108	0.098
IMF 8	192.44	0.025	0.012	0.244	0.221
IMF 9	384.89	-0.339	-0.283	2.386	2.159
IMF 10	577.33	0.693	0.331	0.139	0.126
Residue	866.00	0.981	0.939	107.3	97.108

Source: Field survey (2021)

As shown in Table 5, it can be seen that the residue is the dominant mode of the GHS/USD exchange rates. The residue has a mean period which is more than 2 years. The Pearson correlation coefficient and the Kendall correlation coefficient between the residue and the original exchange rates are 0.981 and 0.939 respectively. This means that there is a very strong and positive relationship between the residue and exchange rates. Also, the residue makes a 97.108% contribution towards the fluctuations in the GHS/USD exchange rates. This means that a greater proportion of the total volatility in the GHS/USD exchange is explained by the residue. The residue shows a deterministic long-term behaviour. This suggests that the exchange rate market in Ghana is driven mainly by fundamentals, which are most probably rooted in long-term macroeconomic fundamentals. This finding is consistent with the

previous study by Adam, Kyei, Moyo, Gill and Gyamfi (2021) who studied the exchange rate behaviour in the Southern African Development Community (SADC) and observed that domestic currencies to USD of all of the 15 SADC countries were driven by economic fundamentals. This finding is not surprising because the exchange rate market is normally engaged by market participants such as the governments and the central banks whose motives are driven by macroeconomic performance.

IMF 9 and IMF 10 have a mean period of more than one year but less than two years which depicts medium to long-term characteristics which are usually influenced by effects of significant events. The effects of significant events such as financial crisis, diseases or pandemics, bad weather, political impacts, significant changes in relations and politics, natural disasters etc. (Zhang, Lai & Wang, 2008; Zheng & Qu, 2014) are primarily represented by IMF 9 and IMF 10. With the Pearson correlation of -0.339 and Kendall correlation Coefficient of -0.283, IMF 9 has a weak and negative relationship with the original GHS/USD exchange rate series. IMF 10 has a Pearson correlation coefficient of 0.693 and a Kendall correlation coefficient of 0.331. The sum of the variances for IMF 9 and IMF 10 shows that IMF 9 and IMF 10 contribute about 2.285% of the total volatility in the GHS/USD exchange rate series. This means that when these events occur they make a contribution of 2.285% towards the total fluctuations in the GHS/USD exchange rates. The mean periods of IMF 9 and IMF 10 are 384.89 days and 577.33 days respectively, and this signifies that the effect of these significant events, when they occur, last for more than one year but less than two years.

In addition, IMF 1 to IMF 8 contributes only 0.608% of the total fluctuations in the original GHS/USD exchange rate series. This means that IMF 1 to IMF 8 does not have any serious impact on exchange rate movements. IMF 1 to IMF 5 has a mean period which is less than 30 days and contributes only 0.214% of the total volatility in the GHSUSD exchange rate series. IMF 1 to IMF 5 has a mean period which is less than 30 days, thus IMF 1 to IMF 5 is considered to have short-term durations. Consistent with the heterogeneous market hypothesis, short-term durations are assumed to correspond to speculative factors (Tittle, 2008). Therefore, IMF 1 to IMF5 represent speculative factors. The variance percentage of IMF 1 to IMF 5 means that speculative factors contribute only 0.214% to the total volatility of the GHS/USD exchange rates. This suggests that speculative activities have little impact on the movement of the GHS/USD exchange rate. This empirical finding is in line with the findings of Amoa-Gyarteng (2016) and Omane-Adjepong et al. (2018), who discovered that speculative activities have little or no impact on the behaviour of exchange rates.

IMF 6 to IMF 8 on the other hand have a mean period which is more than 30 days but less than 365 days and contributes 0.394% of the total fluctuations in the original data series. The mean period of IMF 6 and IMF 8 ranges between 45.58 days and 192.44 days. This shows that IMF 6 to IMF 8 can be considered to have a medium-term duration. Consistent with the heterogeneous market hypothesis, the medium-term duration corresponds to the business cycle of the economy (Donati & Donati, 2008). The variance percentage of IMF 6 to IMF 8 is 0.394% and this shows that business cycle contributes just 0.394% to the fluctuations in the GHS/USD dollar exchange

rates. This indicates that business cycles have little influence on the movement of exchange rates. Therefore, IMF 1 to IMF 8 has no significant effect on the movement of exchange rates.

Generation Frequency and GHS/USD Exchange Rate Behaviour

Objective 2 of this study is to determine which generation frequency influences the GHS/USD exchange rate behaviour. This objective was achieved by classifying the intrinsic mode functions (IMFs) into the high-frequency components, medium-frequency components and low-frequency components. Table 6 presents the reconstruction of the ten IMFs into the high-frequency components, medium frequency components and low-frequency components using the mean periods. Using the mean periods, IMF1 to IMF5 can be recognized as the short-term components, IMF 6, IMF 7 and IMF 8 can be treated as the medium-term components whiles IMF 9 and IMF 10 are recognized as the long-term components. The short-term components correspond to mean periods less than 30 days (high-frequency components), the medium-term components represent IMFs with mean periods of more than 30 days but less than 365 days (medium-frequency components). The long-term components correspond to mean periods above one year but less than two years (low-frequency components). According to Bouoiyour et al. (2016), the residual varies slowly around the long-term mean thus the residual is regarded as the long-term trend component with a mean period of two years and above. The low-frequency components correspond to the effect of significant events; the medium frequency components represent the business cycle, the high-frequency components correspond to the speculative activities whiles the trend component represents the long-term macroeconomic fundamentals (Bouoiyour

et al, 2016; Tiwari et al. 2016; Zhang et al. 2008; Zeng & Qu, 2014; Zhu et al. 2013).

Table 6: Correlation and Variance of Components for the GHS/USD Exchange Rate

Components	Pearson Correlation	Kendall Correlation	Variance as % of Observed	Variance as % of $(\sum IMFs + residual)$
High Frequency	0.057	0.009	0.3	0.27
Medium Frequency	0.066	0.007	0.604	0.545
Low Frequency	-0.149	-0.228	2.794	2.517
Trend	0.981	0.939	107.3	96.668

Source: Field survey (2021)

To analyse the relationship of the various components with the original series, the Pearson correlation coefficient and the Kendall correlation coefficient were calculated presented in Table 6. The Pearson correlation coefficient and the Kendall correlation coefficient between the observed GHS/USD exchange rate and the high-frequency component are 0.057 and 0.009, respectively. This means that there is a very weak but positive relationship between the high-frequency component and the observed GHS/USD exchange rate series. Also, the variance percentage of the high-frequency component is 0.27%. This means that the high-frequency component contributes less to the total variability that exists in the original GHS/USD exchange rates. The correlation coefficients and variance percentage of the high-frequency component show that the high-frequency component (speculative activities) has a weaker effect on the movement of the

exchange rates. This conforms to the findings of Omane-Adjepong et al. (2018), who found out that the foreign exchange market is heterogeneous, thus, the heterogeneity in the exchange rate market gives very little room for speculative activities to drive or influence the movement of exchange rates in Ghana. In addition, this empirical finding is consistent with the work of Amoa-Gyarteng (2016) who concludes that speculative activities have minimal or no effect on the movement of exchange rates in Ghana. Amoa-Gyarteng (2016), additionally, contended that a domestic currency is only vulnerable to speculative attacks when a country's fiscal position is weak.

The medium-frequency component with a Pearson correlation coefficient of 0.066 and Kendall correlation coefficient of 0.007 depicts that the medium-frequency component (Business cycle) has a very weak but positive relationship with the original GHS/USD exchange rates. The variance percentage of the medium-frequency component shows that the medium-frequency component contributes 0.545% to the total volatility of the GHS/USD exchange rate data. According to the International Monetary Fund World Outlook (1998), business cycles and exchange rates are interrelated. The IMF world outlook explained that domestic currencies tend to appreciate during economic upturns (expansion) and depreciate during economic downturns (contractions). This explains the positive relationship between business cycles and GHS/USD exchange rates but the effect is very weak.

Table 6 also depicts that there is a weak and negative relationship between the low-frequency component (effect of significant events) and the observed exchange rate data because the Pearson correlation coefficient and the Kendall correlation coefficient between the low-frequency component and

the observed GHS/USD exchange rate series are -0.149 and -0.228 respectively. The low-frequency component also contributes 2.517% to the total fluctuations in the original GHS/USD exchange rate data. This means that the occurrence of any significant event will have a negative effect on the Ghanaian currency, thus the Ghana Cedi will depreciate against the US dollar.

IMF 9 and IMF 10 are primarily recognized as low-frequency components since their mean periods are above one (1) year but less than two (2) years. The low-frequency components represent the impact of significant events on exchange rates (Zhang, Lai & Wang, 2008; Zheng & Qu, 2014). Therefore, IMF 9 and IMF 10 mainly describe the effect of significant events. Some examples of these events are; financial crisis, pandemics or diseases, bad weather, natural disasters, political impacts, significant changes in international relations and politics, etc. With the advancement of world economic globalization, the impact of local significant trend events will spread globally (Zheng & Qu, 2014).

For instance, the 2007/2008 US financial crisis had an impact on the global economy. According to Duah (2018), the financial crisis of 2007/2008 brought about a barrage of shocking news about weak financial systems, bank failure to service debt, depreciating currencies and low international. Because of the effect of the downturn on commodity prices, the Ghanaian economy, which trades primarily with the United States and the European Union, was not immune to the global crisis, as most investors fled to alternative investments as a form of haven (Duah, 2018). Ltaifa, Kaendera and Dixit (2009), investigated the effect of the US financial crisis on the currencies of the majority of Sub-Saharan African countries. According to their research,

the currencies of Ghana, Kenya, Zambia, Nigeria and Uganda depreciated against the US dollar by at least 20% from June 2008 to March 2009 and this is in line with the empirical findings of the study.

The emergence of Coronavirus Disease (COVID-19) is also an example of a significant event that has affected the movement of the GHS/USD exchange rate. According to the Bank of Ghana quarterly report between January 2020 and March 2020, the Ghana Cedi appreciated by 1.7 percent against the US dollar. Despite the appreciation of the Ghana Cedi against the US dollar at the start of the year, the effect of the COVID-19 pandemic had eroded all of the Cedi's gains away. This resulted in the Cedi's depreciation. The Bank of Ghana quarterly report between April 2020 and June 2020 stated that the Ghana Cedi depreciated by 4 percent against the US dollar. Also, between July 2020 and September 2020, the Ghana Cedi depreciated against the US dollar by 0.6 percent (Bank of Ghana quarterly report, July 2020–September 2020). According to Quartey (2020), the depreciation was expected given the impact of the COVID-19 pandemic on global trade. Quartey further contended that the exchange rates are determined by the interaction of foreign exchange demand and supply. On the supply side, he explained that Ghana's foreign exchange supply had decreased because Ghana was unable to export due to border closure and because the oil and other commodity prices have fallen as a result of the pandemic. For the demand side, he mentioned that demand for foreign currencies increased since Ghanaians were converting their Ghana Cedi into US dollars with the hopes of being able to trade once the borders were opened.

The Pearson correlation coefficient and the Kendall correlation coefficient between the trend component and the original exchange rate data are 0.981 and 0.939 respectively with a contribution of 96.668% to the total volatility in the original exchange rate data. The trend component's contribution to the volatility in the original GHS/USD exchange rate series is the highest and this means that a greater proportion of the total volatility in the original data series is explained by the trend component. This means that the trend component (long-term macroeconomic fundamentals) has a very strong and positive relationship with the GHS/USD exchange rate series. This also means that the GHS/USD exchange rates are mainly driven by long-term macroeconomic fundamentals. This is therefore not surprising given that the exchange rate markets are typically engaged by market participants specifically the government and central banks whose motivations are driven by macroeconomic performance. This empirical finding is consistent with the work of Adam et al. (2021) who applied the EMD and the EEMD to determine the main drivers of the exchange rate of the Southern African Development Community (SADC). They concluded that the exchange rates in SADC are mainly driven by macroeconomic fundamentals. In Ghana, the finding of this study is also in line with the work of Anku (2018) who concluded that the fundamentals of the Ghanaian economy play a very significant role in determining the GHS/USD exchange rate. Also, these empirical findings confirm the findings of the studies of Adusei and Gyapong (2017) and Mumuni and Owusu-Afriyie (2004) who conclude that the Ghana Cedi / US Dollar exchange rate is heavily influenced by macroeconomic fundamentals.

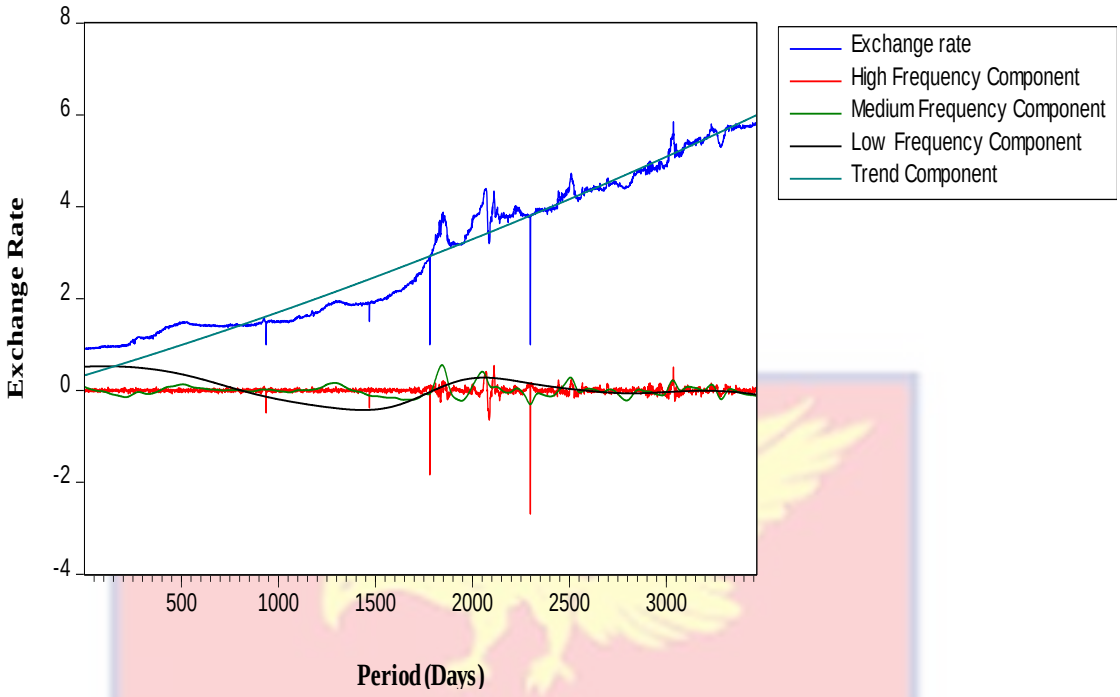

Figure 3: The Four Components of the GHS/USD Exchange Rate Series from 2000 to 2019.
Source: Field survey (2021)

The curves of the four components, as well as the original GHS/USD exchange rates series, are depicted in Figure 3. The exchange market's short-term fluctuations are generally represented by the high-frequency component. The high-frequency component is consistent with speculative activities, the medium frequency is consistent with the business cycle and the low frequency corresponds with the effect of significant events. The long-term trend component represented by the residue component is consistent with long-term macroeconomic fundamentals.

Long memory behaviour of the original and denoised GHS/USD exchange rates

Objective 3 was to investigate the presence of the long memory behaviour in the original GHS/USD exchange rate series and the denoised GHS/USD exchange rate time series. To achieve this objective, the EEMD

was used to denoise the original GHS/USD exchange rate and the ARFIMA and the R/S analysis were used to determine the long memory behaviour. First, the ARFIMA model was employed to investigate the long memory behaviour of the original and denoised GHS/USD exchange rate. Then the R/S analysis was also employed to investigate the long memory properties of the original and denoised GHS/USD exchange rates.

This section presents the results of long memory behaviour in GHS/USD exchange rates ranging from 2000 to 2019 using two long memory approaches; the rescaled range analysis with Hurst exponent method and the autoregressive fractionally integrated moving average (ARFIMA) method.

The ARFIMA model was proposed by Granger and Joyeux (1980) and Hosking (1981) to examine long memory properties in time series data. The ARFIMA model generalizes the Autoregressive Integrated Moving Average (ARIMA) model by allowing non-integer values of the differencing parameter (d) to take up the real values rather than being limited to the integer domain. The long memory characteristics of a process depend greatly on the value d takes on.

The Rescaled range was first introduced by Hurst in 1951 in hydrological research. It was later improved by Mandelbrot in 1963 in studying the fractal nature of financial markets. The R/S analysis uses the Hurst Exponent which is denoted by (H) to analyse the long memory behaviour in time series data. The value of the Hurst Exponent ranges from 0 to 1 (Raimudo & Okamaoto-Junior, 2018).

Table 7 summarizes the general interpretation of H and *d* concerning the nature of long memory properties following the interpretation given by Boateng (2017) and Alfred, and Sivarajasingham (2020).

Table 7: Interpretation of the Hurst Exponent and the Fractional Differencing Parameter

Hurst Exponent (H)	Fractional Differencing Parameter (*d*)	The behaviour of the Process
H = 0.5	*d* = 0	Random Walk Process
0.5 < H < 1	0 < *d* < 0.5	Long Memory Behaviour (Persistent Behaviour)
0 < H < 0.5	-0.5 < *d* < 0	Anti-persistent (Mean Reversion)

Source: Field survey (2021)

Denoising of Data

The daily exchange rate data were denoised before determining the long memory properties. Denoising helps to reduce the influence of noise in the original GHS/USD series; that is the extraction of a signal from a signal-noise mixture. When data is analysed in the presence of noise, it mostly results in incorrect interpretation of the data. Thus, denoising allows us to concentrate on the most important components of the time series. The daily exchange rate data were denoised by applying the wavelet thresholding in the EMD. This was done by performing the thresholding in each of the IMFs so that the low-energy IMF component that is expected to be influenced and corrupted significantly by noise is locally excluded. Figure 4 depicts the denoised daily GHS/USD exchange rate ranging from the period 2000 to 2019.

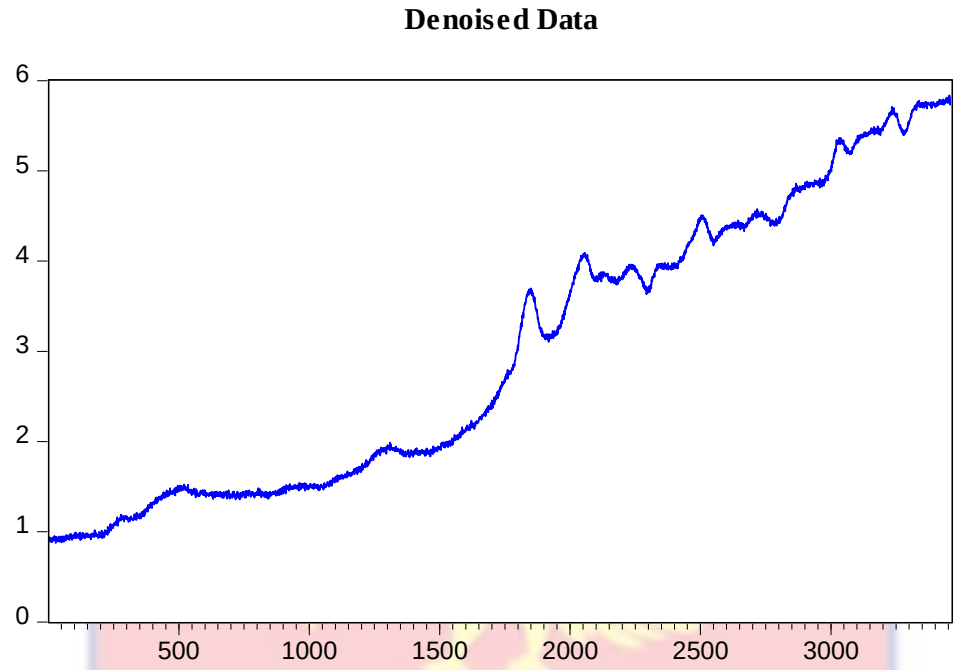

Figure 4: Denoised Daily GHS/USD Exchange Rate Ranging from 2000 to 2019.
Source: Field survey (2021)

The ARFIMA model and the Hurst Exponent were estimated using R. The results from the estimation are presented in Table 8, Table 9 and Table 10.

Table 8: Results from ARFIMA for the GHS/USD Exchange Rates Series

	Estimates	Standard Error	Z value	P-value
d	0.4998495	0.002194	2278.462	2e-16

Note: *d* is the fractional differencing.
Source: Field survey (2021)

Table 8 depicts the estimated results from ARFIMA for GHS/USD exchange rates. Table 8 shows the memory property of the GHS/USD exchange rates. The memory behaviour of a process depends greatly on the value of *d*. Therefore, it can be concluded from Table 8 that the GHS/USD exchange rates have long memory since the value of *d*, which is 0.4998495, is between the intervals of 0 to 0.5. In addition, the P-value of the fractional differencing parameter, *d*, indicates that the estimated value of *d* is statistically

significant. This implies that the daily exchange rates between the Ghana Cedi and the US Dollar ranging from 2000 to 2019 exhibit long memory behaviour.

Table 9: Results from ARFIMA for the Denoised GHS/USD Exchange Rate Series

	Estimates	Standard Error	Z value	P value
d	0.4999	0.00006018	8307.88	2e-16

Note: *d* is the fractional differencing.
Source: Field survey (2021)

Table 9 shows the estimated results of the denoised GHS/USD exchange rates series using the ARFIMA model. The denoised daily exchange rates between the Ghana Cedi and the US Dollar have long memory properties as the value of *d*, which is 0.4999, lies between the interval of 0 and 0.5. At a significance level of 5%, Table 9 signifies that the fractional-differencing parameter, *d*, is significant. The estimated value of the long memory parameter *d* reveals that the denoised GHS/USD exchange rates have a long memory behaviour.

Table 10: Hurst Exponent Estimate for the GHS/USD Exchange Rates and the Denoised GHS/USD Exchange Rates

	Daily Exchange Rate	Denoised Daily Exchange Rate
Hurst Exponent	0.9044449	0.8789704

Source: Field survey (2021)

Table 10 depicts estimated results for both the daily GHS/USD exchange rates and the denoised GHS/USD exchange rates. The Hurst Exponent for the daily GHS/USD exchange rates and the denoised GHS/USD exchange rates series with respect to the period being considered are 0.9044449 and 0.8789704, respectively. The Hurst exponent obtained for both

series are within the interval of 0.5 and 1, this implies that both the original and the denoised GHS/USD exchange rate series exhibit long memory properties.

From Table 8, Table 9 and Table 10 the estimated results from the ARFIMA model and the Hurst exponent show that the daily exchange rates and the denoised daily exchange rates between the Ghana Cedi and the US Dollar exhibit long memory properties. The long memory property of the GHS/USD exchange rates series with the period ranging from 2000 to 2019 indicates that the series is persistent. Both the ARFIMA model and Hurst's rescaled range analysis justify that GHS/USD exchange rates, concerning the period being considered, possesses long memory properties. The persistence in the GHS/USD exchange rates series suggests that a higher exchange rate tend to be followed by another higher exchange rate and the lower exchange rate will be followed by another lower exchange rate. The long memory property in GHS/USD exchange rates means that future GHS/USD exchange rates can be predicted by past GHS/USD exchange rates.

This empirical finding is consistent with the work of Aidoo, Saeed, Ababio, Nsowah-Nuamah and Louis (2012) which concludes that GHS/USD exchange rates have long memory properties, thus, the exchange market in relation to the Ghana Cedi and the US Dollar is inefficient and can be predicted with past exchange rates and information. The long memory property makes a financial market predictable; therefore this allows investors to exploit the market for profit. This makes the exchange rate market in Ghana inefficient and unstable. The empirical findings of this study are consistent with existing studies presented by (Aidoo, Saeed, Ababio, Nsowah-Nuamah &

Louis, 2012; Caporale, Gil-Alana & Plastun, 2019; Floros, 2008; Raimundo & Okamoto-Junior, 2018) in Ghana and other countries. This empirical study is not consistent with the findings of Uthayakumar and Prabha (2014) which showed that their exchange rates series is a random walk process and there is no correlation between the present and past values.

Chapter Summary

The primary objective of the study was to examine the behaviour of the GHS/USD exchange rates. The study used the Eviews Version 10 and R version 4.0.3 as the statistical software to analyse the data. This chapter presented the descriptive statistics on the variable (GHS/USD exchange rate). The ADF, PP and KPSS unit root test revealed that the daily GHS/USD exchange rates series are not stationary at level but became stationary at the first difference level. The ensemble empirical mode decomposition (EEMD), the Pearson correlation and the Kendall correlation were used to analyse the first and second research objectives of the study.

The objectives were to determine which Intrinsic Mode Functions (IMFs) and which generation frequency influenced the behaviour of GHS/USD exchange rates. It was discovered that the residue and trend components (macroeconomic fundamentals) were the main drivers of GHS/USD exchange rates. This is because the exchange rate markets are mainly engaged by the government and the central bank whose motivations are driven by the performance of macroeconomic fundamentals. Also, the autoregressive fractionally integrated moving average (ARFIMA) and the rescaled range analysis (Hurst exponent) were used to investigate the presence of long memory in the GHS/USD exchange rates. The ARFIMA and the R/S

analysis were both used for robustness purposes. The result from both the ARFIMA and the R/S analysis justify that the GHS/USD exchange rates with respect to the period being considered to possess long memory properties. Thus, this means that the exchange rate market in relation to the Ghana cedi and the US dollar is inefficient since past GHS/USD exchange rates information can be used to predict the future movement of the GHS/USD exchange rates.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Introduction

Chapter five presents the summary, conclusion and recommendations and also suggestions for further research. The first section of this chapter is the summary of the study which gives a brief overview of the purpose of the study, the research objectives, the research method employed and findings; whereas the conclusion summarizes the main points from the result and discussion section and the most important findings of the research. Recommendations are derived from the key findings of the study. Recommendations call for specific measures to be taken regarding policy, practice, theory or future research works. In addition, the chapter also makes suggestions for future and further studies.

Summary of the Study

The main aim of the study was to assess the behaviour of the GHS/USD exchange rate in Ghana by determining the main drivers or factors that influenced GHS/USD exchange rate behaviour in Ghana. To achieve this objective, the main objective was divided into three specific objectives. The first objective was to determine which intrinsic mode function influenced the behaviour of the GHS/USD exchange rates. The second objective was to determine which generation frequency (high-frequency component, medium-frequency component and low-frequency component and the trend component) influenced the behaviour of the GHS/USD exchange rate in Ghana. Lastly, the study investigated the presence of long memory behaviour in the GHS/USD exchange rate time series. The study also presented the

significance of the study, delimitations, and limitations, definition of terms and organisation of the study.

The research was based on the heterogeneous market hypothesis (HMH). The HMH presented the theoretical foundations for the study. After a thorough review of the previous empirical literature on the subject of the study, it was discovered that there have been few studies in Ghana that have used the EMD and EEMD techniques, particularly with the GHS/USD exchange rate data to reveal the intrinsic characteristics and the main drivers of the exchange rate in Ghana. It is also clear that there is little research in Ghana on the long memory behaviour of the GHS/USD exchange rates.

Chapter three presented the research method of the study. The study focused on the research philosophy of positivism and the quantitative research approach. The study also adopted explanatory research. To examine the dynamics of the GHS/USD exchange rates, the study used the ensemble empirical mode decomposition (EEMD) techniques and Hurst's rescaled range analysis (R/S analysis) and the ARFIMA model. The data was collected from Bloomberg Financial Database. The data consisted of the daily GHS/USD exchange rate. The data ranged from the year 2000 to the year 2019. The data was analysed using Eviews and R programming software. In addition, the study's results and discussion were presented in chapter four.

Summary of Findings

In the first stage of the analysis, the study provided descriptive statistics for the GHS/USD exchange rates used in the study. The descriptive statistics included the measure of dispersion, and the mean value, the maximum and the minimum value, the kurtosis and skewness as well as the

Jarque-Bera test statistics. The study further presented the unit root analysis. The study used the ADF, PP and KPSS unit root test to check and examine the stationarity status of the GHS/USD exchange rate series. It was observed that the GHS/USD exchange rate was not stationary at level but was stationary at first difference based on the ADF, PP and KPSS unit root test at a 5% level of significance. The study's findings were primarily focused on the three objectives.

Objective 1 was to determine which intrinsic mode function influenced the GHS/USD exchange rates behaviour. The second objective was to determine which generation frequency influenced the behaviour of the GHS/USD exchange rates and the third objective was to investigate the presence of long memory in the GHS/USD exchange rate series. For the first research objective, the GHS/USD exchange rate series was decomposed into ten (10) IMFs and a residue using the EEMD. The decomposition of the data into IMFs assisted in revealing hidden and detailed information that was hidden in the series which provided a better understanding of the dynamics of the GHS/USD exchange rate series over time and also the robustness of the results. The IMFs were evaluated using the following measures; the mean period, correlation of the IMFs with the original series and the contribution of each IMF to the volatility of the original series. It was found out that the residual was the dominant mode of the GHS/USD exchange rate. Based on the Pearson correlation coefficient and the Kendall correlation coefficient, it was revealed that the residue has a very strong and positive relationship with the GHS/USD exchange rates. From the results, it became known that the residue contributed to a greater proportion of the total volatility in the GHS/USD

exchange rates. This suggests that the GHS/USD exchange rates are mainly driven by macroeconomic fundamentals.

For the second objective, the IMFs were then reconstructed into four-generation frequencies; that is the high-frequency component, medium-frequency component, low-frequency component and the trend component. It was observed that the trend component which corresponds to macroeconomic fundamentals had a strong and positive relationship with the observed daily exchange rate data. The study revealed that the high-frequency components (Speculation) and the medium-frequency component (business cycle) had a very weak but positive correlation with the GHS/USD exchange rate series. It was found out that there was a weak and negative relationship between the low-frequency components which is consistent with significant events and the observed exchange rate data.

For the third objective, two techniques namely; the ARFIMA model and the rescaled range analysis were used to investigate the presence of long memory in the GHS/USD exchange rate data. The GHS/USD exchange rate data were denoised before determining the long memory properties. Denoising the data simply means reducing the noise in the data. The GHS/USD exchange rate data were denoised by applying the wavelet thresholding in the EMD. The estimated results from the ARFIMA technique for both the denoised GHS/USD exchange rate data and the original exchange rate data showed that the GHS/USD daily exchange rate has long memory properties. When the R/S analysis technique was used, similar results were obtained. The findings indicated that both the GHS/USD exchange rate series and the denoised exchange rates have long memory properties.

Conclusions

The primary aim of this study was to examine the behaviour of daily GHS/USD exchange rates in Ghana from the year 2000 to 2019 by determining the main drivers of the GHS/USD exchange rates and also by investigating the long memory of the daily GHS/USD exchange rates. The following conclusions were reached taking into account the research objectives and the major results and findings of the study.

For the first objective, it was observed that the residue was the dominant mode in the GHS/USD exchange rate movements. The residue corresponds to macroeconomic fundamentals therefore it can be concluded that the GHS/USD exchange rates are mainly driven by macroeconomic fundamentals.

For the second objective, it was revealed that speculative activity has little or no effect on the movement of GHS/USD exchange rates in Ghana. The result from the second objective showed that the trend component which is consistent with macroeconomic fundamentals, mainly drive or influence GHS/USD exchange rate movement in Ghana. It is concluded that macroeconomic fundamentals are the main drivers of the GHS/USD exchange rates and also account for the larger proportion of the total volatility in the GHS/USD exchange rate.

For the third research objective, the result revealed that the GHS/USD exchange rates have long memory properties. This indicates that the GHS/USD exchange rates series is persistent. The long memory of the GHS/USD exchange rates suggests that the impacts of shocks on the exchange rate last for a long time. The long memory properties of the GHS/USD

exchange rate also mean that future exchange rates can be predicted by past exchange rates, therefore, investors can exploit the exchange rate market for profit. This makes the exchange rate market inefficient. Based on the result, it is concluded that the GHS/USD exchange rate has long memory properties. Also, the presence of the long memory properties contradicts the efficient market hypothesis (EMH) which suggests that the exchange rate market should follow the martingale process. Therefore it can be concluded that the exchange rate market is inefficient and can be predicted using past exchange rate information.

Recommendations

The results and findings from the study show the importance to adopt policies to ensure a stable GHS/USD exchange rate. The following are proposed as recommendations based on the findings from the study.

From the findings of the study, it was observed that the movements in the GHS/USD exchange rates were mainly influenced by long-term factors. Therefore, it is recommended that policymakers should avert policy formulation aimed at tackling fluctuations in the movement of exchange rates from short-term policies to long-term policies.

Financial institutions, investors as well as other participants of the exchange rate market must hedge their investments from the varied volatilities that exist in the exchange rate market.

Government agencies such as the Ministry of Finance and the Foreign Exchange Development Committee and policymakers must pay close attention to the shocks in the macroeconomic fundamentals and assess their impact on the exchange rate when formulating and implementing exchange rate policies.

The monetary policy unit of the Bank of Ghana must monitor the movement of macroeconomic fundamentals to help them put in place measures to achieve the inflation targeting goal.

The Bank of Ghana must pay particular attention to the movement of macroeconomic fundamentals to be well-informed about strategies to use when formulating and implementing monetary policies and fiscal policies for the exchange rate to be stable.

Financial intermediaries, as well as financial managers of national and multinational corporations, must closely monitor the movement of macroeconomic fundamentals to predict the movement of exchange rates and assist them to decide on the best internal management method for managing exchange rate risk.

Suggestion for Further Research

More empirical studies are required in this area of study since it cannot be denied that there is little research done in this field of study. Therefore, the following are some suggestions made for further research. Firstly, future studies can look at the behaviour of GHS/USD exchange rates during the COVID-19 period using the EEMD. Additionally, different frequencies such as weekly and monthly time series data could be used in future studies to investigate the behaviour of exchange rates in Ghana. Also, further studies can test for the long memory properties for the IMFs as well as the generation frequency components. This will help give detailed information to better explain the relationship between the original exchange rate series and each IMF.

Future studies can also study the behaviour of exchange rates in Ghana by using other currency pairs such as the Ghana cedi/ Pound sterling (GHS/GBP), Ghana cedi/ Australian Dollar (GHS/AUD), Ghana cedi/ Euro (GHS/EUR), Ghana cedi/ Naira (GHS/NGN) etc. To overcome the limitations associated that with the EEMD technique, further studies can employ the complete ensemble mode decomposition with adaptive noise (CEEMDAN) and improved complete ensemble empirical mode decomposition with adaptive noise (ICEEMDAN) to investigate the behaviour of exchange rates in Ghana. Finally, additional research should be conducted to find out if the long memory of macroeconomic factors that influence exchange rate movement in Ghana is motivated by the long memory of exchange rates in Ghana.

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