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Determinants of exchange rate in Ghana: Cointegration and wavelet analysis

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Declaration

I hereby declare that except where specific reference is made to the work of others and acknowledge in customary manner, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements.

I declare that this project has been fully done by me and duly supervised.

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Contents

Dedication

This work is dedicated to my beloved late father, John Jingo Abavare, for not living to see me having formal education

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Abstract

We empirically examine the determinants of the nominal exchange rate in Ghana using both time series econometric techniques and wavelet application for annual data spanning the period 1960-2014. The determinant variables under consideration included: inflation, supply of money(M1 and M2), GDP growth and trade openness. In particular, Engle-Granger method was used to test for the causal relationship, wavelets power and wavelets coherency spectrum for direction of co-movements among the variables were applied. In addition, we determine the long and short run relationships between nominal exchange rate and its determinants using autoregressive distributive lag (ARDL) and other variants of ordinary least square cointegration techniques such as fully modified(FM), dynamics and integrated modified-OLS. As required in standard econometric analysis, unit root tests were initially performed using Augmented Dickey-Fuller, Philips-Perron and Kwiatkowski Philip Schmidt and Shin methods to assess the data generating process of the interested variables. The time series econometric analysis showed that all the variables exhibited bidirectional relationship with exchange rate with the exception of supply of money which showed unidirectional causation, from money supply to exchange rate. In the cointegration analysis, we found that all the variables showed statistically significant long term equilibrium relationship although money supply and GDP had ambiguous signs. However, inflation and trade openness coefficients were theoretically consistent with expectation. Also the lagged dependent variable and the dummy variable for exchange rate regime appears to influence exchange rate dynamics in the long run. In short, all the interested variables have positive coefficients, signifying depreciating effect on the exchange rate. The adjustment coefficient obtained was 60.78%, indicating that it takes approximately 20 months for exchange rate to fully revert to equilibrium from any deviations. The results from the wavelet application are also striking. Wavelets power spectrum clearly shows activities in the short to medium frequency band of the variables. The cross coherency test also indicated that exchange rate depreciation leads (or Granger cause) the other variables, with the exception of trade openness which drives exchange rate depreciation.

Chapter One

INTRODUCTION

1.0 Background of the study

The agreement in policy circles in developing nations is that, the main objectives of exchange rate policy should be to reduce persistence in misalignment, which is a general common issue in most developing countries. However, in order to manage misalignments, it is relevant to successfully identify what determines real exchange rate (Afari et al., 2004). When the exchange rate is seen to have become excessively misaligned, it is expected to adjust to the equilibrium level in the future. The adjustment is expected to take place through the appreciation or depreciation of the nominal exchange rate which invariably discourages domestic agents in holding assets dominated in the domestic currency (Montiel, 2003). The behaviour of exchange rate brings so much concern to importers, exporters, investors and monetary authorities, as it affects them directly or indirectly. This implies, the behaviour of exchange rate is a useful measure of economic performance hence it needs to be clearly understood. According to Takaendesa (2006), exchange rate is the nominal exchange rate adjusted for price level differential between the domestic economy and the rest of the world. Real exchange rate is more important than nominal exchange rate, and is particularly good for developing countries where traded goods are a significant share of gross domestic product (Edwards and Savastano, 1999). This work extends the literature in the following facts on real exchange rate in Ghana. First, we explore the likely time-varying behaviour of long-run and short-run macroeconomic variables affecting exchange rate in Ghana and their co movements. We use more sophisticated method, the continuous time wavelet (Morlet) approach. The reason for the use of wavelets analysis is that, present macroeconomic models rely on the stationarity of time series data as a caveat for analysis, however the world is not in equilibrium hence dynamic data should be treated in tandem and this can be achieved by the use of wavelets decomposition to investigate the relationship between economic indicators. Transient dynamics are easily analysed with the aid of cross-wavelets coherency-phase between two time series.

Overview of exchange rate policies in Ghana

Exchange rate is the price of one currency relative to another in the world. It generally reflects the purchasing power of one currency to another. Generally, a country has choice to decided between two exchange rate systems, (fixed or floating and mixture of variations between them. When a government or monetary authority purposefully maintain the exchange rate administratively by deploying monetary policy to fix the exchange rate is termed as fixed exchange regime. However, when it allowed to be determined by market forces of demand and supply of the exchange rate market, then its referred to us floating exchange rate regime. Some countries might choose to operate the variants of the two, neither pure fixed nor floating rate regimes.

At independence, Ghana was practising the fixed exchange rate regime under the mechanism of the colonial international economic arrangement where the British West African Currency Board of 1912 was responsible for currency control and supply to the British West African Colonies. During this time, inflation was barely noticeable because the Government could not print money its own discretion because there was strict discipline as consequence had no independent monetary policy. As a consequences, government did not worry about exchange rate depreciation between the West African Pound and the pound

Stirling (Bawumia, 2014). To increase money supply government must backed it with corresponding exchange reserves.

Because of the inability of the Government of adhere to the strict fiscal requirements, abandoned the British West African Currency Board (WACB) in 1963 and introduced the Cedi in 1965 and still continued to operate the fixed exchange rate system. The cardinal rule was that, the Government could not again have independent monetary policy simultaneously referred to as the impossible trinity and no government has succeeded in such an effort.

Although, the Ghanaian economy adopted the fixed exchange rate system which was supported by the Bretton Woods system during the 1960s - thus shortly after the attainment of independence. Subsequent governments after through to 1983 attempted to operate this fixed exchanged regime. For most part, these exchanged rate policy failed because of break down in discipline of fiscal and monetary policy of inflation, shortage of foreign exchange, imposition of exchange rate controls and vibrant and striving black market of foreign currency (Bawumia, 2014)

Adjustments were made only when there was fundamental balance of payment problems. The choice of the fixed exchange rate regime during that time was consistent with the thinking during the period. Due to the inheritance of the large foreign exchange reserves from the colonial era, Ghana exercised no control over the foreign exchange market, which was in the hands of a few commercial banks.

Ghana moved away from the fixed exchange rate towards the floating rate regime determined by the market during the launching of the Economic Recovery Programme (ERP) brought series of devaluation of the Cedi between 1983 and 1986. Particularly, the Cedi was devalued to the stages of 2.75: US$1.00 in 1983 to 90.00: US$1.00 by the third quarter of 1986 (Appiah and Adetunde, 2011).

Over the last two decades, the exchange rate in Ghana has gone through four notable phases. These include; Phase 1 (The Pre - 2000 era): This is the time of high exchange rate fluctuations, during which the Cedi lost more than its value against the major trading currencies. Phase 2 (The Pre - redenomination era): During this era, the Cedi was resolute against the US Dollar and other major trading currencies. Phase 3 (The Post - Election 2008 era): During this period, the global financial crises and other factors pushed the Cedi down marginally. Phase 4 (The Post - 2010 era): After several months of stability and erratic exchange rate appreciation, the cedi begun to show signs of instability, showing fears of significant loss in value similar to what was experienced years ago.

In each of the periods, significant attention was focused on the cedi value and extensive public dialogue centred on the subject (Nana, 2012). Unfortunately, the fears that were anticipated became a reality with the Ghana Cedi depreciating by 17.3% in 2010 (CEPA, 2012). In the year 2000, the cedi was described variously as the free fall. At the same time, parallel market operations had re-emerged just a decade after foreign exchange was liberalized. The question that follows is that, "what are the forces behind the movement of the cedi in the foreign exchange market?"

1.1 Statement of the problem

The determination of exchange rate is confined in the field of international finance which has received major interest from researchers in the Post-Bretton Woods Era. Surprisingly, the interest in this area of research is on the rising, and experts do not see this interest diminishing in the foreseeable future. Many researchers attribute interest in the determination of exchange rate to the fact that the determinants of exchange rate are different in different jurisdictions or countries (Kilian and Taylor, 2001).

However, given the importance and the unpredictable nature of the exchange rate determination which has elicited a lot of interest from other countries, it is surprising to know that not much study have been done on Ghana on the Determinants of Real Exchange rate.

The study would adopt ARDL approach to Co-integration, error correction model and Granger causality test approaches to conduct the study. Similarly, we would then employ wavelets analysis techniques, a novel methodology to study periodic phenomenon in the presence of time-varying frequency. It is important tool for analysing local variations of power associated with time series. This technique is critical since previous studies on determinants of exchange rate in Ghana has not been carried out yet. The wavelets analysis between the pairs of macroeconomic variables with the real exchange rate univariate will explore the relationships over different time scales and determine their co-movements. This will seek to clarify the long and short term distinction of investors who have different investment objectives both locally and internationally. Thus, this work will fill the information gap by providing relevant answers to the question about exchange rate determination in order to form policy direction in Ghana. This work uses multivariate analysis rather than the usual bivariate or trivariate which results in information lost, in the final determined models.

1.2 Research objectives

The following research objectives were set to guide the study;

1. To examine the determinants of exchange rate in Ghana

2. To examine the causal relations between exchange rate and its covariates

3. To study the coherency of the determinants co-movements if any

1.3 Research questions and hypothesis

In order to ascertain the findings of the study, the following research questions were to guide the study;

1. What are the determinants of exchange rate in Ghana?
2. What is the direction of causality between exchange rate and its covariates?
3. What is the time-evolution of the cross-wavelet coherency among the pair variates?

In order to make an important contribution to the determinants of real exchange rate in Ghana, the following null hypothesis will be formulated to guide the study;

1. Inflation, trade openness, money supply, Gross Domestic Product and terms of trade are not determinants of exchange rate in Ghana
2. Inflation, trade openness, money supply , GDP and terms of trade do not Granger cause exchange rate
3. There is no periodicity in the variables hence no cross-wavelet coherency relationship exist among the independent pairs of the variables

1.4 Significance of the study

In the field of international finance, the determination of exchange rate is very important and particularly good for developing countries where traded goods are a significant share of gross domestic product (Edwards and Savastano, 1999).

The study has direct impact on macroeconomic policies to be put in place since the determinants of exchange rate is very important for the growth of economies. For instance, the findings of this study will enable policies makers to know those forces that lead to appreciation and depreciation of the Ghana cedi in relation to the major trading currencies.

The study will also narrow the research gap with respect to the determinants of exchange rate determination in Ghana. Future researchers can use the models that will be developed for this research in advancing further studies in the area.

1.5 Scope of the study

The study on the determinants of exchange rate has been researched on many boundaries; regional dimensions, across several countries and specific country basis. The study was conducted on country basis. The scope of this study covers the Ghanaian economy. As a result, time series data spanning from the period 1960 to 2014 were collected from World Bank Development Indicators and Bank of Ghana.

1.6 Limitations of the study

As the study is conducted on Ghana, there are two limitations that call for clarification in the following specific areas. The following limitations may affect the ability to take a broad view of the findings of this research.

The study covers a period spanning from 1960 to 2014 on the Ghanaian economy. Annual time series spanning from the aforementioned period were collected from the World Bank Development Indicators of the World Bank. One limitation is the over reliance of data from World Bank. This implies that, the validity of the findings and conclusion is limited to the extent to which the data are credible and authentic.

Also, the research was conducted on the Ghanaian economy. Since the country has unique attributes and characteristics and also certain legislation which have implications on economic policies. It presupposes that, results obtained cannot necessarily be replicated elsewhere since no two countries have exact characteristics.

1.7 Organisation of the study

The chapter one of the study will introduce the subject and cover areas such as background to the study, statement of problem, research objectives, research questions and hypotheses, significance of the study, brief methodology, scope of the study and limitation of the study. Chapter two will review relevant literature on the determinants of exchange rate in Ghana. The third chapter would cover the research design taking into account the sample design, models to be specified and data analysis techniques. Chapter four of the study will cover data presentation, analysis and discussion detailed into introduction and the regression analysis where the hypotheses would be tested and wavelet analysis rigorously treated. The last chapter which is chapter five will be organized into introduction, summary of findings;

summary of test of hypotheses, recommendations and conclusion and followed by references and appendices.

Chapter Two

LITERATURE REVIEW

2.0 Introduction

In this section, we shall focus on analyses of the theoretical framework and reviews of some important literatures on the determinants of exchange rate. We begin with the concepts of exchange rate and how it works, purchasing power parity brief introduction, the Balassa Samuelson effect, exchange rate models, fundamental equilibrium model, determinants of exchange rate and some empirical reviews. We shall also review Fourier analysis in finance, wavelets analysis and applications in finance and economics and give conclusion to the study.

2.1 Basics and mechanism of exchange rate market

The exchange rate is determined in the exchange rate market. This implies that through the exchange rate market, one country's currency is converted to the other for trade to take place. The exchange rate is the price of one currency in terms of another currency. In other words, it is the rate at which currencies are exchanged, for example the units of cedis needed to buy a unit of a dollar. There are two major types of exchange rate. Firstly the spot exchange rate, is the exchange rate for immediate (at most two days) for bank deposits or currencies. The second is called the forward exchange rate, which is the rate for the exchange of bank deposits or currencies at some specified future date (Forward transaction). When a currency falls in value in relation to another, that currency is said to be depreciating. On the other hand, when a currency increases in value in relation to other currencies, that currency is said to be appreciating (Takaendesa, 2006).

Exchange rate could also be Nominal, Real, Bilateral and Multilateral exchange rates. These concepts are discussed below:

Nominal exchange rate is simply the price of one currency in terms of other currencies. According to Takaendesa (2006), the nominal exchange rate can be expressed in two forms, namely the direct quotation (America quotation) and the indirect quotation (European quotation). The American quotation or direct quotation is the price of the local currency in terms of units of foreign currency. The indirect or the European quotation is the price of foreign currency in terms of units of the local currency.

In relation to the real exchange rate, literature has shown that researchers or economists have not had a consensus on its measurement. This is because economists use different types of macroeconomics models for different purposes; a series of analytical real exchange rate (RER) tends to be used. Theory has is that real exchange rate can be defined in terms of internal and external exchange rate. The internal exchange rate is the ratio of domestic tradable to non-tradable goods within a single economy whilst the external exchange rate is the nominal exchange rate adjusted for price level differences among countries Takaendesa (2006). The internal real exchange rate indicates domestic resources allocation incentives in the home country, it is defined as the internal relative price for the production or consumption of tradable goods as opposed to non-tradable goods. Different expressions of the internal exchange rate can be derived depending on whether one is looking at two or multi goods models. According to Black (1994), the most widely used internal exchange rate definition derives from the SalterSwan non-traded goods model. The exchange rate in this case is expressed as the ratio of the price of tradable to non-tradable goods as follows;

$$RER = G\frac{pt}{pn} \quad (2.1)$$

Where RER is real exchange rate, pt is the world prices of traded goods, pn is the domestic prices for non-traded goods and G is the nominal exchange rate. From the equation, an increase in RER means depreciation whilst a decrease in RER means appreciation. The RER stated in the equation above can be stated indirectly, in which case an increase in RER will mean an appreciation whilst a decrease in RER will mean depreciation.

The external Real exchange rate emanates from the Purchasing Power Parity (PPP) theory, which make comparison of two countries and the relative prices of baskets of goods produced or consumed. In this case, real exchange rate is defined as the ratio of prices of foreign goods to that of local goods expressed in domestic currency (Montiel, 2003). The real exchange rate is calculated by beginning with the nominal exchange rate - the home country's price of foreign exchange then dividing it by the home country's price index for the class of goods in question and finally multiplying by the corresponding foreign price index Takaendesa (2006). For instance, we take the Ghanaian price of the US dollar denoted by F_t and multiply it by factor P_t^*/P_t where P_t^* and P_t represent the consumer price indices for United States and Ghana respectively. These steps give the real exchange rate- thus RER(t) for the period t as follows;

$$RER_t = F_t\frac{P_t^*}{P_t} \quad (2.2)$$

There are also concepts of nominal effective exchange rates (NEER) and Real effective exchange rates (REER). The concept of nominal effective exchange rate was introduced by Hirsch and Higgins (1970). The nominal effective exchange rate index is a multilateral rather than bilateral and can be defined as the weighted average of a basket of currencies over time, deriving from exchange rate movement over time. It shows the effects of exchange rate movements relative to a selected basket of currencies in a given base period. The concept of real effective exchange rate (REER) goes beyond finding the weighted average of currencies to include differences in inflation rates between countries. In other words, it inculcates both the concepts of nominal exchange rate and inflation differentials, with the main aim of deflating the exchange rate indices by corresponding indices of relative prices. The REER is thus the NEER of a currency adjusted for inflation differentials between the home country and other nations to be included in calculating the index. As is the case with the NEER, the REER is multilateral, the exchange rate of a currency in relation to a basket of other currencies, rather than bilateral Takaendesa (2006).

According to Korsu and Braimah (2005), most studies that have looked at real exchange rate have the notion of real effective (multilateral) rather than real effective bilateral exchange rate. The real effective exchange rate can be computed as follows;

$$REER = \sum_{i=1}^{i=n} S_i \left(\frac{CPI_i^*}{CPI} \right) \quad (2.3)$$

Where;

REER is the real effective exchange rate i

is the major export partners of Ghana

S_i is the weight of the export partner i in the total export of Ghana

CPI_i^* is the consumer price index of country i

CPI is the consumer price index in Ghana

2.1.1 Brief discussion on purchasing power parity

According to Korsu and Braimah (2005), a strand of literature on the subject (real exchange rate) focuses on developed countries. These literatures on the developed economies uses purchasing power parity (PPP) or macroeconomic balance approach to determine the equilibrium real exchange rate and hence the degree of real exchange rate misalignment without paying much attention on the determinants of real exchange rate. This implies that their focus is mainly on real exchange rate misalignment rather than real exchange rate determinants. Another strand of literature on real exchange rate is the case of developing countries, where the subject is mainly on the determinants of real exchange rate. This was pioneered by Edwards (1988, 1989) and later works of Rodr´ıguez (1989), Elbadawi (1994) and Montiel (1997).

There are two research schema of dealing with real exchange rate, its determinants and effects of misalignment. The first is based on purchasing power parity hypothesis whilst the second is based on behavioural and fundamental models connecting the real exchange rate to a set of determining variables or fundamentals (Elbadawi, 1994). Below are the brief look at these models and theories.

Being the first approach to literature, it was first formulated by Cassel (1918) who defined the theoretical nominal exchange rate as a report between national and foreign prices - thus $E^{PPP} = P/P^*$ Yet, the market value of the exchange rate could present deviations from the former values which are considered as over or under valuations from the national currency. By this, the real exchange rate according to the purchasing power parity theory is the report between the market and the theoretical value of the national currency expressed in other currency. $Q = E/E^{PPP}$. Therefore, a real exchange rate higher than one reflects the under-valuation of the national currency, while it is less than one it can be said that the national currency is overvalued. Formulating the theory of PPP, Cassel (1918) used a number of hypotheses which should be fulfilled in order that the theory could be valid.

This theory is based on the Law of one price which supposes that a given commodity costs the same in two different countries when the priced is expressed in the same currency. This means that, if international arbitrage should work, perfect competition should work in both local and foreign markets, capital movement and trade should be free without any barrier (taxes) or restrictions. From the above mentioned hypothesis, there are a number of reasons why PPP might be wrong and misleading indicator for equilibrium exchange rate, especially in developing countries. Firstly, there are significant differences between the compositions of the price basket because of the fact that consumer preferences and the structure of the manufacture production differ from one country to another. Secondly, if the perfect competition is not working (the cost of transportation are different), the loop does not hold. The problem is present especially in the case of developing countries where governments control the level of regulated prices, subsidizes certain categories of services, like public transport, telecommunication and others. Consequently, the price of non-tradable goods will be lower than that in the developed countries (Cassel, 1918).

The Purchasing Power Parity (PPP) hypothesis shows that in equilibrium foreign and domestic currencies should have the same purchasing power. Given the basket of goods, this definition gives as easy to calculate benchmark for the equilibrium real exchange rate. The empirical evidence, however, ends up rejecting PPP based models in both developed and developing countries. This is because they fail to explain continuous deviations of the real exchange rate from the PPP benchmark Mussa (1986) and/or because of the rate of convergence to equilibrium is too slow to be compatible with the PPP hypothesis, even one is to allow for plausible nominal rigidities (Rogoff, 1996). However, even if one is willing to use such long horizon benchmark, it should acknowledge that purchasing power based models are unlikely to provide adequate description neither of the causes of the real exchange rate fluctuation nor of its fluctuations.

2.1.2 The Balassa Samuelson effect

Balassa (1964) and Samuelson (1964) are the first people who proved that the purchasing power parity approach is not realistic in practice. They considered economies split into two sectors; tradable and non-tradable. They also proposed that: if demand and supply are at work in both sectors, wages are linked to the level of productivity in the open sectors; tradable prices are equal in each country; so PPP holds in this open sector; while the increase in labour productivity is higher in the tradable sector than the non-tradable sector; wages tend to equalize between sectors. Next, they considered the developing country having lower productivity level in the open sector than the developed country. Considering the above mentioned hypothesis, if the home country is in a catching-up process with the developed economy, productivity tends to increase in the open sector, so there is a possibility of wage increase in the tradable sector without any inflationary effect. But, due to the wages equalization assumption between sectors, the productivity gain in the open sector will create inflationary pressures in non-market based sectors. In this way, the overall price level will rise faster in the home country (creating a positive inflationary differential vis--vis the foreign country) than in the foreign country because of the positive productivity differential between sectors in the home country, which will in turn result to a real appreciation of the home countrys real exchange rate. This phenomenon is known in literature as the Balassa-Samuleson effect to which the trend appreciation of the real exchange rate in the developing countries can be attributed to.

2.1.3 Other exchange rate models

A consensus has formed that equilibrium real exchange rate is subject to the influence of a relatively wide range of time-varying exogenous and policy fundamentals. The equilibrium real exchange rate is defined as the relative price of traded to non-traded goods that is in line with internal and external balance. Despite the simplicity of this concept, its practical implementation gives a number of different methodological approaches (Elbadawi, 1994). Following the works of Clark and MacDonald (1998) and Elbadawi (1994), the study distinguishes between two broad classes of models; the Fundamental Equilibrium Real Exchange Rate (FEER) and the Behavioral Equilibrium Real Exchange Rate (BEER).

2.1.4 The fundamental equilibrium exchange rate model (FEER)

The concept of fundamental equilibrium real exchange rate was propounded by Williamson (1985) and extended among others like Isard and Faruqee (1998). In the FEER approach, internal and external balances are usually defined as those compatible with ideal conditions determined by the econometricians. Thus, the equilibrium exchange rate is defined as a function of what the researcher thinks is the optimal internal balance (example the non-accelerating inflation rate unemployment) and the sustainable external flows (usually projected or assumed to obtain in the medium-to-longer run). Because these conditions are imposed ex-ante, and may not exist in the future, the FEER corresponds to a normative idea of equilibrium Real Exchange
Rate (Elbadawi, 1994)

According to Williamson (1985), the fundamental equilibrium real exchange rate is a real effective exchange rate which ensures the external and internal balance at the same time for two countries. The internal equilibrium is not only characterized output which is equal to its potential level (the economy produces maximum level of output), but also by the Non-Accelerating Inflation Rate of Unemployment. This approach allows the researcher to reflect the effects of other factors on the real exchange rate than the productivity differential as it appears in the Balassa-Samuelson framework. Furthermore, the real interest rate differential, fiscal policy, determinants of savings and investments are potential determinants of the level of real exchange rate. Considering the features of the above mentioned approach, one can confidently say that the Balassa-Samuelson approach seems to be the most realistic framework, but at the same time the most challenging framework to implement in practice because it supposes a great amount of work, high statistical and data availability for a long period of time. There are a fewer number of studies implementing the fundamental equilibrium real exchange rate approach owing to its challenging nature in the case of CEECs countries (Smˇ ´ıdkova et al., 2002).´

Behavioural equilibrium real exchange rate (BEER) on the other hand takes into consideration short term flow variables as well as factors influencing long run stock equilibriums (Edwards, 1988). This approach is inter-temporal as the equilibrium is assumed to be influenced by the current values of the fundamentals and also the anticipations regarding the future evolutions of these variables. (Elbadawi, 1994) developed a methodology in the context of cointegration error correction time series model that (1) computes the equilibrium RER as a forward-looking function of the fundamentals; (2) allows for flexible dynamic adjustments toward equilibrium; and (3) allows the identification of the influence of macroeconomic policies on the equilibrium RER. The empirical application to BEER is subject to problems (Edwards and Savastano, 2000). This is because of the lack of a general connection between the equilibrium real exchange rate and the current account position and the frequent disconnection between the econometric specification and the analytical model. Consequently, the interpretation of the results is debatable and policy evaluation is not always rigorous. (Elbadawi, 1994)

MacDonald and Clark (2000) propose a new approach known in literature as Permanent Equilibrium Exchange Rate (PEER). This is a derivative of BEER using new statistical tool. The only difference between the BEER and PEER approaches is the econometric tool used to estimate the equilibrium exchange rate.

Another approach is the Natural Rate of Exchange Rate (NATREX) developed by Stein (1995). This approach gives the differences between a medium and a long term equilibrium exchange rate. The medium term rate is defined similarly to the FEER approach. In addition to that, a system of interlinked equations also includes the capital stock and the stock of foreign debt. For the medium term the current values are assumed while for the long term steady state levels are calculated.

2.2 Brief review of determinants of exchange rate

Kempa (2005) postulate that it is very difficult to compile the theoretical literature on exchange rate determination, this is because there is no generally accepted exchange rate model one can resort to. In addition, many of the studies on this subject area avoid the theoretical issues on the determination of real exchange rate.

Mundell (1971) provided an analysis on the determination of equilibrium exchange rate using macroeconomic model of a monetary economy. Mundells model assumes a small, open economy that faces given prices (no influence over terms of trade) and defined the equilibrium real exchange rate as the relative prices of international to domestic goods that equilibrates the money market. The problem with this model and other models mentioned above with the exception of the fundamentals model is that, they do not allow for a distinction to be drawn between the effects of short run and long run changes in the determinants of real exchange rate (Takaendesa, 2006). Literature has it that, the two most used models for empirical analysis of the determinants of real exchange rate are the Inter Temporal Optimizing Model by Edwards in 1989 and the Analytical Model on the determinants of long run equilibrium real exchange rate by Montiel in 1999.

Takaendesa (2006) argues that, Mundells model is an extension to Edwards model and is based on the idea that the real exchange change is an endogenous variable. In this model, the economys endogenous variables are determined by three variables;

1. Predetermined variables
2. Exogenous policy variables and
3. Other exogenous variables

Predetermined variables are the endogenous variables that changes slowly over time, for instance capital stock, technology, net international creditor position and nominal wage. Exogenous policy variables include fiscal and monetary policies, trade policies and other variables under the control of domestic authorities. Other exogenous variables include observable variables such as terms of trade, world interest rate. It also includes unobservable variables and bubble variables. Bubble variables are those variables that affect the economy only through their influence on sentiments (Takaendesa, 2006)

From the two models above, among the variables that affect real exchange rate includes; Balassa-Samuelson effect, changes in values in international transfers, changes in international financial situations, changes in commercial policy, terms of trade, changes in fiscal and monetary policies, changes in foreign exchange reserve and changes in nominal exchange rate pol-
icy.

Taking into consideration the relationship between the real exchange rate and these factors, theory suggest that with regard to the balassa-samuelson effect, an increase in differential productivity growth in tradable goods sector creates an appreciation in real exchange rate whiles a decrease in differential productivity growth in tradable goods sector results in depreciation of the real exchange rate (Edwards, 1994; MacDonald, 1998). With respect to the international transfers, Edwards (1994) and Montiel (1999) hold the view that, increase in capital inflows permits an expansion of absorption and consequently an appreciation of the real exchange rate and a decrease in capital inflows consequently leads to a depreciation of the real exchange rate. Concerning the changes in the international financial conditions, changes in real exchange rate is caused by changes in real interest rate between countries. Hence if real interest rate differential increases the real exchange rate will appreciate and vice versa irrespective of the channels chosen to trace their transmission (Montiel, 1999).

With openness to trade as a determinant of real exchange rate, models of real exchange rate assigns a critical role to the effects of export and import taxes. Permanently, higher levels of these taxes (that is reducing openness to trade) lead to real exchange rate appreciation. This occurs because future consumption becomes more expensive. In response to this, people tend to favour current consumption; as demand for all goods increase, the price of non-tradable rises, leading to real exchange rate appreciation. In applied work, it is very difficult to obtain a sufficiently long time series of import and exports taxes. Consequently, these are proxied to the ratio of exports plus imports to GDP. An increase in this ratio reflects an increase in the openness of the economy to international trade, presumably caused by a reduction in trade taxes (both explicit and implicit)

Fiscal policy constitutes the last group of basic factors which is considered by researchers and economists. It can be quantified by different fiscal policy indicators such as the ration between budget deficit and GDP, the final consumption expenditure of general government normalized by real GDP. Generally the relationship between real exchange rate and the above mentioned indicators is positive; respectively, an increase in government expenditure or a decrease in taxation (expanding budget deficit) will generate inflation pressures leading to a decrease in the national currency. Also there may be specific structural problems, particularly in the case of transition economies, which changes the sign of the correlation (Egert, 2005)´

Commercial or trade policy is another variable that affects the real exchange rate in both Edwards and Montiels models. For instance an increase in import tariff can increase domestic price of imports, which are constituents of the tradable goods. The increased demand for foreign currency, following the domestic price of imports also appreciates the real exchange rate. An increase in export subsidies also creates a balance of payments surplus which requires an appreciation of the real exchange rate to correct. This implies that a more open economy is likely to be associated with a more depreciated real exchange rate and a closed economy is expected to experience an appreciation in its real exchange rate (Takaendesa, 2006)

Terms of trade (TOT) is defined as the ratio between the export unit value and the import unit value or by dividing the export deflator by the import deflator. The sign of correlation of TOT with real exchange rate is dependent on the price elasticity of imports and exports. An increase in terms of trade, if imports and exports have low price elasticity, can influence the structure of the domestic manufacture, stimulating the increase of the tradable sector and generating an excess demand in the non-tradable sector, respectively rising export revenues and appreciating the nominal and thus real exchange rate. Otherwise, when export and imports are price sensitive the impact may be negative (Takaendesa, 2006).

2.3 Empirical review of exchange rate determinants

In this section, we review some, but not all of the previous empirical works on exchange rate and its determinants. We also study the relationship between exchange rate and other macroeconomic variables. The literature on this subject is vast and therefore have sought to consider only key results here. It must be emphasised that earlier works on exchange rate are focused on developed and developing countries. Among some of these studies include;

According to Korsu and Braimah (2005), exchange rate measures the competitiveness of an economy to international trade. In Sierra Leone, the nominal exchange rate has seen depreciation since early 1970s as a result of either official intervention, during the fixed exchange regime or a combination of official and intervention and market forces during the managed floating exchange rate regime. Earlier studies on the determinants of exchange rate in developing countries captured the effects of nominal exchange rate on exchange rate without capturing the effects of price changes. Their study therefore investigates the determinants of exchange rate for Sierra Leone by controlling for the effects of price changes, using annual aggregate date from 1970 to 2005. The estimated model was based on the inter-temporal optimizing frameworks of Edwards (1989). Unit root and cointegration test were carried out and error correction model of the actual real exchange rate model was estimated in the context of Hendrys generalto-specific modelling while the equilibrium real exchange rate was estimated using Johansen Maximum Likelihood procedure. The study reveals that, an increase in price level, capital inflow, capital accumulation and trade restriction appreciates the actual exchange rate in Sierra Leone while increases in nominal exchange rate and output decrease it. Improvements in terms of trade and increase in capital inflow depreciate the equilibrium real exchange rate while capital accumulation, increase in output, increase in government expenditure and trade restrictions appreciate equilibrium real exchange rate. Hence, for a depreciation to be sustained, policy makers should strengthen efforts to control the rate of inflation and concentrate revenue from capital inflow on investment in the tradable goods sector. Moreover, increased trade liberalization and use of supply-side policies to increase output are important for realizing depreciation of the real exchange rate of Sierra Leone.

Dogo et al. (2016) investigated whether market sentiments determines the Naira exchange rate evidence from Nigeria with a monthly data spanning the period of 2005 to 2013 and BidAsk spread with the foreign exchange markets as proxy for the sentiments and employed hybrid model. Their conclusion was that, Naira-dollar exchange rate is determined by both standard economic fundamentals in literature and also market expectations.

Ahmed et al. (2012) in their work on econometric analysis of determinants of exchange rate in Pakistan found that, stock of money, debt and foreign exchange reserve balance all in relative terms are significant determinants of exchange rate between Pakistani Rupee and US Dollar. Moreover, Political instability has a significant negative effect on the value of domestic currency. ARDL approach to co-integration and error correction model were applied in the study.

Appiah and Adetunde (2011) worked on monthly exchange rate between the Ghana Cedi and the US Dollar and forecast future rates using time series analysis. ARIMA model was developed by employing the use of Box and Jenkins method of Time Series Analysis on the monthly data collected from January, 1994 to December, 2004 and validated. The study revealed that predicted rates were consistent with the depreciating trend of the observed series. ARIMA (1,1,1) was found as the most appropriate model with least normalized Bayesian information criterion (BIC) of 9.111, mean absolute percentage error (MAPE) of 0.915, Root Mean Square Error of 93.873 and a high R-Square value of 1.000 was estimated using Ljung-box test, with (Q18)=15.146, 16 DF and p-value of 0.514 with no auto correlation between the residuals at different lag times. Finally a forecast of two year period from January, 2011 to December, 2012 was calculated with showed a depreciation of the Ghana Cedi against the US Dollar.

Also, Osei and Assibey (2010) in a thesis analysed the exchange rate behaviour in three Less Developed Countries; Ghana, Mozambique and Tanzania. They examined whether exchange rate in these countries are influenced by similar factors. The results suggested that, exchange rate in these countries is generally affected by similar factors. In particular, the series exhibit the empirical regularities found in other exchange rate/financial markets, justifying the application of the ARCH methodology which they use to estimate the volatility of exchange rate in these countrie

Lossifov and Elena (2007) in estimating the behavioural equilibrium exchange rate model for Ghana postulated that exchange rate is explained by GDP growth, real interest rate differentials (both relative to trading partner countries), and the real world prices of Ghanas main export commodities. On the basis of these fundamentals, exchange rate in the late 2006 was found to be very close to its estimated equilibrium level. The result also suggests that deviations from the equilibrium path are eliminated within two to three years.

Siddiqui et al. (1996) estimate the determinants of real exchange rate for Pakistan and find that increase in governmental expenditures leads to depreciation in real exchange rate. Coefficient of terms of trade (TOT) is positive and statistically insignificant. Excess domestic credit creation significantly contributes to real exchange rate appreciation. Openness has also contributed towards appreciation in exchange rate. Technological progress has negative sign but

statistically insignificant.

Karfakis (2003) tests the monetary model for Romanian Lei and US Dollar exchange rate and concludes that Money is positively related with the exchange rate. Increase in money is the source of depreciation in the domestic currency. According to him, real income is negatively related with value of currency and Inflation is positively related with the value of Romanian currency against Dollar.

Hyder and Mahboob (2005) in their study to find the value of the real effective exchange rate of the Pakistan Rupees concluded that, that degree of openness, increase of governmental expenditure and capital account balance bring depreciation in the real effective exchange rate. Rise in worker remittances from abroad and the betterment in terms of trade (TOT) and total factor productivity (TFP) relative to trading partners cause appreciation in the real effective exchange rate. Wilson (2009) examined the effective exchange rate of US Dollar based on the weighted average trading partner of USA. Money supply is positively related to the effective exchange rate and increase in money causes decline in the value of currency. Hsieh (2009) has studied the behaviour of Indonesian Rupiah per unit of US Dollar. His conclusion was that, relatively more real money aggregate, a relatively higher domestic interest rate, or a relatively more expected inflation rate causes real depreciation for Indonesian Rupiah. Higher ratio of governmental spending to GDP or higher stock prices lead to real appreciation in IDR/USD exchange rate. According to Takaendesa (2006), Real exchange rate has important effect on production, employment and trade. Therefore it is important to understand the factors responsible for their variations. His study analyzed the main determinants of real exchange rate and the dynamic adjustment of the real exchange rate following shocks to those determinants using quarterly time series data in South Africa spanning from 1975 to 2005. The study used co-integration and vector auto regression (VAR) analysis with variance decomposition and impulse response analysis to provide robust long run effect and short run dynamic effects on the real exchange rate. The result of the study shows that, the variables that are found to have long run relationship with real exchange rate in South Africa include terms of trade, real interest rate differential, domestic credit, trade openness and technological progress. The estimate of the speed of adjustment coefficient in the study indicates that, about a third of the variation in the real exchange rate from its equilibrium level is corrected within a quarter. Egert (2010) examines the behaviour of South African Rand against US Dollar using data from January 2001 to July 2007. He concluded that, the four factors that affect South Africas exchange rate value include; non-linear monetary equilibrium mean reversion property, changes in gold prices, general risk perception of the market and innovations in exchange rate of Dollar and Euro.

In addition, Zakari and Owusu-Afriyie (2004) used a simple monetary model of exchange rate determination for Ghana and employed the technique of cointegration analysis to empirically investigate the principal factors driving the Cedi/Dollar rate of exchange since the adoption of floating exchange rate regime in the country. They augment the basic model with political variables to examine any political impact on the exchange rate. The empirical results corroborate the model with the effect that, macroeconomic fundamentals play an important role in the Cedi/Dollar dynamics. Similarly speculation based on the recent past behaviour of the cedi/dollar (to extrapolate the future behaviour of the rate) is crucial and this has been linked hugely to the under development of the financial system and the exchange rate market. However, while political variable was correctly signed, it is not significant at any level of conventional significance. Finally, they examined the effectiveness of Bank of Ghana intervention (as measured by non-oil forex sales) on the value of the cedi.

Furthermore, Bawumia and Otoo (2003) explored the relationship between monetary growth, exchange rates and inflation in Ghana using an error correction mechanism. The empirical result confirms the existence of a long-run equilibrium relationship between inflation, money supply, the exchange rate, and real income. In line with theory, the findings demonstrate that in the long-run, inflation in Ghana is positively related to the money supply and the exchange rate, while it is negatively related to real income. MacDonald and Ricci (2003) estimated the equilibrium real exchange rate for South Africa using Johansen cointegration procedure with data spanning from 1970 to 2002. The explanatory variables included in the model were; real interest rate differential, real GDP relative to trading partners (productivity), real commodity prices, openness, the ratio of fiscal balance to GDP and the ratio of net foreign assets to the banking system to GDP. Based on their cointegration estimation results, much of the long run behaviour of the real exchange rate of South Africa can be explained by real interest rate differential, relative GDP per capita (Productivity), real commodity prices (terms of trade), trade openness, the fiscal balance and the extent of the net foreign assets. As in other empirical studies, they find that an increase in the real interest rate differential, productivity, terms of trade, fiscal balance and net foreign assets appreciate the real exchange rate in South Africa.

Mkenda (2001) analysed the main determinants of the real exchange rate in Zambia. His results suggested that, (i) a decline in the terms of trade and government consumption depreciates the real exchange rate for imports, while an increase in investment share of GDP appreciates the exchange rate for imports; (ii) a decrease in the terms of trade, an increase in central bank reserves and trade taxes appreciate the exchange rate for exports in the long run; (iii) in the long run, the internal real exchange rate is strengthened by a decrease in the terms of trade, an increase in investment share and the rate of growth of real GDP (a proxy for technological progress); (iv) in the short run, however, aid and openness depreciate the exchange rate indices. MacDonald (1998) presented a reduced form model of the exchange rate to re-examine the determinants of real exchange rate in a long run setting. His model features productivity differentials, term of trade, fiscal balances, net foreign assets and interest rate differential as key fundamental determinants of the exchange rate. Using multivariate cointegration methods, the model is implemented for the effective exchange rate of the U.S Dollar, Yen and Deutschmark, over the period 1974 to 1993. He finds evidence of a significant and sensible long run relationship for his model, indicating that fundamentals mentioned above have an important and significant bearing on the determination of both long and short run exchange rates. All variables were found to have a positive relationship with exchange rate; an increase in any of them leads to an appreciation of the exchange rate

Elbadawi (1994) concluded that, a greater abundance of natural resources relative to human capital stocks which make non-traded goods relatively more expensive than resource based exports, affects significantly the equilibrium real exchange rate. Likewise, the econometric results indicate the labour productivity growth in the non-traded had been at the core of different observed trajectories of the real exchange rate in African and Latin American countries vis--vis Asian economies. High, sustained productivity gains in the Asian economies have induced a significant long run depreciation of the real exchange rate, a feature that is completely absent in other developing countries. Finally the study finds that the equilibrium-consistent current account appears to be quite important. Observed shock (of size one standard deviation) would induce wide swings in the equilibrium exchange rate of around 15%, indicating the need for market flexibility to avoid paying high adjustment costs.

Edwards (1989) built a theoretical model for developing countries to explain the short and long run determinants of real exchange rate. The model was applied to 12 countries observed from a period 1962 and 1985 by using fixed effect model. His sample was made of Brazil, Columbia, Elsavador, Greece, India, Israel, Malaysia, Philippines, South Africa, Srilanka, Thailand and Yugoslavia. His finding is consistent with theoretical prescription that in the short run, both real and nominal variables affect the real exchange. The finding showed that the long run determinants of exchange rate are terms of trade, level of composition on government consumption, controls on capital flows, exchange and trade controls, technological progress and capital accumulation. His study reveals that in the short run, nominal exchange rate and domestic credit as well as the real variables that determine the long run real exchange rate are the determinants of real exchange rate. The coefficient of terms of trade was found to be negative, the coefficient of the ratio of government expenditure to GDP was found to be negative, the coefficient of exchange and trade controls (proxied to parallel market premium) was found to be negative, the coefficients of technological progress (proxied to output growth) was found to be positive (contradicting the Ricardo-Balassa Hypothesis), the coefficient of capital flow (lagged) was found to be negative and the coefficient of capital accumulation (measured as investment to GDP ratio) was found to be positive. He also found that in the short run, nominal exchange rate depreciation leads to a depreciation of the exchange rate while an increase in domestic credit leads to appreciation of the exchange rate.

2.4 Brief introduction to Fourier analysis in finance

Fourier series is a linear combination of trigonometric functions of sines and cosines. They are themselves function of frequency as a consequences, Fourier transform is regarded as decomposition of frequency-by-frequency basis. The basis function(sines and cosines) of Fourier series are great when dealing with stationary time series. The properties of financial or economic time series are are generally not stationary but exhibit complicated pattern over time for example trends, abrupt changes and volatility clustering hence restricting oneself to stationary series is not appealing. As a result, the Fourier transform cannot sufficiently and efficiently capture such dynamic events in the course . In fact, if frequency components are not in equilibrium over time, traditional spectral tools cannot sample all the frequency components(Genc¸ay et al., 2001).

The alternative representation of original time series, which actually summaries information in a data as function of frequency is the Fourier transform but does not preserve information in time. This is the opposite of how we observe the original time series where no frequency resolution is provided(Genc¸ay et al., 2001). When time series data are sampled we obtain a time-amplitude representation, this representation is not the best of the signal since the most distinguished information is hidden in the frequency content of the signal. This associated frequency components information (frequency spectrum) can only be observed when the time series has been Fourier transformed into the frequency-amplitude representation. This means, its impossible to simultaneously obtain both time-amplitude and frequency-amplitude representations of a given signal. Fourier transform only indicates that frequency exist in a signal but does not show when in time frequency components occurs(Polikar, 1996). That is, Fourier transform only allows for either time-domain or frequency-domain information.

For non-stationary signal, the frequency component of the signal changes in time as a results, the processed signal when viewed in frequency-domain is distorted. To circumvent this problem, non-stationary signals are artificially made stationary by using Windowed Fourier

Transform (WFT) which is a tool for extracting local-frequency information from a signal(Valens, 1999; Torrence and Compo, 1998). The idea behind these time-frequency representation is to cut the signal of interest into several segmented stationary parts and then analyze the parts separately. This is achieved by using a certain windowed size and sliding it alone in time and computing the Fast Fourier Transform (FFT) within the window. Naturally, analyzing the non-stationary signal this way will give more information about the when and where of different frequency components, but it leads to a fundamental problem too. How to cut the part of interest(Valens, 1999; Badu, 2016). The key problem of WFT is the consistent treatment of different frequencies: for low frequencies there are few oscillations within the window that the frequency localization is lost, similarly, for high frequencies there are so many oscillations that the time localization is lost(Santos and Freire, 2012; Kaiser, 1994). Another problem is that cutting the artificial stationary signal is equivalent to a convolution between the signal and the cutting window. Convolution in time domain is the same as multiplication in frequency domain which leads to smearing out all frequency axis(Valens, 1999). The method to solve the time and frequency localization problem is the wavelets. Wavelet analysis seeks to decompose time series into time-frequency space at the same time so that one gets the amplitudes of any periodic signals within the series and how it varies with time.

2.5 Wavelet analysis

The *Wavelet transform* is a *defacto* tool for analyzing localized variations of power within a timer series. It adapt itself intelligently to capture events that localises in time. This is done through the decomposition of a time series into time-frequency domain by determining the salient modes of variability and how they vary with time(Torrence and Compo, 1998; Genc¸ay et al., 2001; Valens, 1999). Hence the decomposition process of different time horizons clearly appeals well for differentiating seasonalities, unravels structural breaks, volatility clusters and identifies both global and local dynamic properties involving process with these times scales(Genc¸ay et al., 2001).

Here the use of scalable modulated window solves the signal-cutting problem. The window is shifted along the signal and for every position the spectrum is calculated several times repetitively with slightly shorter(or longer) window for every cycle(Valens, 1999). This results in a collection of time-frequency representation of the signal with different resolution. This means the wavelet transformation is an excellent tool for studying non-stationary or transient times series or signal. In wavelets analysis, one do not speak of time-frequency representation instead time-scale representation. Technically, the term *frequency* is a reserved word for Fourier transformation. Torrence and Compo (1998) pointed out that the earlier studies on wavelets analysis lacked statistical significance tests as in the work of Wang and Wang (Wang and Wang, 1996), for this reason, wavelets have been criticised that it produces only colourful and yet qualitative results. The origin of the misconception is the transformation of one-dimensional time series to a diffused two-dimensional time-frequency image and compounded by use of arbitrary non-normalization. The introduction of significance testing in wavelets theory by the work of Torrence and Compo (1998) now has put more renewed interest in the application of wavelets transform analysis.

2.5.1 Wavelet applications in finance and economics

Wavelets have wide applications in Geophysics, Medicine, Engineering in signal processing and in recent times have been applied in economics and finance. In the following discussion, we here presents few recent areas of applications of wavelets analysis in finance and economics. Wavelet methodology is increasingly gaining popularity in financial times series analysis because of the possibilities it offers researchers in extracting new information in frequency-time domain among macroeconomic data Ranta (2013) by examining the contagion of the world markets using wavelets and concluded that short time scale co-movements increases during major crisis while long time scale co-movements remains the same. Gallegati et al. (2005) studied the industrial production index of G-7 countries using wavelets techniques and the linkages between countries are always significant only at a business cycle, Kim and In (2005) found a relationship between stock returns and inflation which provided a new perspective on the [1] Fisher hypothesis. Again, the method was used to examine the hedge ratio and the empirical relationship between the stock and futures markets and empirical results indicates existence of feedback according toIn and Kim (2006). Similarly, Raghavan et al. (2010) investigated the impact of capital control measures implemented by Malaysian central bank in the late 1998 on the stock market in relationship to other major equity markets and their effects on pre-, after, and post- capital control measures by the bank. In the pre-, Singapore and US were more influential in transmitting news to Malaysia, in the after- there were spillovers effects coming from Singapore and in the post-, all the markets imparted similar effects on the Malaysian market. Using wavelets to

[1] The Fisher hypothesis states that, in the long run, inflation and nominal interest rates move together, meaning that real interest rates are stable in the long term. This is also called the Fisher effect. It was formulated by Irving Fisher.

decomposed the time-frequency representation Aguiar-Conraria et al. (2008) collaborators for the first time showed effects of the relationship between monetary policy and macroeconomic variables and its time evolution. They found that the changes are not homogeneous across the different frequencies.

Wavelets tools have been applied to the studies of international stock market movements. Sharkasi et al. (2005) examined the interrelationship among seven internationals stock markets prices with evidence of intra-continental and international spillover from the developed markets to emerging markets and similar to the work of Shik Lee (2004) but they investigated international transmission of stock markets movements and reported similar findings.Rua and Nunes (2009) assessed the stock market movements of four developed markets including German, Japan, UK and US for international diversification. Graham and Nikkinen (2011) used wavelets to analyze the long-term and short-term co-movement of international markets from European perspective and found that, Finland and emerging market regions confined to longterm fluctuations and evidence of co-movement for all frequencies between Finland and the developed markets and therefore, it is advantageous to diversify stock portfolios from Finland rather than France, Germany, Switzerland and the UK.

In a new look into the international stock markets indices co-movements, Madaleno and Pinho (2012) examined the variation of price shock transmission with continuous wavelet approach among markets indices of FTSE100, DJIA30, Nikkei and Bovespa. Their results suggested, there was strong relationships among the indices and inhomogeneous across scales, and that local events are more felt than others, fast transmission through markets across the world with significant time delay. Graham et al. (2013) examined the short-term and long-term dependencies of the returns for S&P 500 and S&P GSCI commodity index and found that there was no evidence of co-movement in total return in short term, an indication of diversification gains for equity investors. However, long-term diversification is profitable especially after the financial crisis. In a related studies, Boako and Alagidede (2016) examined the correlation of the emerging Africa equity markets and found that they are segmented regionally and globally and that the African markets should be considered as separate class.

The assessment of the exchange rate volatility and export performance was carried out on Egypt by Bouoiyour and Selmi (2015) with wavelets and found that relationship between exchange rate uncertainty and export performance depended strongly on frequency-to-frequency variations. Mitra and Mitra (2006) modelled exchange rate with wavelets decomposition of generic neural networks, showed a superior performance over the traditional techniques for forecasting spot foreign exchange rates of international trading currencies. Scott Hacker et al. (2012) investigated the relationship between spot exchange rates and nominal interest rate differentials based on wavelet-decomposition and found that the relationship is negative for shorter time horizon less than six month wavelet scale and positive in the longer horizon of wavelet scales longer than a year for the Swedish krona against five major curries US dollar, Japanese Yen, the Euro, Pound sterling and the Swiss franc with additional currencies of Norwegian krone and South Korean Won. The association between the exchange rate, interest rate and stock pricing in US in the period of 1990 to 2008 was analyzed by Hamrita and Trifi (2011) using maximal overlap discrete wavelet transform(MODWT), wavelet variance, correlation and cross-correlation and found that there was no relationship between interest rate and exchange rate at all time scales. However there is strong evidence of association between interest rate returns and stock index returns only at highest scales.

The application review has shown that wavelets techniques can be used for almost any time series data of macroeconomic variables of interest irrespective of stationarity behaviour.

2.6 Conclusion

The review of the empirical literature on the determinants of exchange rate shows that while much has been done on developing countries, the author is not aware of any studies with wavelets on Ghana. We find in the literature that not much studies has been done on the determinants of real exchange rate in Ghana. The few studies employs a single equation with combination of OLS and the ECM technique to determine the long and short run determinants of exchange rate, instead of the Johansen cointegration approach as used by many of the literatures reviewed. This study employs ARDL framework which has gained much ground on recent econometric time series analysis.

The use of wavelets analysis is an indispensable tool to study both stationary and nonstationary time series related applications and hence could be used equally well to probe time series of any macroeconomic variables of interest by any researcher discussed above. It is on this basis, that the methodology is employed for the studies to augments results of the ARDL simulations and to reveal hitherto non-intuitive information in the time series data as well intertemporal relationships.

Chapter Three

RESEARCH METHODOLOGY

3.0 Introduction

In this chapter, we examine the basics and theoretical framework adopted in the research from two perspectives, namely regression and wavelets methods. For the regression studies, we look at the model specification, concept of unit root and unit root testing, order of integration, cointegration techniques, diagnostics test treatments as well as Granger causality tests. The next approach would consist of the wavelet methodologies including wavelet definition, properties, power, coherency and cone of influence.

3.1 Model specification

The study adopts Edward's model of inter-temporal optimizing developed in 1989 to determine the determinants of exchange rate in Ghana. Unlike other theoretical models, this model differentiates factors that determine the equilibrium exchange rate in the long run from those that determine the short run dynamics of the exchange rate. Moreover, this model is developed to capture the structure of a typical developing economy. This model has been used to estimate exchange rate models in many developing countries (for example, Mungule (2004) used it in Zambia, also Ghura and Grennes (1993) used it for Sub-Sahara Africa).

The exchange rate (RER) model is represented by the following equation below:

$$RER = e^* = \times(a, gNT, PT \text{ } and \text{ } \tau) \tag{3.1}$$

Where $\delta x/\delta a<0$; $\delta x/\delta gNT<0$; $\delta x/\delta PT>0$; $\delta x/\delta \tau <0$

Equation (3.1) indicates that the long run real exchange rate is a function of real variables only. The value of real assets, government consumption, price of tradable and trade restrictions. The variables in this equation are in most instances influenced by changes in other real variables such as terms of trade (TOT) shocks, technological progress and changes in trade and capital restrictions. Changes in these variables can cause real exchange rate to deviate from its equilibrium level.

In the estimation of determinants of exchange rate, it is crucial to specify an empirical equation for the exchange rate. Based on the theoretical model developed by Edwards, the exchange rate is determined by the following variables; inflation, trade openness, money supply and Gross Domestic Product. Capturing the above mentioned variables, and in line with the works of Takaendesa (2006) and MacDonald and Ricci (2003), a model of exchange rate was formulated in the following equations;

$$ex = f(inf, trade\ openness, MS, GDP) \tag{3.2}$$

This can be transformed into regression equation as;

$$lnex = \beta_0 + \beta_1 lntrade + \beta_2 lnMS + \beta_3 lny + \beta_4 lncpi + \varepsilon_t \tag{3.3}$$

Where; ex: exchange rate $trade$: is trade openness proxy to the ratio of the sum of exports and imports to GDP ratio

MS: money supply proxy to M1(m1) or M2(m2) alternatively used in the text and equation. GDP: gross domestic product proxy to GDP growth represented by y inf: inflation proxy to consumer price index, cpi ε_t: is stochastic error term β_0, β_1, β_2, β_3 and β_4, are parameters or covariates. The *a priori assumption* is that: trade openness, money supply and inflation are expected to have a positive signs on the model, an indication of depreciation to the local.

However, Gross Domestic Product is expected to have a negative sign, a measure of appreciation to the local currency.

3.2 The concept of unit root testing

The advances in time series econometrics, normally in the testing for the non-stationarity and cointegration between time series data have provided new insights to empirical economic analysis. This is because a unit root is often a theoretical implication of models which postulate the rational use of information that is available to economic agents. Included in examples but not limited to: various financial market variables such as futures contracts stock prices, dividends, spot and forward exchange rates and even aggregate variables like real consumption. Formal statistical tests of unit roots hypothesis are important in economics because they help to evaluate the nature of the non-stationarity that most macroeconomic data exhibit. They help in determining whether the trend is stochastic, through the presence of a unit root, or deterministic, through the presence of a polynomial time trend Phillips and Perron (1988). As a consequence, testing for the existence of unit roots and cointegration have become standard procedures in econometrics analysis. Hence, they are indispensable in modern empirical research because cointegration required some economic parameters to be constant or stationary over time.

3.2.1 Test of unit root

Unit root test is for testing the stationarity of time series data. The concept of stationarity is related to the properties of stochastic process. Non stationarity in time series occurs where there is no constant mean, no constant variance or both of these properties. When an equation becomes random walk without drift model there is non-stationarity and there is a problem. The stationarity of time series data is important because correlation could persist in non stationarity even if there is large sample and may result in what is called spurious regression (Yule, 1989). The unit root problem can be solved, or stationarity can be achieved by differencing the data set (Wei, 2006).

The starting point for the empirical analysis is an investigation of the unit root property of variables. Unit root test are essential to ensure that we do not get spurious regression. A time series that contains a unit root is said to be non-stationary otherwise the time series is stationary. The problem with non-stationary or trended data is that the standard OLS regression procedures can easily lead to incorrect conclusions. It can be shown that in these cases the norm is to get very high values of R^2 (sometimes higher than 0.95) and very high values of $t{-}ratios$ (sometimes higher that 4) whiles the underlying variables used in the estimation have actually no interrelationship at allAsteriou and Hall (2007), (like trying to relate oranges and mangoes, it does not add up).

The null hypothesis of a unit root cannot be rejected at the convectional levels of significance. In conducting stationarity tests of the variables, we apply the Augmented Dickey-Fuller (ADF) unit root test, which is derived from (Dickey and Fuller, 1979, 1981) formlism. It tests the null of the unit root[1]. It is important to state that when the number of observations is low, unit root test have little power Chebbi and Lachaal (2007). For this reason we complement the ADF unit root test with different tests such as Kwiatkowski Philip Schmidt and Shin (KPSS)

Kwiatkowski et al. (1992) stationarity unit test, which test the null of stationarity[2]. Also, the Philip-Perron unit root test Perron (1990); Phillips and Perron (1988)*ibid* was also used.

[1] In the ADF test, the null hypothesis is that the variable in question has a unit root (i.e., it is not stationary)

[2] KPSS are used for testing a null hypothesis that an observable time series is stationary around a deterministic trend

Augmented Dickey Fuller procedure is meant to treat possible parametric serial autocorrelation in the error terms by adding the first lagged difference terms of the regressand. KPSS stationarity unit root, test the null of stationarity. The ADF is estimated by the following regression. In order to examine the stationarity of the respective time series in this work, the following ADF test is performed on each series:

$$\triangle X_t = \alpha + \beta t + (\rho - 1)X_{t-1} + \sum_{i=1}^{k} \rho_j \triangle X_{t-1} + \epsilon_t \quad (3.4)$$

where $4X_t$ is the first difference of X_t series, α and βt constant deterministic terms, t is a linear time trend variable, k is the number of lag differences included to capture any autocorrelation, ρ which are included to allow for serially uncorrelated residuals and is determined by the Akaike Information Criterion or the Schwartz Bayesian Criterion and $_t$ is the residual term.

The null hypothesis is that X_t is a nonstationary series and accounted for by a $t - test$ of $(\rho - 1 = 0)$. The alternative hypothesis of stationary requires that $(\rho - 1 < 0)$ be significantly negative. If the absolute value of the computed $t - statistics$ for $(\rho - 1)$ exceeds the absolute critical value, then the null hypothesis, that the series X_t is nonstationary must be rejected against its alternative hypothesis. That is, if on the other hand, it is less than the critical value, it is concluded that the X_t series is nonstationary.

The Philips-Perron unit root test makes use of non-parametric statistical methods to take care of the serial correlation without adding lagged difference Gujarati (2003). Due to the possibility of structural changes that might have occurred during the period under consideration, the ADF test might be biased in identifying variables as being integrated. However, the Philips-Perron test is expected to correct this anomaly.

The Philips-Perron test is estimated by the following regression:

$$\triangle X_t \ = \ \alpha + \beta t + \rho X_t + \epsilon_t \tag{3.5}$$

where the second equation includes a trend variable t. The PP test is verified by the $t{-}value$ associated with the estimated coefficient of ρ. The series are to be stationary if ρ is negative and significant. The test is to be performed for all the variables where both the original series and differences of the series are to be tested for stationary.

The KPSS test for unit root differs from the ADF and PP test in that the series is assumed to be (trend-) stationary under the null. The KPSS test reverses the null and the alternative hypothesis. The KPSS statistic is based on the residuals from the OLS regression, which takes the following form:

$$\triangle X_t \ = \ \alpha_t + b_t + \epsilon_t \tag{3.6}$$

where t is a linear deterministic trend, $_t$ is a stationary error and b_t is a random walk; $b_t = b_{t-1} + \mu_t$, where μ_t are i.i.d$(0, \sigma^2_\mu)$. The initial value of b_0 is treated as fixed and is interpreted as an intercept. The test is conducted by first regressing X_t on a constant and a trend, allowing one to obtain the residuals.

The KPSS test statistic is defined as:

$$\eta(\mathbf{u}) \ = \ V^2 \sum \frac{q_t^2}{q^2(k)} \tag{3.7}$$

where $q_t = \text{P} s_t$, s_t is the partial sum of the residuals, $q^2(k)$ is a consistent non-parametric estimate of the disturbance variance and V is the sample size. (Kwiatkowski et al., 1992) show that the statistic $\eta(\text{u})$ has nonstandard distribution, and critical values are provided therein. If the calculated value of $\eta(\text{u})$ is larger than the critical values, then the null of stationary for the KPSS is rejected.

The test involves testing the null hypothesis of non-stationarity of the exchange rate determinants data series against the alternative hypothesis of stationarity of the variables. We use the natural logarithms of the variables time series as relative values.

3.3 The Concept of Cointegration

The basic requirement that for any econometric model using non-stationary time series data to be useful must be cointegrated. That is, if the variables involved are not cointegrated then we have the problem of spurious regression and the econometric modeling being meaningless. Cointegrated variables are therefore perquisites for detecting relationships linking among economic structures. The crux is that if there is a true long-run relationship between the variables, although the variables would rise over time (because they are trended), there will be a common trend that would link them together; that is there may be a long-run co-movement between the time series data with a common equilibrium relation. For an equilibrium relationship to exist, linear combination of Y_t and X_t must be stationary. In a more formal way, time series Y_t and X_t are said to be cointegrated of order d,b where $d > b > 0$, written as $Y_t, X_t\ CI(d,b)$ if (a) both series are integrated of order d, (b) there exist a linear combination of these variables, $\beta_1 Y_t + \beta_2 X_t$ which is integrated of order $d - b$. The vector $\{\beta_1, \beta_2\}$ is called the cointegrating vector.

In short, the rational for using cointegration is that if the variables are non-stationary but there exists linear combination of the series which are stationary, then in the long-run these series do not drift apart. In this way, we can infer the level exchange rate. Cointegration is therefore a vehicle to correctly test a hypothesis concerning the relationship between macroeconomic variables having unit roots. Clearly, Cointegration is a powerful tool to treate a limited econometric time series data. Again, if the variables are cointegrated, a test of causality can be carried out between them. For example, if the series of the macroeconomic variables are cointegrated, an error correction representation of the cointegrated series can be estimated to examine the causality between the variables as a consequence cointegration is viewed as statistical expression of the nature of the long run equilibrium relationship Doh-Nani and Awunyo-Vitor (2012); Abavare (2016).

3.3.1 The Method of Cointegration testing

The theory has it that an integrated variables of order I(1), may have a cointegration relationship, it is so crucial to test the existence of such relationship. If a group of variables are individually integrated of the same order and there is at least one linear combination of these variables that is stationary, the variables are said to be co-integrated. Co-integrated variables will never move far apart, and will never be attracted to their long-run relationship. Testing for cointegration implies testing for the existence of such a long run relationship between the variables. In order to verify that all variables are integrated for order one in at least first difference, the study use Dickey Fuller test to verify the integration order. The equation estimated for the Dicker Fuller test is estimated as follows;

$$\Delta X_t = \alpha + \beta_t X_{t-1} + \sum_{i=0}^{n} \theta i \Delta X_{t-1} + \varepsilon_t \qquad (3.8)$$

Where Δ is the first difference operator, t is the time trend, is the stationary random error and n is the maximum lag length.

3.3.2 Order of integration and hypothesis definition

The variables are cointegrated if they have a long-run or equilibrium relationship between them. In this case, let us suppose the following generic variables Y_t and X_t, are integrated of order d, $I(d)$, If there exists a linear combination such that the disturbance term $_t$ from regression is of a lower order of integration, $I(d-b)$ and $b > 0$ then Engle and Granger (1987) defines Y_t and X_t as cointegrated. Thus if Y_t and X_t were both $I(1)$ and residual ϵ_t are $I(0)$, the two

series would be cointegrated, in this case, equation (5) is longer spurious.First, the order of integration of the dependent Y_t and independent X_t variables are determined by employing the unit root test. We then run the OLS regression on what is called the cointegrating regression based on the model below:

$$X_t = \alpha_0 + \alpha_1 Y_t + \epsilon_t \tag{3.9}$$

which will not yield a satisfactory estimates of $\hat{\alpha}_0$ and $\hat{\alpha}_1$, we follow by testing whether the residual $_t$ from the regression are stationary. If Y_t and X_t are not cointegrated, any linear combination of them will be non-stationary, and hence the residual will be non-stationary. If the time-series included in the analysis are $I(1)$ and cointegrated, by definition the residual term $\epsilon_t \sim I(0)$, the simple Granger causality test should not be used (Al-Khulaifi, 2012). From equation (3.9), we formally state the hypothesis to be tested in support of the objective of this study as follows:

H_0 : *The variables are not cointegrated.*

H_1 : *The variables are cointegrated.*

This result is possible if the series of residuals $_t$ is stationary and display no unit root. Hence we apply the estimated cointegration relationship to generate residual errors. The estimated OLS residuals are then also tested for unit root and corresponding hypothesis for stationarity is stated below:

$$H_0 : \epsilon_t \quad is\ no\ stationary$$

$$H_1 : \epsilon_t \quad is\ stationary$$

However, if the unit root tests suggest different order of integration for the variables (i.e., some variables stationary and others are not) then we apply autoregressive distributed lag method (ARDL). Again, if the variables are stationary at levels, then we apply an OLS regression. In this work, we used Fully Modified(FM), Dynamic and Integrated Modified -OLS Aschersleben and Wagner (2016). The subsequent section briefly outline the methods experimented.

3.3.3 ARDL cointegration

Basically, the ARDL procedure involves three steps for estimating long run relationship. The first step is to test for the existence of level relationship among all variables in the equation. This is done by estimating equation (3.10) by ordinary least square and performing F-test for joint significance of the associated lagged coefficients.

The hypothesis defined as

$H_o : \$_1 = \$_2 = \$_3 = \$4 = \$_5 = \$_6 = 0$

$H_1 : \$_1\ 6{=}\ \$_2\ 6{=}\ \$_3\ 6{=}\ \$_4\ 6{=}\ \$_5\ 6{=}\ \$_6\ 6{=}\ 0.$

Since the asymptotic distribution of the F-statistic and the non-standard under the null hypothesis of no cointegration among variables under consideration, Pesaran et al. (2001) have tabulated two sets of asymptotic critical values for inference. The first set (lower bound) assumes that all variables are I(0) while the second set (upper bound) assumes that all variables are I(1). The computed F-statistic underlying the equation is compared with the critical values and its greater than the upper bound critical values, then the null hypothesis of no cointegration is rejected and we conclude that there exist a steady state equilibrium among the variables. On the other hand, if the F-statistics is less than the lower bound critical value, then the null hypothesis of no cointegration cannot be rejected, indicating non-existence of long run relationship among the variables. Lastly if the computed F-statistics fall within the lower and upper bound critical values, the results become inconclusive and in this case the time series properties of the variables must be known before any inferences can be drawn (Pesaran et al., 2001).

The second step involves estimating the long run and short run coefficients of the same equation. It is important to state that the second step is conducted only if there is evidence of a long run relationship in the first step (Narayan et al., 2004). The appropriate long run and short run models associated with the equation can be based on the minimization of information criteria such as Akaike Information Criteria. Once it becomes clear that a long run (cointegration) relationship exist among the variables, long run models can be estimated as;

$$lnex_t = \beta_0 + \sum_{i=0}^{p} \beta_1 lnex_{t-i} + \sum_{i=1}^{q} \beta_2 lnMS_{t-i} + \sum_{i=1}^{r} \beta_3 lntrade_{t-i} + \sum_{i=1}^{q} \beta_3 lny_{t-i} + \sum_{i=1}^{q} \beta_2 lncpi_{t-i} + U_t \tag{3.10}$$

All variables are previously defined and have their usual meanings. The Final stage of the ARDL is the short run dynamics which can be derived by constructing the error correction term(ECT) model This involves the analysis of how changes in the regressors impact on real exchange rate (dependent variable) in the short run. The short run equation to estimate is;

$$\Delta lnex_t = \beta_0 + \sum_{i=0}^{p} \beta_1 \Delta lnex_{t-i} + \sum_{i=1}^{q} \beta_2 \Delta lnMS_{t-i} + \sum_{i=1}^{r} \beta_3 \Delta lntrade_{t-i} + \sum_{i=1}^{q} \beta_3 \Delta lny_{t-i} + \sum_{i=1}^{q} \beta_2 \Delta inf_{t-i} + \Delta\Psi ECT_{t-i} + U_t, \tag{3.11}$$

where ECT_{t-i} is the one lagged period error correction term and $\Psi$is the coefficient of the error correction term which measures the speed of adjustment to obtain equilibrium following shock to the system in the short run.

Supposing that there exist a long run relationship among our variables under consideration, then the correction mechanism must exist in other to moderate the variables to their long term relationship such that temporary shocks from the equilibrium would be corrected. This mechanism is achieved through equilibrium correction model. The coefficient of the error correction term represents speed of adjustment to long run equilibrium following shocks to the system.

3.3.4 Diagnostic testing

The concern of theoretical econometrics researchers is the disturbance in the structure of econometric models. Kramers and collaborators offer recommendation for test for the residual normality, homoscedasticity and autocorrelation of the errors in the equation as well as procedures to rectify adverse inconsistency in convectional regression output Kramer and Sonnberger¨ (1986). Finally, models were taken through the Ramseys Reset test, Normality test and stability tests for parsimony. The test for normality of the variables uses Jarque-Bera test. This is based on OLS residual and the test statistic follows the chi-square distribution with two degrees of freedom. It jointly tests skewness ($S = 0$) and kurtosis ($K = 3$) of the residuals. The null hypothesis that the residuals are normally distributed is tested against alternative that the residuals are not normally distributed. In testing for heteroskedasticity ensures that the OLS assumption that the variance of each of the disturbance term is same. In this case, if we insist in using the usual testing procedures despite heteroskedasticity, whatever conclusion is drawn or inference arrived at could be very misleading Gujarati (2003). We tested for heteroskedasticity on the hypothesis:

H_0 : *There is no homoskedasticity.*

H_1 : *There is heteroskedasticity.*

The hypothesis is carried out by employing the white heteroskedasticity test. For accuracy of the estimates, the study tested for autocorrelation since the classical regression models assumes the existence of no autocorrelation in the residual term. This is crucial because, in the absence of the assumption, the OLS estimator may no longer have minimum variance among all linear unbiased estimators. In this case, the estimates may not be as accurate as other linear unbiased estimators and that the t,F and χ^2 test may give misleading conclusions as suggested by (Gujarati, 2003). In testing for autocorrelation, the following hypothesis was stated:

H_0 : *There is no autocorrelation in the residual term.*

H_1 : *There is autocorrelation in the residual term.*

The test for autocorrelation in this work uses the Durbin-Watson $d - test$ because it is the best for our samples.

3.3.5 Granger causality test

The connections with macroeconomic variables are examined by using Pairwise GrangerCausality test. Let us assume a variable X is caused by Y if X is better predicted from past values of Y and X together rather than from past values of X alone. The use of Granger causality tests helps to identify and address the potential simultaneity biases, especially in fitting a single-linearly specified model for the variables. The simultaneity bias emerges when the OLS estimation violates the strict exogeneity assumption of the right hand side variables. That is, the explanatory variables do not correlate well with each other or with the residual terms and also there is no feedback effect from the left hand side variable.

We examine the direction of causality between the variables based on the following distinguished patterns a) unidirectional causality from X to Y , denoted by $X \longrightarrow Y$, b)unidirectional causality from Y to X, denoted by $Y \longrightarrow X$, c) feedback or bidirectional causality $X \longleftrightarrow Y$, and d) no causality. The simplest Granger test that define causality is that, a variable Y_t is said to Granger-cause X_t, if X_t can be predicted with greater accuracy by using past values of the Y_t variable rather than not using such past values, all other terms remaining unchanged.

Classically, Granger causality test works on the assumption that the series are stationary. Therefore, in this study, the series that were non-stationary were differenced to achieve stationarity before applying the Granger-causality test. The test involves the estimation of the following pair of regressions in equations (3.12) and (3.13) shown below.

$$X_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} X_{t-i} + \sum_{i=1}^{p} \alpha_{2i} Y_{t-i} + \epsilon_t \quad (3.12)$$

$$Y_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} Y_{t-i} + \sum_{i=1}^{p} \beta_{2i} X_{t-i} + \mu_t \quad (3.13)$$

where X is dependent variable, and Y is vector of explanatory variables including

The Granger causality can be tested through the null hypothesis in equation (3.12) as this; Y does not cause X, that is $\alpha_{2i} = 0$ for all i and for equation (3.13) the null hypothesis is X does not cause Y , or $\beta_{2i} = 0$ for all i. If $\alpha_{2i} = \beta_{2i} = 0$ for all i, we conclude that there is no causality between X and Y . If both null hypotheses are rejected, then $\alpha_{2i} \neq 0$ and $\beta_{2i} \neq 0$, then bidirectional relationship exists between the two variables X and Y . This simple causality is valid only for a stationary series $I(0)$.

In the test of the granger causality test, between exchange rate and the alternative determinants of the exchange rate, the models of interest take the following forms;

$$\Delta lnex_{*} = \sum_{i=1}^{p}\beta_1 \Delta lnex_{*t-1} + \sum_{i=1}^{q} r_i \Delta lnexD_{t-i} + \varepsilon_t \quad (3.14)$$

$$\Delta lnexD = \sum_{i=1}^{p}\alpha_1 \Delta lnexD_{t-1} + \sum_{i=1}^{q} \alpha_i \Delta lnex_{*t-i} + \varepsilon_t \quad (3.15)$$

The null hypothesis for equation (3.14) is that the determinants of exchange rate do not alternatively granger cause real exchange rate in Ghana. This reduces testing the restricted hypothesis

that;

$$H_o = r_1 = r_2 = \ldots r_q = 0 \quad (3.16)$$

In the same vein, the null hypothesis of equation (3.15) is that real exchange rate does not granger cause the determinants of real exchange rate alternative in Ghana. This hypothesis is tested by the imposition of restrictions on the parameters on the lag differences on the real exchange rate;

$$H_o = \alpha_1 = \alpha_2 = \ldots \alpha_q = 0 \quad (3.17)$$

The rejection of both hypothesis in both equation (3.14) and (3.15) implies a bidirectional granger causality between real exchange rate and any of the determinants of the real exchange rate. Contrary, simultaneous acceptance of both equations implies no granger causality among the variables in Ghana. If one of the equations is rejected, the implication is that there exists a unidirectional relationship running for real exchange rate to (any of its determinants) or any of the determinants to (real exchange rate)

3.4 Wavelet analytical framework

In this section, we discuss the pedagogical framework of wavelet analysis. It is a mathematical treatment for the study of periodic phenomenon in time series with frequency change across time Roesch and Schmidbauer (2014).

3.4.1 Types of wavelet transformation

The Wavelet transform is used to analysize time series that contains non-stationary power at many different frequencies. Wavelet function may either be orthogonal or nonorthogonal depending on the kind of its basis set function. The orthogonal basis function are termed as discrete wavelet transforms. The non-orthogonal basis function refered to as continous wavelet transform. In this work, we focus mainly on the non-orthogonal treatmentTorrence and Compo (1998).

3.4.2 Formal definition of continuous wavelet transform

The continuous wavelet transform is formally defined as:

$$\gamma(s,\tau) = \int f(t)\Psi^*_{s,\tau}(t)dt, \tag{3.18}$$

where $*$ is complex conjugate, $f(t)$ the time dependent function which is decomposed into the corresponding basis function $\Psi^*_{s,\tau}(t)$ called wavelets and the continuous wavelet transform is $\gamma(s,\tau)$. The parameters s and τ are *scale* and *translation* respectively, are new dimensions after the wavelet transform Valens (1999).

The *daughter wavelets* $\Psi^*_{s,\tau}(t)$ or simply wavelets are considered as small waves that can decay in a limited time period. Wavelets are generated from a single basic wavelet called the mother wavelet or Morlet wavelet, by scaling and translation are defined as:

$$\Psi_{s,\tau}(t) = \frac{1}{\sqrt{s}}\Phi\left(\frac{t-\tau}{s}\right), \tag{3.19}$$

with $\frac{1}{\sqrt{s}}$ being the energy normalization factor which ensures that wavelets are comparable across scales and times series. The *Morlet wavelet* allows good identification and isolation of periodic signal and also provides a balance between localization of time and frequency. The Morlet wavelet in its simplest version is defined as:

$$\Phi(t) = \pi^{-\frac{1}{4}}(e^{i\omega_o t} - e^{-\frac{\omega_o^2}{2}})e^{-\frac{t^2}{2}}, \tag{3.20}$$

the term $e^{-\frac{\omega_o^2}{2}}$ ensures the admissibility condition and approaches zero with appropriate ω_o, the simplified version then becomes:

$$\Phi(t) = \pi^{-\frac{1}{4}}e^{i\omega_o t}e^{-\frac{t^2}{2}}, \tag{3.21}$$

with its corresponding Fourier transform given as

$$\hat{\Phi}(\omega) = \pi^{\frac{1}{4}}\sqrt{2}e^{-\frac{1}{2}(\omega-\omega_o)^2}, \tag{3.22}$$

is a plane wave modulated by a Gaussian where ω_o is non dimensional angular frequency per unit time, set to be 6 in the literature to ensure that Morlet is approximately analytic. The transform can be separated into its real and imaginary parts necessary for studying synchronism between different time series. This separation provides the instantaneous phase of the periodic process in time domain and prerequisite for the investigation of two time series.

Morlet wavelet keep its shape through frequency shifts and provides reasonable separation of contributions from different frequency bands without loss of information in time resolution during reconstruction. Since Wavelet window can continuously resize itself means sampled signal with small window indicates detailed feature can be seen. In the same way, sampled signal with large window means coarse features can be observed. Hence using wavelets enable one to see both fine details and approximations. The link between frequency and scale is given by the relation $f = \mu_f/s$ indicating that the wavelet scale is inversely related to the frequency.

3.4.3 Properties of Morlets wavelet

Morlet wavelet must satisfy the admissibility and regularity condition. These are the properties which gave the Morlets their name. It can be shown that integrable function $\Phi(t)$ obeys the so called *admissibility conditions*,

$$0 < C_{\hat{\Phi}} = \int_0^{+\infty} \frac{|\hat{\Phi}(\omega)|^2}{|\omega|} d\omega < +\infty \tag{3.23}$$

which is used to analyze and reconstruct the data without lost of information, with the Fourier transform given by the expression (Torrence and Compo, 1998; Rua and Nunes, 2009; Roesch and Schmidbauer, 2014):

$$\hat{\Phi}(\omega) = \int_{-\infty}^{+\infty} \Phi(t) e^{-i\omega\tau} dt \tag{3.24}$$

This means the transform of $\Phi(t)$ varnishes at the zero frequency.

$$|\hat{\Phi}(\omega)|^2 \Big|_{\omega=0} \tag{3.25}$$

indicating that the wavelets must have a band-pass like spectrum. This suggests that the mean value of the wavelets in time domain is zero, i.e.

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$$\Phi(t)dt = 0 \quad (3.26)$$

and therefore it must be oscillatory. Again, the morlet square must integrate to unity which means it is limited to an interval of time.

$$\int_{-\infty}^{+\infty} \Phi^2(t)dt = 1 \quad (3.27)$$

3.4.4 Continuous wavelet transform and signal reconstruction

A continuous wavelet transform $\Omega_x(s,\tau)$ with respect to the Morlet function of a discrete time series (x_t) is defined as the convolution of the series with a set of wavelet daughters. The position of a particular generated daughter wavelet by the mother wavelet in time domain is determined by localizing time parameter τ and shifted by time increment of dt.

$$\begin{aligned}\Omega_x(s,\tau) &= \int_{-\infty}^{+\infty} x(t)\Psi_{s,\tau}(t)dt \\ &= \int_{-\infty}^{+\infty} x(t)\frac{1}{\sqrt{s}}\Phi^*\left(\frac{t-\tau}{s}\right)dt\end{aligned} \quad (3.28)$$

For discrete time series, $x(t), t = 1,\ldots N$, equation (3.28) be written as:

$$\Omega_x(s,\tau) = \frac{1}{\sqrt{s}}\sum_{t=1}^{N} x(t)\Phi^*\left(\frac{t-\tau}{s}\right). \quad (3.29)$$

The Mother wavelet is a prototype for producing other window functions. The translation parameter, τ, refers to the location of the window (where it is centred). As the window shifts along the signal, the time information in the transform domain is obtained. Again, the scaling parameter s is the dilation factor (if $|s| > 1$) or compressing (if $|s| < 1$) controls the length of the wavelet by extracting frequency information from the time series. The Morlet wavelet is dilated or compressed to correspond to cycles of different frequencies as a consequences, the entire set of wavelets can be generated which is used to analysis the time series.

We are also able to reconstruct the signal from its wavelet transform from the equation:

$$x(t) = \frac{1}{C_\Phi} \int_{-\infty}^{+\infty} \left\{ \int_{-\infty}^{+\infty} \Phi^* \left(\frac{t-\tau}{s} \right) \Omega_x(s,\tau) d\tau \right\} \frac{ds}{s^2}. \tag{3.30}$$

The choice of the set of scales s is determined by the wavelet coverage in the frequency of the series(Rua and Nunes, 2009; Roesch and Schmidbauer, 2014; Valens, 1999) and scales written as a fractional powers of two for convenient.

$$\begin{aligned} s_j &= s_{min} 2^{jdj}, \qquad\qquad j = 0, 1, \ldots J \\ J &= (dj)^{-1} log_2 \left(\frac{Ndt}{s_{min}} \right) \end{aligned} \tag{3.31}$$

where s_{min} is the smallest resolvable scale and J the largest scale and dj is the resolution and depends on the spectral width of the wavelet function(Torrence and Compo, 1998; Roesch and Schmidbauer, 2014).

3.4.5 Analysis of wavelet power spectrum

In general, wavelet function is a complex function, making wavelet transform also a complex $\Omega_x(s,\tau)$ with real and imaginary components and phase angle. As a result, the local amplitude (A) of any periodic time series can be obtained from the modulus of wavelet transform give by the expression,

$$\mathcal{A}_x(s,\tau) = \frac{1}{\sqrt{s}} \mid \Omega_x(s,\tau) \mid \tag{3.32}$$

The square of the amplitude is defined as the time-frequency and regarded as the wavelet energy density called wavelet power spectrum given by,

$$\mathcal{P}_x(s,\tau) = \frac{1}{s} \mid \Omega_x(s,\tau) \mid^2, \tag{3.33}$$

as measure of the local variance. Wavelet power of univariate series describes the evolution of the variance at different frequencies, with periods of large variance associated with periods of larger power at the different scales Aguiar-Conraria et al. (2008). The statistical significance of wavelet power is assessed against the null hypothesis that the data generating process is given by a stationary process with a certain background power spectrum (P_f).

In many applications, time-averaged wavelet power spectrum is use to investigate the overall strength of periodic phenomenon. Contour lines are drawn to the wavelet power spectrum to delineate areas of high significance. The displacements of periodic phenomenon with respect to the localizing origin τ shifted across time domain is given by the instantaneous local wavelet phase Θ.

$$\Theta_x(\tau, s) = Arg(\Omega_x(s,\tau)) = \arctan\left(\frac{\Im\Omega_x(s,\tau)}{\Re\Omega_x(s,\tau)}\right), \quad (3.34)$$

wrapped in the range $[-\pi, \pi]$.

3.4.6 Cross-wavelets power and phase differences

Cross-wavelet analysis is a tool for comparing the frequency components of two time series at a certain periods to check if they are synchronous across certain range of time. For two financial time series (x_t) and (y_t) with corresponding wavelet transforms $\Omega_x(s,\tau)$ and $\Omega_y(s,\tau)$ respectively, we define the cross-wavelet power spectrum as

$$\Omega_{x,y}(s,\tau) = \frac{1}{s}\Omega_x(s,\tau)\Omega_y^*(s,\tau). \quad (3.35)$$

The square of cross-wavelet spectrum has the meaning of cross-wavelet power given as,

$$P_{x,y}(s,\tau) = |\Omega_{x,y}(s,\tau)| \quad (3.36)$$

The cross-wavelet power spectrum in the time-frequency domain can have cone of influence optionally and contour lines to indicate regions of significance of joint periodicity.

The phase difference of x over y at each localizing time origin and scale gives information about the delays of the oscillations. It must be viewed as as a position in the pseudo-cycle of the series. The is defined as;

$$\begin{aligned}\Theta_{x,y}(\tau,s) &= Arg(\Omega_{x,y}(s,\tau)) \\ &= \arctan\left(\frac{\Im\Omega_{x,y}(s,\tau)}{\Re\Omega_{x,y}(s,\tau)}\right) \\ &= \Theta_x(\tau,s) - \Theta_y(\tau,s)\end{aligned} \quad (3.37)$$

(3.38)

equivalent to the difference between the individual phases when converted to an angle in the range $[-\pi,\pi]$, six cases can be distinguished.

- case one: When the phase difference between the two series is zero $\Theta_{x,y} = 0$, it means they co-move at the the specified frequency, we do not know which series drives the other.
- case two: If the angle between the two series is $\Theta_{x,y} \in (0,\frac{\pi}{2})$ then the series move in phase, however, the time series y leads x.
- case three: If the angle between the two series in the range $\Theta_{x,y} \in (-\frac{\pi}{2},0)$ then it is x that is leading y.
- case four: A phase difference of $\Theta_{x,y} = \pi$(or $-\pi$)shows an anti-phase relation, meaning the series have no relationship.
- case five: If the phase difference between the series is in the range $\Theta_{x,y} \in (\frac{\pi}{2},\pi)$ then x

is leading y.

- case six: Finally, $\Theta_{x,y} \in (-\pi, -\frac{\pi}{2})$ then y is leading x.

Note that, this analysis is straight forward when one draws a geometric representation of x,y series (diagrammatically) on cartesian coordinates. The series with largest individual angle of Θ is the lagging series and the least is the leading.

3.4.7 Wavelets coherency

Coherence is important when one considers fluctuating quantities, indicating how closely X and Y are related by a linear transformation. This is observe when their measure of coherence is close to maximum value of unity. In a similar fashion as Fourier analysis, wavelets coherency is mathematically defined as the ratio of the absolute squared of the smoothed cross-wavelet spectrum to the product of the smoothed individual squared spectrum and can be understood as local correlation both in time and frequency between the two series

$$R^2(s,\tau) = \frac{|S(s^{-1}\Omega_{x,y}(s,\tau))|^2}{S(s^{-1}|\Omega_x(s,\tau)|^2)S(s^{-1}|\Omega_y(s,\tau)|^2)} \tag{3.39}$$

where S indicates the smoothing operator in both time and scale. Smoothing is critical otherwise, coherency would always be 1 at all time and scales. Smoothing is done through convolution in time and scale and with Gaussian.

The wavelets squared coherency $R^2(s,\tau)$ value lies between 0 and 1, with a high value suggesting strong co-movement spectrum for two series and vice versa. Clearly, one can see that, square coherency mimics classical correlation around each moment in time for each frequency. Its only takes positive values and can therefore be used to determine the degree to which two time series move together over time and across frequencies. Wavelets squared coherency technically provides an important measure that can be used to study and identify region in time-frequency domain where the behaviours of two macroeconomic variables co-vary and to capture both time-frequency changing characteristics of interest Rua and Nunes (2009).

Again, the three-dimensional wavelet coherency approach makes it possible to identify regions in time-frequency domains where two macroeconomic variables co-vary. We have clearly demonstrated that this technique is superior since the degree of co-movement is not constant over time as results, short-term and long-term dynamics could be distinguished(Graham and Nikkinen, 2011).

3.4.8 Cone of influence and confidence interval

Time series data are finite in length and in treating such a data, errors are bound to occur at the beginning and the end of the wavelet power spectrum when the Fourier transform especially assumes cyclic data. To overcome this problem is to pad the ends of the time series with zeros before conducting the wavelets transform and then removing them afterwards. There is introduction of discontinuities when the series are padded with zeros at the end points. As one goes to higher scales the amplitudes decreases near the edges as more zeros enter the analysis. The regions in the wavelets spectrum where edge effects are important is termed as *cone of influence (COI)* and is defined as the exponential folding time for the autocorrelation of wavelets power at each scale. The size of the COI is an indication of the extend of decorrelation time for a single spike in the time series. When decorrelation time is compared with the width of a peak in the wavelet spectrum, we are able to discriminate the noise in the data from a spike as a result of random noise.

The wavelet power spectrum null hypothesis is defined as: The assumption is that the time series has a mean power given by

$$P_k = \frac{1-\alpha^2}{1+\alpha^2-2\alpha\cos(2\pi k/N)} \tag{3.40}$$

where $k = 0 \cdots N/2$ is the frequency index, α is the assumed lag-1 autocorrelation coefficient, we obtain white noise when $\alpha = 0$. If a peak in the wavelet spectrum is significantly above this background spectrum, the we consider the feature with certain confidence.

The confidence interval is the probability that the true wavelet power at a time and scale lies within an interval about the estimated wavelet power re-written from equation (3.41) as,

$$\frac{|\Omega_x(s,\tau)|^2}{\sigma^2 P_k} \Rightarrow \frac{\chi_2^2}{2}, \tag{3.41}$$

where σ is the standard deviation. One easily replaces the theoretical wavelet power of $\sigma^2 P_k$ with the true wavelet power written as Ω.

3.5 Data source and type

This study specifically used secondary data, although in research we have both primary and secondary data. The study used annual time series data spanning for the period 1960 to 2014 and obtained from published sources. The data were taken from three official sources; World Bank Development Indicators (2015), Bank of Ghana (BoG) Statistical Bulletins and International Financial Statistics CD-ROM (2015). All estimations and the econometric techniques were carried out using an open source R-packages.

3.6 Definition and measurements of variables in the model

In basic terms, a variable represents a property of an event or phenomenon associated with a particular object (Ryan et al., 1992). Variables can be dichotomized into dependent and independent variable (Harris, 1995). The impact of changes in the independent variable upon the dependent variable is considered in the data analysis. This means that the dependent variable is predicted to change when the independent variables changes.

To investigate whether the exogenous components of trade openness, terms of trade, money supply, gross domestic product and inflation influence real exchange rate, exchange rate regression model is set up. The dependent variable is the exchange rate and the independent variables are trade openness, terms of trade, money supply, gross domestic product and inflation.

3.6.1 Exchange rate

Nominal exchange rate is defined as the unit of Ghana Cedis per US dollar. This implies that an increase means depreciation while a decrease indicates appreciation of the domestic currency. Moreover, most studies that have estimated real exchange rate models have used the idea of real effective (multilateral) rather than real bilateral exchange rate. The real effective exchange rate is computed as shown in equation (2.3). The exchange rate estimation in this work is nominal.

3.6.2 Trade openness

Trade openness refers to the sum of exports and imports of goods and services measured as a share of gross domestic product. It is given by the expression $[X + M)/Y]$ and it used as an indicator of trade policy restrictions such as tariffs and quotas. A less restrictive trade regime is only one of the major factors of trade openness, as international trade is also determined by other factors affecting imports and exports, including RER (Cottani et al., 1990). Exchange and controls is proxy by the degrees of trade openness of the economy and is the standard practice in many literatures. This is as a result of the non-availability of consistent and longer period data on tariffs revenues as proportion of imports.

3.6.3 Money supply

This refers to the entire stock of currency and other liquid instruments in a country's economy at a particular point in time. The money supply can include cash, coins, and balances held in checking and savings account. The money supply or monetary base includes M1 and M2. M1 refers to currency outside the banks and demand deposits. M2 refers to money and quasi money growth. M2+ refers to M2 plus deposits at trust, mortgage loan companies and credit unions but it contains components of foreign current, which would inherently require exchange conversion. Therefore, M2+ would indirectly affect the exchange rate hence the model would not be a true reflection of the results. By this knowledge, we do not include M2+ in our model
analysis.

3.6.4 Gross domestic product growth (y)

This refers to annual percentage change in the gross domestic products. Gross domestic product refers to the total value of goods and services produced within the borders of an economy or a country during a given period of time measured in market places. It is calculated without making deductions for depreciation. It is used as a proxy for technological progress and productivity improvement. Technological progress has been used as an explanatory variable to capture the Ricardo-Balassa effect on the equilibrium exchange rate. According to this hypothesis, productivity improvement in rapidly growing economies tends to be concentrated in the tradable sector and usually accounts for an appreciation of the exchange rate through increasing the income and price of non-tradable (Balassa, 1964)

3.6.5 Inflation

Inflation refers to a persistent and appreciable increase in general prices of goods and services for a country over a specified period of time, usually one year. Inflation is measured by the consumer price index which reflects the annual percentage change in the cost to the average consumer acquiring a basket of goods and services.

3.6.6 Dummy variables

Since Ghana has had a fixed exchange rate regime in the past, and presently practising manage flexible regime, these two regimes has to be captured as dummy variable. Also, election periods were included to study its effect on exchange rate.

Chapter Four

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.0 Introduction

The chapter would present and discuss the results of the present study. The variables used includes: trade openness, gross domestic product (nominal GDP growth), money supply (M1 and M2) and inflation proxied to consumer price index. We also considered the effect of dummy emanating from floating and fixed exchange rate regimes practised in the past and present. Similarly, the effect of election was included in the period of investigation as dummy.

We would establish the relationship between these variables using the technique of Granger causality. We shall examine the long run and short run dynamics of the exchange rate determinants using autoregressive distributive lag technique(ARDL). The variables local correlation and co-movements are discussed with the help of wavelet power and wavelet coherency spectral analysis. In the wavelet treatment, we used depreciation rate, economic growth rate, money supply growth rate, inflation rate rather than cpi to study the wavelet analysis.

4.1 Descriptive statistics

The study conducted description of the relevant variables involved. Table (4.1) explains vividly the statistical relevance of the investigated variables. Table (4.1) presents the summary statistics

Table 4.1: Descriptive statistics for the variables

Variable	Min.	Max.	Mean	Std.dev	Skewness	Kurtosis
lnex	-0.3425	9.8782	4.2942	3.9602	0.0742	1.3178
lny	8.5657	10.3810	9.1887	0.4933	0.8394	2.5898
lncpi	-2.9511	2.0836	-0.4546	1.8270	-0.1231	1.4710
lnm2	-7.2241	6.1054	-1.1570	4.4581	0.0280	1.5792
lntrade	3.8248	4.7540	3.8248	0.6208	-0.9636	4.0328
lnm1	-4.3118	9.4652	1.9137	4.5694	0.1034	1.6060

for the variable. The variables shows positive signs of their average values (mean) with the exception of consumer price index and M2 monetary growth. The minimal deviations of real GDP growth and trade openness from their mean values are shown by their standard deviation, this implies slow growth rate for the period under consideration. This observation suggest that the Ghanaian economy has potential gap.

4.2 Unit root test

According to Engle and Granger (1987) direct application of non-stationary data produces regression that is misspecified or spurious in nature. The economic implication is that if a variable is non-stationary and there is a shock, it leads to a permanent effect. Before the application of Granger causality test and co-integration analysis, unit root test was conducted in order to examine the stationary properties of the data.

Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) tests were applied to all variables in their levels and first difference to formally establish the order of integration. The ADF and PP tests were applied since they provide more convenient procedures to determine the properties of the time series data and simple to understand. The probability values were presented and used for making the unit root decision. Table 4.2 presents the results of both ADF and PP tests for all the variables at levels with intercept and trend as well as first difference. However, because the power of ADF and PP tests is limited in distinguishing between time series data, that are purely non-stationary process and those with near unit roots are limited, we performed again the Kwiatkowski, Philips, Schmidt, and Shin (KPSS) test as a robustness check. The KPSS tests have a null hypothesis that the time series is stationary as against the alternative of non-stationary.

Table 4.2: Results of the Unit Root Tests for Levels and First Differences of the Variables: 1960 to 2014

	ADF(0)	PP(0)	KPSS(0)	ADF(1)	PP(1)	KPSS(1)
lnex	[0.5619]	[0.7812]	[0.0100]***	[0.3874]	[0.0197]**	[0.1000]
lny	[0.9900]	[0.9900]	[0.0100]***	[0.0989]*	[0.0100]***	[0.0100]***
lncpi	[0.3944]	[0.8148]	[0.0100]***	[0.4863]	[0.0100]***	[0.1000]
lnm2	[0.3419]	[0.6966]	[0.0100]***	[0.6145]	[0.0100]***	[0.0617]*
lntrade	[0.5147]	[0.6676]	[0.0100]***	[0.1996]	[0.0100]***	[0.1000]
lnm1	[0.2639]	[0.6967]	[0.0100]***	[0.5900]	[0.0100]***	[0.0243]**

Note: ***, **, * denote 1%, 5% & 10% significant levels respectively; values in [] are probability.

As illustrated in table 4.2, the ADF test clearly shows that, all the variables are nonstationary at levels. This is corroborated by both PP and KPSS tests. This is because the t-statistics for all the variables are less than the critical values of the ADF and PP test at 1%, 5% and 10% significance levels. Thus the ADF and PP tests indicates that the null hypothesis of non-stationarity of all the variables at levels cannot be rejected. This is confirmed by the KPSS test as the null hypothesis that the series are stationary is rejected. This implies that all the variables are integrated of order one or higher.

As expected, all the variables became stationary after the first difference in PP test. This is because the t-statistic values of the variables are greater than the PP critical values at either 10%, 5% or 1% statistical significance level. This means that the null hypothesis of non-stationarity for the variables at first difference is reject in favour of the alternative hypothesis of stationarity, implying that all the variables are integrated at order I(1). In contrast, ADF test showed that all the variables are non-stationary at first difference except output (lny). On the other hand the KPSS test showed that lny and money supply (lnm1 and lnm2) to be non-stationary at first difference. We confirm they are stationary at the second difference suggesting I(2) order of integration. The tests have been performed using R package (*ardl*) implemented by Barbi (2016).

4.3 Granger causality test

After identifying the order of integration of the variables, we proceed to examine the causal relationship among them. We accomplished this by performing pairwise Granger causality test. Actually, the Granger causality test is a technique for checking how variable dynamics can be known by relying on their previous lags. In this regard, the testing hypothesis: ”variable X does not granger cause variable Y” again the alternative hypothesis that ”variable X does granger cause variable Y”. Table 4.3 presents the results of the pairwise Granger causality test at levels a way of determining long run dynamics (1 in appendix also present granger causality test in difference). The Granger causality has been studied in the long run for variables in lag one and lag two.

In the proceeding sub-sections, we focus on the causal relationship between exchange rate and the interested variables.

4.3.1 Exchange rate versus inflation

From the results of table 4.3 demonstrates that, the null hypothesis that inflation (cpi) does not granger cause exchange rate is rejected at 0.1% level of statistical significance. This means inflation inflation is a key determinant of exchange in Ghana. The reverse causation is also true at 0.1%, implying the existence of a bidirectional relationship between exchange rate and inflation.

4.3.2 Exchange rate versus money supply

From table 4.3, the null hypothesis that narrow money supply (M1) does not granger cause exchange rate is rejected at 5% significance level. In the same vein the null hypothesis that exchange rate does not granger cause M1 is not rejected . This implies unidirectional causal relationship from M1 to exchange rate in Ghana. That is a change in money supply would also results in a change in exchange rate in the long run. However in the case of broad money (M2), the causality was found to bidirectional between exchange rate and M2 at 5% significant level. That when there is excess liquidity in the economy without corresponding investment opportunities, people would resort to storing the value of their funds in forex, hence exerting depreciative pressures on the local currency.

4.3.3 Exchange rate versus trade openness

A bidirectional relationship between trade openness and exchange rate was observed in Ghana. From the table, the null hypothesis that trade openness does not granger cause exchange rate is rejected at 1% significance level. Also, the null hypothesis that exchange rate does not granger cause trade openness is rejected at least 10% statistical significance level. This means that trade openness has strong effect on exchange rate, and this is consistent with economic intuition.

4.3.4 Exchange rate versus GDP growth

Finally, we found a bidirectional relationship between gross domestic product and exchange rate in Ghana at lag one. This is because , the null hypothesis that GDP does not granger cause exchange rate in Ghana cannot be rejected at lag one and is statistically significant at 5% in the long run at lag one.

Table 4.3: Results of the Granger causality test for long run dynamics

Pairwise Granger Causality Tests at Levels (Long Run)

Null Hypothesis:	Obs	Lag 1 Prob.	Lag 2 Prob.
lncpi does not Granger Cause lnex	54	0.0000	0.0004
lnex does not Granger Cause lncpi		0.0001	0.0089
lnm1 does not Granger Causelnex	54	0.0468	0.0470
lnex does not Granger Cause lnm1		0.1145	0.1432
lnm2 does not Granger Cause lnex	54	0.0015	0.0100
lnex does not Granger Cause lnm2		0.0033	0.0731
lntrade does not Granger Cause lnex	54	0.0165	0.0000
lnex does not Granger Cause lntrade		0.0153	0.0587
lny does not Granger Cause lnex	54	0.0104	0.2328
lnex does not Granger Cause lny		0.0356	0.1151
lnm1 does not Granger Cause lncpi	54	0.3094	0.2442
lncpi does not Granger Cause lnm1		0.0515	0.2319
lnm2 does not Granger Cause lncpi	54	0.1228	0.8465
lncpi does not Granger Cause lnm2		0.0107	0.0506
lntrade does not Granger Cause lncpi	54	0.0001	0.0193
lncpi does not Granger Cause lntrade		0.0157	0.0289
lny does not Granger Cause lncpi	54	0.0746	0.0573
lncpi does not Granger Cause lny		0.2377	0.2151
lntrade does not Granger Cause lnm1	54	0.0041	0.1018
lnm1 does not Granger Cause lntrade		0.0288	0.1166
lny does not Granger Cause lnm1	54	0.0323	0.2036
lnm1 does not Granger Cause lny		0.1903	0.3310

lntrade does not Granger Cause intrade	54	0.0001	0.0022
lnm2 does not Granger Cause lntrade		0.0195	0.0874
lny does not Granger Cause lnm2	54	0.0273	0.0367
lnm2 does not Granger Cause lny		0.1769	0.3326
lny does not Granger Cause lntrade	54	0.1677	0.2433
lntrade does not Granger Cause lny		0.0179	0.0952

4.4 Estimation of long run dynamics: ARDL

After identifying the order of integration, we examined the long run relationship of the interested variables using autoregressive distributed lag model (ARDL) in R package. Before interpreting the results from the ARDL, we performed several diagnostics tests as well as ascertaining evidence of cointegration using bound test.

4.4.1 Diagnostics test

We carried out diagnostic tests to ensure that the result meet the standard classical linear regression assumptions in order to avoid any possibility of spurious results and conclusions. We examined whether the residuals from the ARDL estimation satisfy the assumptions of autocorrelation, normality, heteroskedasticity and stability test. Table 4.4 below shows the tests of autocorrelation, heteroskedasticity and stability test whilst figure 1 in appendix (.1) presents quantine-quantine plots for normality test.

Table 4.4: Autocorrelation and Heteroskedasticity test

Breusch-Godfrey Serial Correlation LM Test			
F-statistic	0.8014	Prob. F(2,34)	0.4570
Obs*R-squared	2.3409	Prob. Chi-Square(2)	0.3102
Breusch-Pagan-Godfrey Heteroskedasticity test			
F-statistic	0.4253	Prob. F(16,36)	0.9608

Obs*R-squared	7.8274	Prob. Chi-Square(2)	0.9305
Scaled explained SS	3.9758	Prob. Chi-Square(15)	0.9978
Ramsey RESET test for stability			
t-statistic	0.1185	Prob.	0.9063
F-statistic	0.0140	Prob.	0.9063

The null hypothesis is that the variables are not autocorrelated. Thus, there is the absence of serial correlation in the estimated model. This is shown by the probability of the F-statistic of 0.4570. This mean that the exchange rate function does not suffer from any problem related to autocorrelation. We have similarly examined the variables for the problem of heteroskedasticity and the F-statistics give a probability of 0.9608, hence rejecting the null that the variables are heteroskedastic. For economic inferences, the stability of the regression is very important. As a consequence, the study used the Ramsey RESET test to determine the stability of the regression models of the exchange rate regression model. As indicated in table 4.4. Both the t-statistic and the F-statistic of the Ramsey RESET test are less than their respective critical values, indicating that the model is stable.

In the case of normal distribution, the quantine-quantine (QQ) plots suggest that the residuals are normally distributed at 5% significance levels because the residuals lie within the 95% confidence interval as shown in figure 1 appendix (.1). This is also confirmed by the Jaque-Bera test with a probability value of 0.7109, exceeding the corresponding values at 1%, 5% and 10%

significant levels.

4.4.2 Bound test

Having satisfied the model diagnostics, we ascertain there existence of a long run relationship between exchange rate and the determinants using bound test. Bound test checks the existence of a long-term relation with critical values of I(0) and I(1) regressors.

The result of the bound test is shown in table 4.5. As decision rule suggests, the computed F-statistic is compared with the critical upper and lower bound values published by Pesaran et al. (2001). The computed F-statistic of 12.39 is greater than all the critical upper bound values at 99% confidence interval. This implies that the null hypothesis of no cointegration is rejected in favour of the alternative hypothesis that cointegration exist between exchange rate and it determinant at 1% significance.

Table 4.5: Bound test for long run relationship

F-Statistics =12.39

Critial values	Lower I(0)	Upper I(1)
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

4.5 Long run coefficients

Since the model satisfies all the diagnostics test coupled with the fact that the bound test also show evidence of cointegration, the coefficients from the ARDL estimation are valid for economic inferences. However, we complimented the ARDL results using other approaches including FM-OLS, D-OLS and IM-OLS as a robustness check. The result is tabulated in table4.6 and 4.7 accordingly. According to the ARDL estimates, all the parameters are significant with the exception of M2. In terms of sign, all the coefficients of the interested variables had a positive sign with exception of M1 and the dummy for election cycles.

In particular, the positive and statistically significant effect of inflation on exchange rate is consistent with theory. Theoretically, a high inflation is expected to be harmful to exchange rate. This is because high inflation rate is deleterious to economic growth. Slower economic growth also discourages investments (including foreign direct investment) and could also trigger portfolio reversal (capital flight) with adverse implication on exchange rate (depreciation). In other wards rising inflation could heighten risk premium with resulting negative impact on the value of the domestic currency as investors look for safe haven investment. The results from the FM-OLS, D-OLS and IM-OLS are consistent with the ARDL. Also, our result is consistent with Takaendesa (2006) on Tanzania. In terms of magnitude, a 1% increase in inflation causes the nominal exchange rate to depreciate between 0.9387% and 2.2069% in the long run.

The coefficient of GDP growth (proxy to technological advancement) is positive and statistically significant at 0.1% in the ARDL model, but was negative but insignificant in the D-OLS and IM-OLS specifications (see table 4.7). A priori, however, the GDP growth rate is expected to have an appreciating effect (negative sign) on exchange rate. This is because advancement in technology results in an efficient, effective and productive use of the factors of production. At the same time, it helps to reduce the cost of production and prices of tradables, because more of the non-tradable would be preferred hence increasing competitiveness. The increase in the demand for non-tradable would increase the prices of non-tradable, leading to an appreciation in the domestic currency. This confirms the Balassa-Samuelson effect. Nevertheless, the observed depreciating effect of real GDP growth on exchange rate may be intuitively plausible as in Ghana the domestic economic activities tend to be heavily dependent on imported intermediate and capital goods. We observe that a 1% increase in real GDP growth tends to cause nominal exchange rate to depreciate between 0.7197% and 1.6672%, and this is statistically significant at least 10%. Our result is consistent with the works of Korsu and Braimah (2005); Elbadawi (1994) and Montiel (1997). Alternatively one can also argue from the perspective that, as Ghanaians become economically better, their insatiable taste for exotic goods increases which means, demand for foreign currency to meet the demand for imported goods also increases therefore causing further depreciation in the local currency.

Surprisingly, our results shows a mixed sign and statistically insignificant coefficient for broad money (M2) from all the estimation techniques. On the contrary, the results from FMOLS, D-OLS and IM-OLS showed a positive but insignificant coefficient for narrow money (M1), while the results from ARDL suggested a negative significant coefficient for M1. The negative and statistically significant coefficient for the money supply (see M2 in FM-OLS and M1 in ARDL model) is not inconsistent with economic theory. For instance, an increase in money supply (that is, higher liquidity) tends to cause interest rate to fall. The lower interest rate will tend to increase aggregate output which could attract foreign exchange inflows, leading to an appreciation in the domestic currency. In terms of magnitude, a 1% increase in broad money supply (M2) or narrow money supply(M1) leads to an appreciation in the nominal exchange rate by 0.3964% or 0.3071% respectively.

The positive and statistically significant coefficient for trade openness is also consistent with the theoretical postulation that trade openness leads to depreciation of exchange rate, especially in developing countries. Our results show that a 1% increase in trade openness leads to 1.0933% depreciation in the nominal exchange rate. The convex is also true. This is becasue a reduction in import tariffs tends to increase demand for foreign goods (imports) in the local market. As people in the economy want to import more goods, the demand for foreign currency would increase, causing depreciation in the local currency. On the other hand, as import tariffs increases, the prices of imports would be higher, discouraging the importation of foreign goods and an ultimate appreciating effect of the exchange rate. This conclusion is consistent with the works of Williamson (1985); MacDonald and Clark (2004) and Kempa (2005).

As expected, the coefficient of the dummy for exchange rate regime (dflex) is positive and statistically significant. This suggests that the change from fixed to flexible exchange rate regime has exacerbated exchange rate depreciation in Ghana, consistent with economic theory.

Table 4.6: Model long run estimates, when m2 is used

ARDL

Long-Run Coefficients. Dependent variable is lnex

	Estimate	Std.Err	Z value	Pr(>z)	
L(lnex, 1)	0.3839	0.1637	2.3450	0.02408	*
Intcept	-1.2580	4.3869	-0.2870	0.7758	
lny	0.2503	0.1143	2.1900	0.0286	*
lnm2	0.0388	0.0306	1.2670	0.2050	
lntrade	1.1209	0.0508	22.0680	0.0000	***
lncpi	1.5530	0.0237	65.5430	0.0000	***
dflex	0.9011	0.1220	7.3850	0.0000	***
delect	-0.0088	0.0732	-0.1200	0.9048	

FM-OLS

Long-Run Coefficients. Dependent variable is lnex

level	-14.6614	3.3855	-4.3306	0.0000	***
trend	-0.0058	0.0162	-0.3559	0.7235	
lny	1.6672	0.3989	4.1793	0.0000	***
lnm2	-0.3964	0.1625	-2.4393	0.0185	*
lntrade	0.9272	0.0858	10.8049	0.0000	***
lncpi	2.2016	0.3084	7.1390	0.0000	***
dflex	1.4166	0.2003	7.0730	0.0000	***
delect	-0.0392	0.0677	-0.5790	0.5653	

D-OLS

Long-Run Coefficients. Dependent variable is lnex					
level	-15.4999	17.6568	-0.8778	0.3845	
trend	0.0159	0.0199	0.8002	0.4276	
lny	1.7732	2.0112	0.8816	0.3825	
lnm2	-0.4981	0.7398	-0.6733	0.5040	
lntrade	0.6251	0.3621	1.7265	0.0908	.
lncpi	2.1439	1.2415	1.7269	0.0908	.
dflex	2.1248	1.1019	1.9283	0.0599	.
delect	0.2169	0.4035	0.5389	0.5925	

IM-OLS

Long-Run Coefficients. Dependent variable is lnex					
level	-2.3739	5.5479	-0.4279	0.6706	
trend	0.0431	0.0190	2.2681	0.0280	*
lny	0.2181	0.6454	0.3378	0.7370	
lnm2	-0.1280	0.2429	-0.5270	0.6008	
lntrade	0.9883	0.1297	7.6215	0.0000	***
lncpi	1.6148	0.4418	3.6554	0.0006	***
dflex	0.9833	0.3161	3.1106	0.0032	**
delect	-0.0644	0.1564	-0.4120	0.6822	

Significance: '***' 0.1% '**' 1% '*' 5% '.' 10% Table 4.7: Model of long run estimates, when m1 is used

ARDL

Long-Run Coefficients. Dependent variable is lnex					
	Estimate	Std.Err	Z value	Pr(>z)	
L(lnex, 1)	0.3825	0.1572	2.4330	0.0195	*
Intcept	-5.3041	4.0499	-1.3100	0.1978	
lny	1.0424	0.1069	9.7555	0.0000	***
lnm1	-0.3071	0.0442	-6.9448	0.0000	***
lntrade	1.0933	0.0526	20.8042	0.0000	***

lncpi	2.2069	0.0145	152.1955	0.0000	***
dflex	0.9722	0.1247	7.7936	0.0000	***
delect	-0.0175	0.0755	-0.2319	0.8166	
R-square	0.99				

FM-OLS

Long-Run Coefficients. Dependent variable is lnex					
level	-5.8328	3.2915	-1.7721	0.0829	.
trend	-0.0196	0.0163	-1.2060	0.2339	
lny	0.7197	0.4087	1.7610	0.0849	.
lnm1	0.1287	0.1635	0.7874	0.4345	
lntrade	0.9948	0.0713	13.9435	0.0000	***
lncpi	1.3345	0.2901	4.5998	0.0000	***
dflex	1.0775	0.1509	7.1396	0.0000	***
delect	-0.0144	0.0646	-0.2225	0.8249	

D-OLS

Long-Run Coefficients. Dependent variable is lnex					
level	1.9910	22.5842	0.0882	0.9301	
trend	0.0277	0.0261	1.0636	0.2930	
lny	-0.2493	2.7485	-0.0907	0.9281	
lnm1	0.2185	0.8306	0.2630	0.7937	
lntrade	0.8592	0.1569	5.4761	0.0000	***
lncpi	0.9387	1.3964	0.6722	0.5048	
dflex	1.2006	0.9424	1.2741	0.2089	
delect	0.7137	0.3378	2.1125	0.0400	*

IM-OLS

Long-Run Coefficients. Dependent variable is lnex					
S.level	1.4726	5.1901	0.2837	0.7779	
S.trend	0.0493	0.0189	2.6063	0.0122	*
S.lny	-0.2264	0.6334	-0.3575	0.7223	
S.lnm1	0.0266	0.2448	0.1088	0.9138	
S.lntrade	1.0429	0.0878	11.8805	0.0000	***
S.lncpi	1.3374	0.4443	3.0102	0.0042	**

S.dflex	0.8049	0.2107	3.8198	0.0004	***
S.delect	-0.0543	0.1669	-0.3256	0.7461	

Long-Run Coefficients. Dependent variable is lnex
Significance: '***' 0.1% '**' 1% '*' 5% '.' 10%

4.6 Short run dynamics

Having established that the variables are cointegrated, their dynamic relationship can be specified by an error correction representation in which an error correction term (ECT) computed from the long run equation, is incorporated in order to capture both the short run and long run relationships (Engle and Granger, 1987). The error correction term indicates the speed of adjustment to long run equilibrium in the dynamic model. In other words, the error correction term shows how quickly variables converge to equilibrium when they are deviated. It is expected to be statistically significant with a negative sign. The negative sign implies that any shock that occurs in the short run will be corrected in the long run. The greater the value of the error correction terms in absolute value, the faster the convergence to equilibrium. The results of the error correction term model or short run dynamics is displayed in the table 4.8.

Consistent with the results from the Bound test, the error correction term is negative, less than one and statistically significant, confirming the existence of long run relationship between exchange rate and its determinants. The results suggest that 60.78-62.73% of any disequilibrium to the exchange rate is adjusted within a year. This implies any disequilibrium to exchange rate is fully adjusted to equilibrium in approximately 20 months.

Similar to the long run results from the ARDL model, all the short run coefficients assume the same sign with the exception of narrow money (M1). Unlike the long run estimates, narrow money supply M1 had a positive and statistically insignificant sign.

Trade openness in the short run exhibit a significant, positive and depreciating effect on exchange rate in Ghana. The short run results is consistent with the proposition that trade openness exerts a depreciating effect on real exchange rate in Ghana. We observed that a 1%

increase in trade openness leads to 0.3325% depreciation in exchange rate, and vice versa in the short run.

The short run results from table 4.8, indicates that GDP growth in Ghana exerts a positive and depreciating effect on exchange rate, though it is statistically insignificant. The result is consistent with the long run results between both variables. In terms of magnitude, a 1% increase in the real GDP growth tends to depreciate the nominal exchange rate by 0.7429% in the short run.

Again, we found a 1% rise in inflation tends to depreciate the exchange rate by 0.7798% in the short run. This The results also demonstrates that all the dummy variables are negative but statistically insignificant in the short run. Similarly, the first lag of exchange has an impact on the exchange rate and this is statistically significant at 10% in the short run.

Table 4.8: Model of short run estimates for m1 and m2

Short-Run Coefficients: Dependent variable is d(lnex), m1

	Estimate	Std.Err	Z value	Pr(>z)	
(Intercept)	-5.0397	0.9082	-5.5492	0.0000	***
L(d(lnex))	0.1941	0.1090	1.7804	0.0750	.
d(lny)	0.7429	0.6790	1.0940	0.2740	
d(lnm1)	0.0032	0.2198	0.0146	0.9883	
d(lntrade)	0.3325	0.1151	2.8874	0.0039	**
d(lncpi)	0.7798	0.3544	2.2005	0.0278	*
dflex	-0.0272	0.0644	-0.4230	0.6723	
delect	-0.0166	0.0697	-0.2388	0.8112	
L(coint)	-0.6078	0.1091	-5.5696	0.0000	***

Short-Run Coefficients. Dependent variable is d(lnex), m2

	Estimate	Std.Err	Z value	Pr(>z)	
(Intercept)	-1.2010	0.2117	-5.6729	0.0000	***
L(d(lnex))	0.2024	0.1034	1.9564	0.0504	.
d(lny)	0.1802	0.6986	0.2579	0.7965	

d(lnm2)	0.2491	0.2081	1.1967	0.2314	
d(lntrade)	0.3433	0.1143	3.0043	0.0027	**
d(lncpi)	0.2507	0.4368	0.5739	0.5660	
dflex	-0.0266	0.0618	-0.4300	0.6672	
delect	-0.0104	0.0685	-0.1521	0.8791	
L(coint)	-0.6273	0.1086	-5.7756	0.0000	***

Significance: ’***’ 0.1% ’**’ 1% ’*’ 5% ’.’ 10%

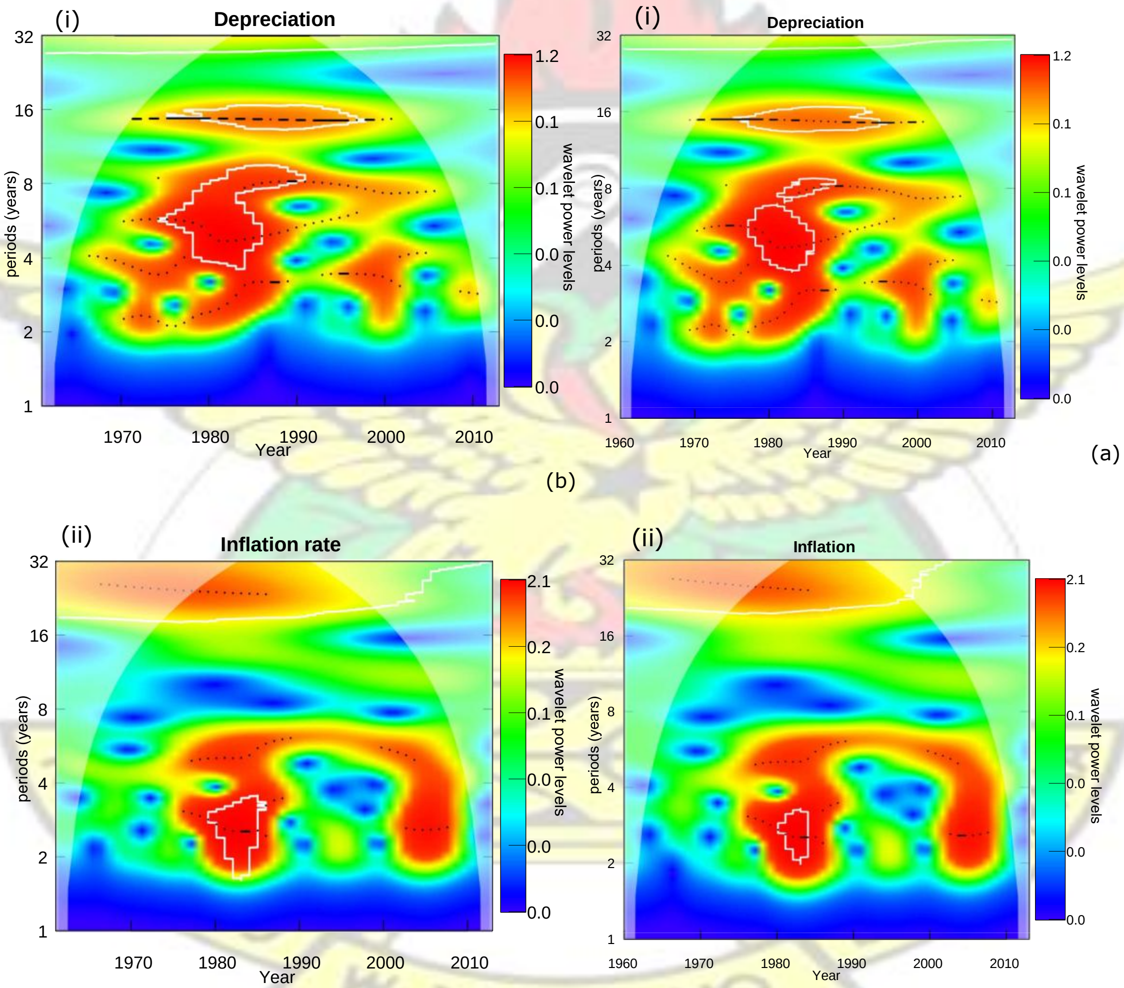
4.7 Wavelets power spectrum empirical analysis

In this section, we discuss the results of the wavelet power spectrum (WPS) calculation of the macroeconomic variates under investigation with the relevant inferences and observations made. One can straight forwardly see in figures (4.1) and (4.2), the time evolution of variance of the five fiscal variable under analysis at several times scales from 1960 - 2014 to glean out the important conclusions of interest.

These figures indicates the continuous wavelet power spectrum for: depreciation rate, inflation rate, monetary growth rate, trade openness and economic growth rate. The thick white contour designates 10% and 5% significant level (90% and 95% confidence interval respectively for figures (a) and (b)) of white noise simulated by Monte Carlo method. The discussion would focus mostly on the 10% significance level for simplicity of comparison as in set of figure (a). The cone of influence shows region affected by edge effects is indicated by inverted cone-like imposition. The maximum cut-off period used was 32 years representing about 59% of the total data and similar value was used for the coherency analysis. This value is sufficient for our analysis. The periods outside the cone of influence is rejected since they do not posses any meaningful statistical significance. The color code for power ranges from low power (blue) to high power (red). The vertical and horizontal axes, respectively denote period and time with period in years in the range lower (1) to upper (32).

Interesting facts can be observed by looking at the time scale decomposition of these variables. Most of the events occurred at high scales(low frequencies). There is a clear striking feature of none-activity through out the years under review where in general, blue power is seen at the very low frequencies for all the variables.

The WPS of depreciation rate reveals significant power event in the period 1974 to 1991 in the yearly time scale of 4 - 8 years as well as 8 - 16 years scale for the time range 1980 - 2000. The WPS of Inflation rate figure (4.1) (b - (ii)) indicates significance at 1989 - 1991 in the 2



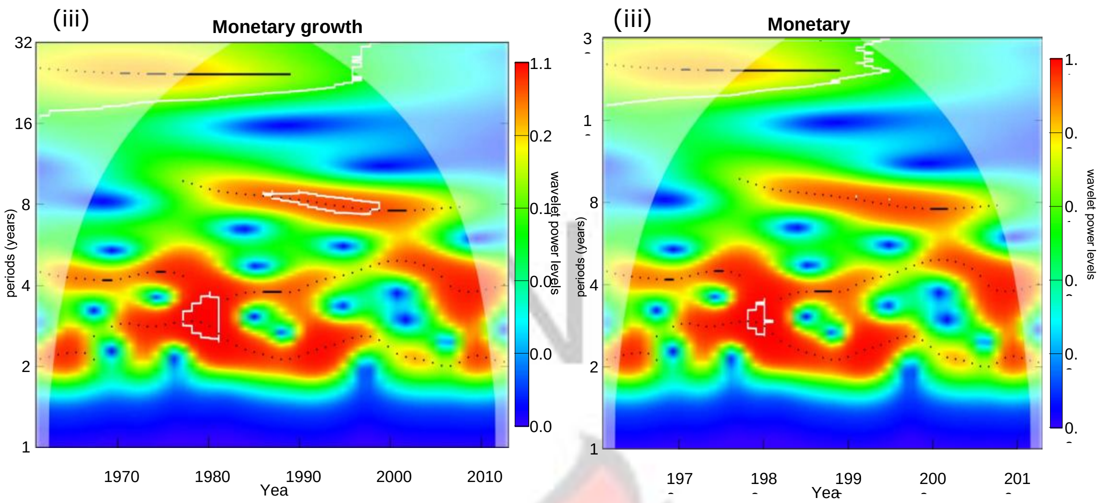


Figure 4.1: Wavelet power spectrum of macroeconomic variables: (a) and (b) (i) Depreciation, (ii) Inflation and (iii) Monetary growth; where the white contour indicates 10% and 5% significance level against a white noise null.

- 4 years time-scape band. Monetary growth WPS event was significant in 1979-1981 in the 2 - 4 time scale band, Economic growth event of WPS is also clearly significant in two time scales for the time range of 1969 - 1978 in the frequency of 4 years and 8 years for time range 1960 - 1980 accordingly. It should be noted that, results outside the cone of influence should be interpreted carefully. The wavelet power scale of Trade openness shows no significant power event action al all, however, what is seen exist at higher scale in the time range of 1980 - 1995. Of interest to note is that, all the variables showed an evidence of potential gap in the 1 - 2 band scale for the entire range of studies.

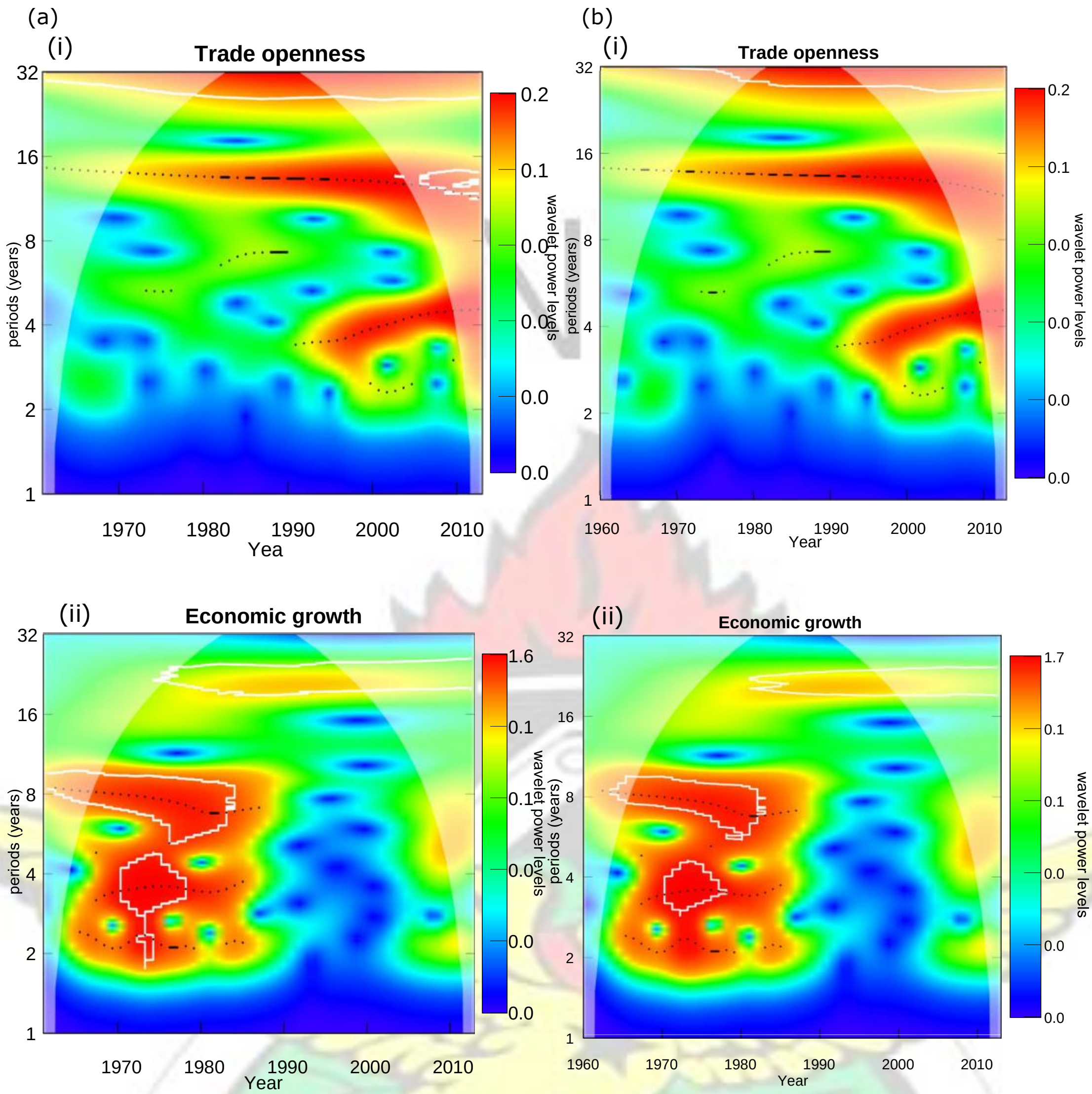


Figure 4.2: Wavelet power spectrum of macroeconomic variables: (a) and (b) (i) Trade Openness, (ii) Economic growth rate; where the white contour indicates 10% and 5% significance level against a white noise null.

4.8 Cross-wavelets power and coherence empirical analysis

Maraun and Kurths (2004) showed that it is not suitable for cross wavelet power spectrum be used to treat bivariate processes since the technique can produce strong peaks and give rise to the existence of spurious significance level testing, rather a wavelet coherence must be used. Aguiar-Conraria et al. (2008) have indicated that the regions of high significance do depend heavily on the null hypothesis and therefore, such information so obtained from cross

power spectrum should be treated with caution. As a consequence, it is rather essential to analysize cross-wavelets coherency because of potential redundancy inherent in cross-power spectrum. Wavelets coherency has the merit of normalization for two time series which allows for comparison. As a result, we shall focus mainly on wavelet coherency spectrum(WCS)
discussion.

In the study of the factors which determines exchange rates in Ghana, its noteworthy that some variables might not directly show causes and effects as pass-through, rather implicitly through other variables. As a consequence, we presents the wavelet coherency in pairwise of macroeconomic variables of interest to asses cross-variable co-movement. For example (depreciation and inflations, depreciation and monetary growth, inflation and economic growth, trade openness and inflation etc. and total of ten pairs were obtained) as a measure of local correlation among the variables. The wavelets plots are shown as contours since they are involved in three dimension. Time and frequency are indicated on horizontal and vertical axes respectively. The scale of wavelets coherency corresponds to an increasing value which corresponds to height in a surface plot, hence through the inspection of the graph, one can easily identify both frequency band (vertical axis) and time interval (horizontal axis) where the series co-move together. Frequency is converted as times units of years since the data is in yearly basis.

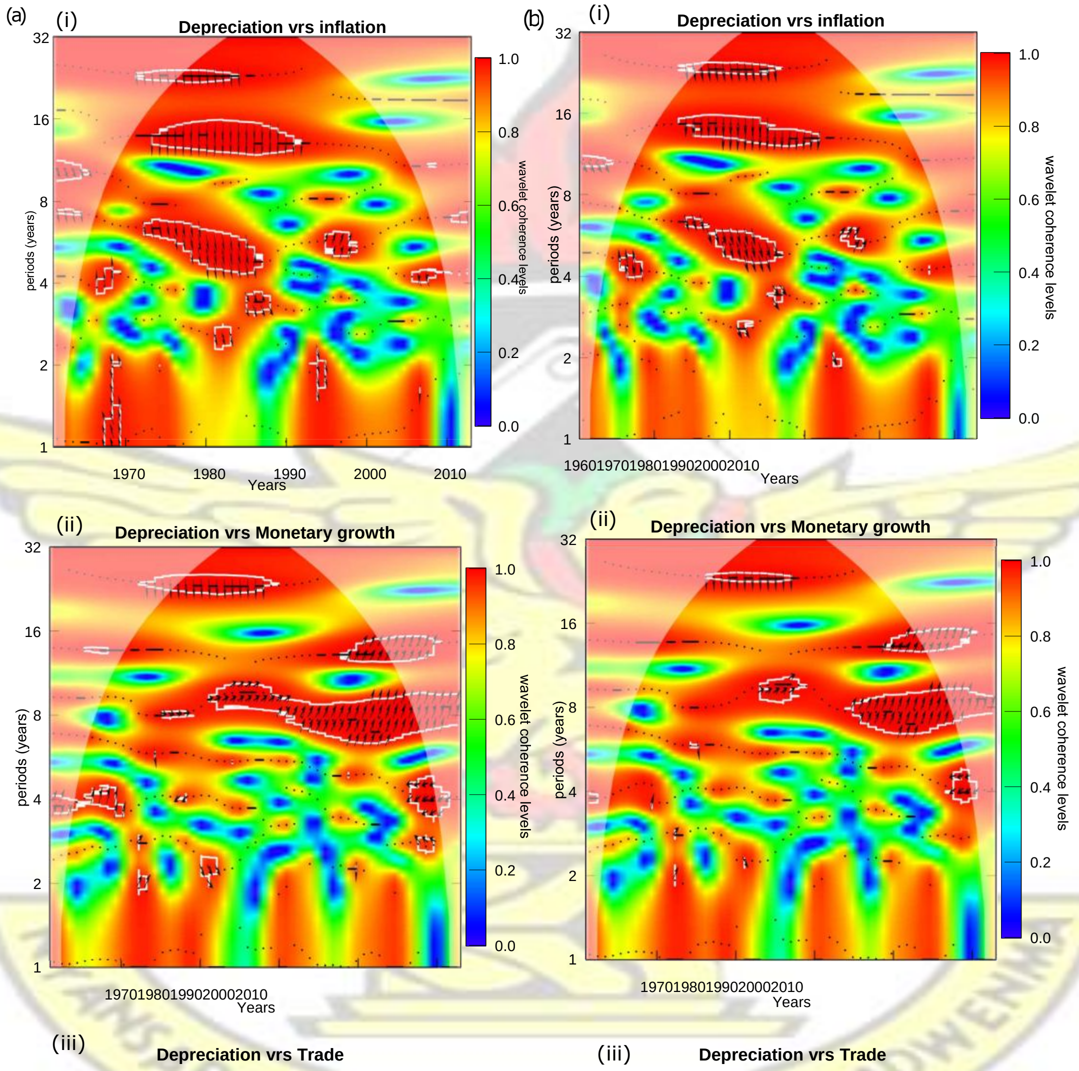
The Figures shown in (4.3, 4.4, 4.5, 4.6) shows the calculated wavelets coherency and phase difference between five variates. The significance values were obtained from Monte Carlo simulation with randomized surrogate series with white noise and Boxcar window type. Coherency is denoted by contour lines, 10% and 5% significance level is designated by thick white line as in the sets of (a) and (b) respectively. The color code for the coherency starts from low currency (blue)-near zero to high coherency (red)-almost one. The scale of color code is interpreted as, with increasing value of wavelet coherency is matched with corresponding deep redness and vice versa. For example, deep red region means strong co-movement. In similar fashion, we can deduce if the comovements has increased or decreased over time and also across frequencies which captures possible varying features in the relationship between the variables in the time-frequency domain. Outside the thin line is the cone of influence indicating the region affected by edge effects.

The phase difference between pairwise series is shown as an arrows vectors. The generated images of cross-coherency are between two variates, with the name of the first and second variables corresponding to the first and second series respectively. This order is necessary for the required validity of the model (Madaleno and Pinho, 2012; Rua and Nunes, 2009). The movement of pairwise macroeconomic variables are depicted by the arrows heads direction which are summarized below: (i) Arrows pointing to the right suggest that the two series are in phase, (ii) Arrows showing up wards to the right means that the first variable is lagging behind, (iii) Arrows pointing right but downwards indicates the first series is leading, (iv) Arrows pointing leftwards indicates that the two series are out of phase, (vi) To the left and up shows the first series is leading. Finally, the arrow pointing left and downwards suggests the first series is lagging. As a consequence, we usually examines the graphs and detect regions where timeand frequency varies with respect to the macroeconomic variables co-movement.

Information on the phases suggest correlation exist among some the macroeconomic variables and are also not homogeneous across the scales since arrows points in all directions constantly. Cross-wavelet coherency is not uniform across all frequency but pockets of regions which are statistically significant are noticeable. Inflation vrs Trade openness appears to show strong coherence at the lower scale frequency bands of 1 - 2 years across all years but they are weak statistically.

In general, the wavelet-coherency shows low to medium (relatively) frequency bands which are statistically significant with pockets of observable islands of medium power across the almost all the pairwise variates with the exception of Inflation vrs Trade openness at the low year frequency regime (high scales) which means the series were not strongly correlated.

Depreciation rate vrs Inflation rate showed strong coherence at lower frequency band 1



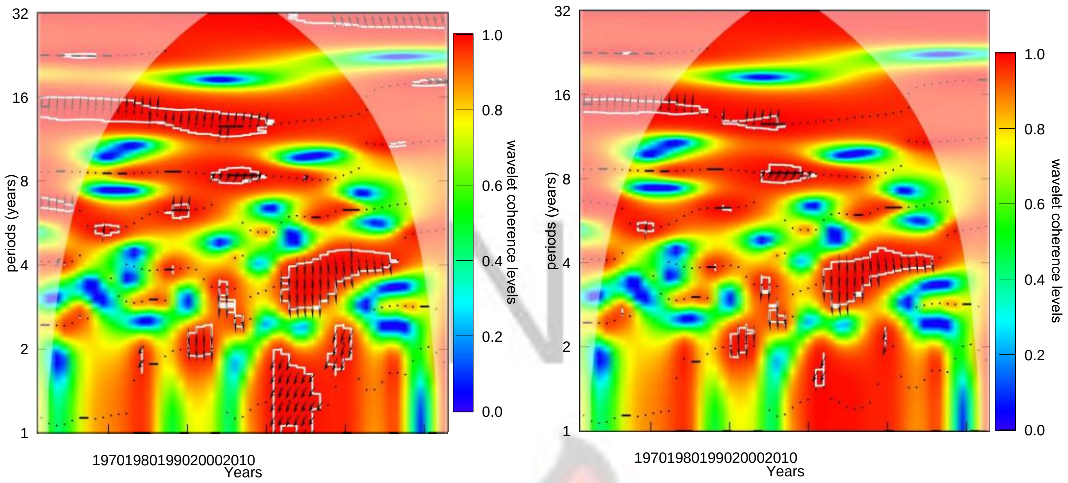


Figure 4.3: Column (a) and (b) respectively denote cross-wavelet coherency and phase plot among: Depreciation, Inflation, Monetary growth and Trade openness with the white contour lines indicating 10% and 5% significance level against a white noise null.

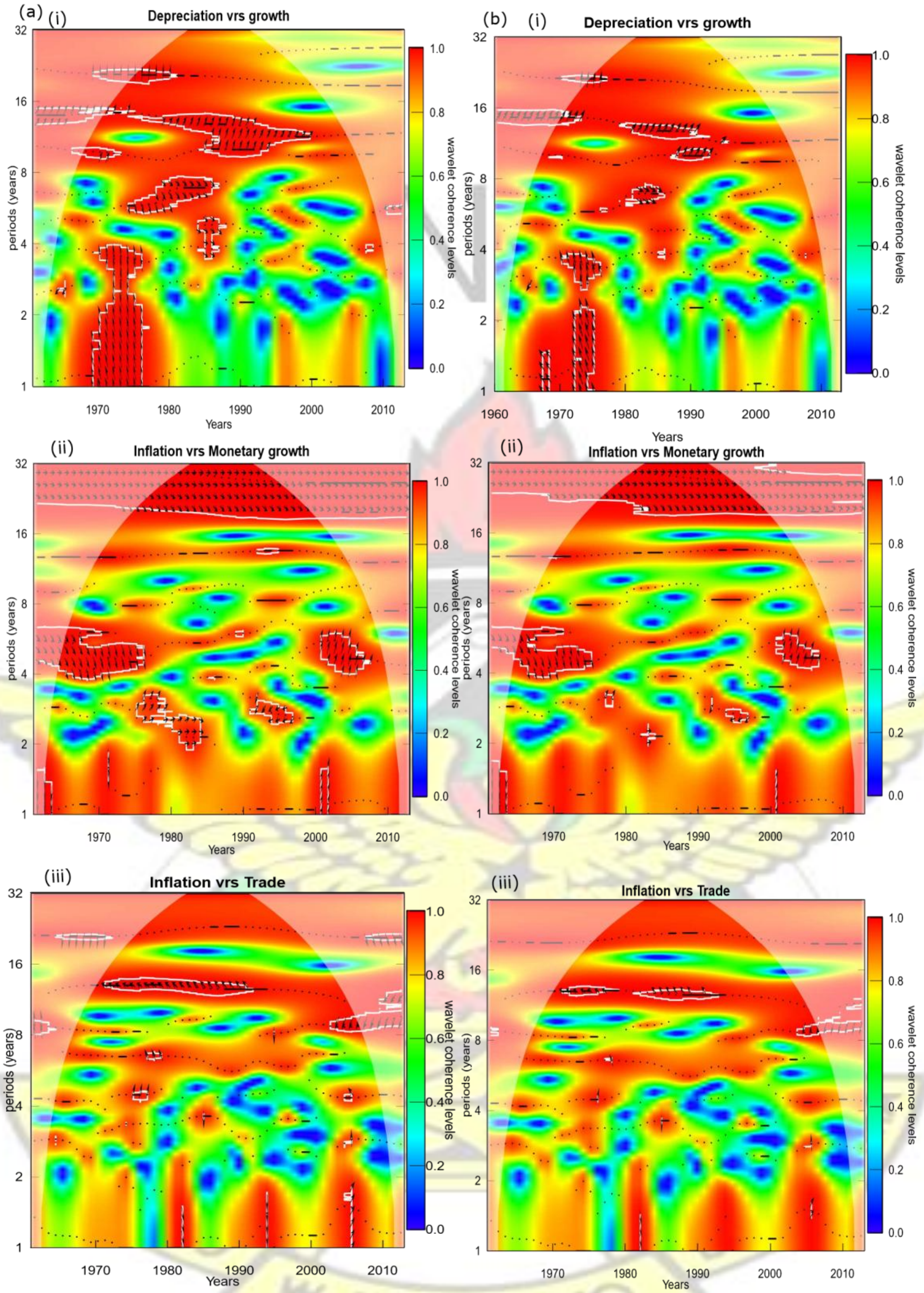


Figure 4.4: Column (a) and (b) respectively denote cross-wavelet coherency and phase plot among: Depreciation, Inflation, Monetary growth, Economic growth and Trade openness with the white contour lines indicating 10% and 5% significance level against a white noise null.

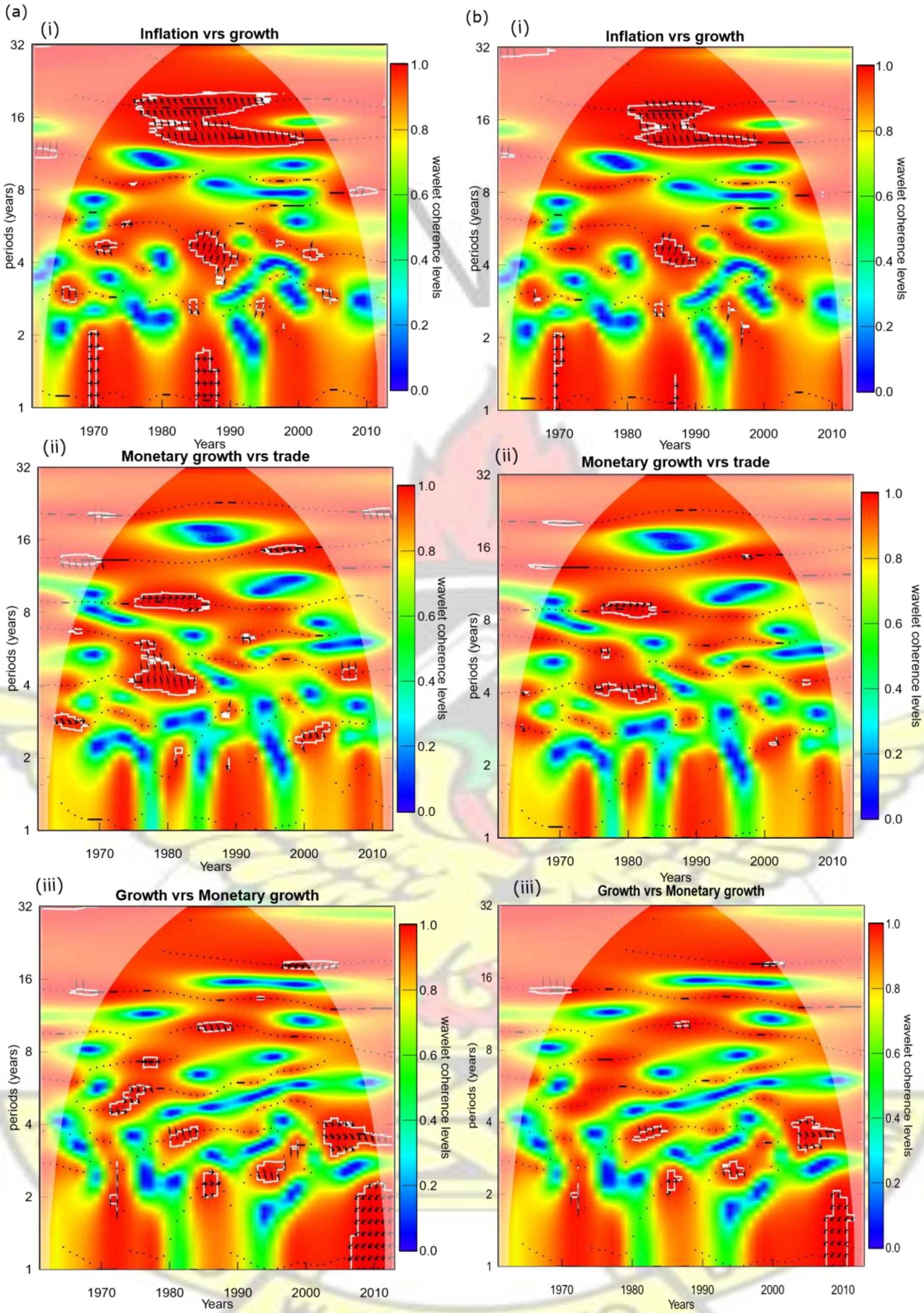


Figure 4.5: Column (a) and (b) respectively denote cross-wavelet coherency and phase plot among: Inflation, Monetary growth, Economic growth and Trade openness with the white contour lines indicating 10% and 5% significance level against a white noise null.

(a) (b)

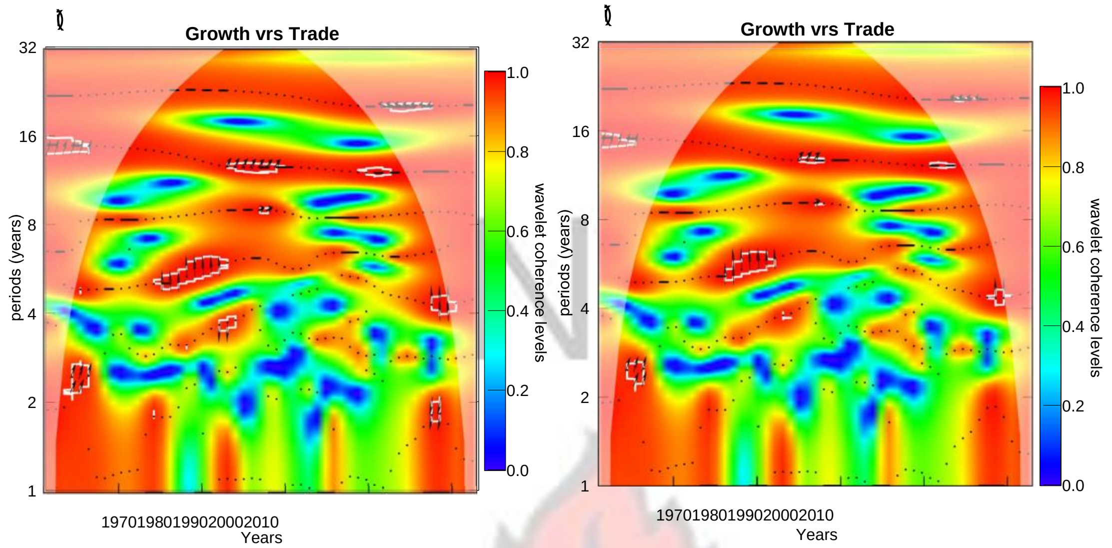


Figure 4.6: Column (a) and (b) respectively denote cross-wavelet coherency and phase plot among: Economic growth and Trade openness with the white lines contour indicating 10% and 5% significance level against a white noise null.

-2 years in the 1968 - 1970 period of time with the phase difference relationship indicating that Depreciation was leading. There is striking similarity with Depreciation and monetary growth. Again shown in Figure (4.3) a(iii) , Depreciation vrs Trade openness showing strong wavelet-coherence is observed at 1989 - 1998 at lower frequency band with phase difference relationship indicating that Depreciation lagging behind, and no coherence from 2008 -2014. Not withstanding, there is strong coherence at higher frequency between these variables.

In Figure (4.4) a(i) we observe that Depreciation vrs economic growth had strong coherency in the frequency band 1 - 4 years for the time range 1969 - 1977 with Depreciation leading and reduces gradually until it become zero from 2009 - 2014.

Of interest to note is the relative weak coherency of Inflation vrs Monetary growth and Inflation and Trade openness rate as shown in (4.4)a(ii-iii) at the lower frequency base on their statistical significance. Although Inflation lagging behind Trade openness is noticeable at the lower frequency 1 -2 band in the mid 2005, similar trend is seen with Monetary growth rate.

In (4.5) a(i), we can argue that, from 1969 - 1989 we observe lower frequency band of 1 - 2 years with Inflation rate vrs economic growth rate showing strong coherency amid weak interaction in 1980, the two variables mostly co-moved from the their phase difference relationship. This is not the situation from mid 1990 to 2014. The wavelet-coherency was relatively weaker. However, in the medium frequency band of 2-8 years to higher 8 -32 years frequency band which variable drives the other is in mixed state.

Monetary growth rate vrs trade openness appears statistically insignificant as with respect to their coherence in the lower frequency band 1 - 2 years across all years is shown in Figure (4.5) a(ii). But in the medium frequency band 2 - 8 years, there are regions with strong coherency and having monetary growth leading for all years. With Figure (4.5) a(iii), it is instructive to note that economic growth vrs monetary growth rates have strong coherency which is significant between 2007 - 2014 at frequency band of 1 -2 years. The phase difference relationship suggest that, the two variables move out of phase. However, in the medium frequency band of 2 - 8 years from 1975 - 2014, economic growth rate leads monetary rate according to their phase difference relationship.

Figure 4.6 a(i) shows that the economic growth rate vrs and Trade openness have statistically weak coherency across all year from short- terms frequency bands of 1 - 2 years, but one can observe few regions that are statistically significant with economic growth appearing to lead from their phase difference relationship.

Chapter Five

SUMMARY, CONCLUSION AND RECOMMENDATION

5.0 Introduction

In this final chapter of the study, we shall give a brief summary of the technique employed and the subsequent results of the research, we follow it with conclusions and offer relevant specific policy prescriptions to remedy the causes of persistent exchange rate depreciation in Ghana.

5.1 Summary of findings

The purpose of the study was to examine the exchange rate determinants in Ghana and the corresponding co-movements using time series data spanning from 1960 to 2014. The research investigated the long run and short run dynamics relationship between exchange rate and its determinants using several econometric techniques. The macroeconomic variables used in this study included supply of money(M1, M2), trade openness, GDP and inflation (using consumer price index).

The study's quantitative research was carried out with two fundamental techniques in mind for a specific purpose. The first method for equilibrium studies with time series econometric techniques which requires that the data is stationary. The second approach, wavelets analysis, was used to study the co-movements of the exogenous macroeconomic variables regardless of the non-stationary nature of the data properties and how they influence exchange rate dynamics in Ghana.

We checked that the data satisfies the necessary and sufficient stationarity condition and appropriate diagnostics were carried out for the quantitative analysis. Afterwards, we begun with Granger causality test to examine which variables drives or interacts with exchange rate. The studies employed ARDL approach to cointegration and error correction model to examine the long run and short run relationships among the variables including other complimentary methodologies such as FM-OLS, D-OLS and IM-OLS for comparison.

All tests and estimations were conducted using econometric open source R package and related dependants. The package Eviews 9.0 was used for stability and normality test for the purpose of comparison with R results.

The second technique which involves continuous Morlet wavelet transforms, is a suitable approach for studying non-equilibrium macroeconomic variables relationships other than Fourier transform, was applied in this study. The usefulness of the technique has been clearly illustrated considering that both decision makers and investors distinguish between long run and short run relation with respect to exchange rate in not equilibrium situation. The strength of wavelet method is however, its power to elucidate transient dynamics of single or multivariate (bivariate) time series data and demonstrate when in time and frequency they occur, would have been difficult to clarify if classical econometric techniques were employed.

The continuous wavelet power spectrum describes the evolution of the variance of a time series at different frequencies. The periods of large variance is associated with periods of large power at different scales. Clearly the results shows that, higher power activities were observed between 2 -6 years of frequency bands across all years with regions showing 10% and 5% significant levels indicated by white contour lines. The band 1 - 2 years indicates that variables were under economic potential.

The cross-wavelet power of the time series gives a description of local covariance between the time series whilst the wavelet coherency is considered as localised correlation coefficient in the time-frequency representation. The phase difference is like a position in a pseudo-cycle of a time series as a function of frequency. As a consequence, the difference in phases signify delay for synchronization between the oscillation of the two series Aguiar-Conraria et al. (2008). We here only give the co-movements of exchange rate and its associated potential determinant variables namely in the pairwise arrangement. The pairwise order is the following: Depreciation rate vrs Inflation rate (not cpi), Depreciation rate vrs Monetary growth rate, Depreciation rate vrs Economic growth rate (GDP growth rate) showed that, Depreciation is leading in the co-movements. However, Depreciation vrs Trade openness indicates that, trade openness leads Depreciation.

5.2 Conclusions

The analysis yielded the following results: The Granger causality tests revealed a unidirectional causality between M1 and exchange rate at 10% significance level, running from M1. However, the remaining variables exhibited a bidirectional causal relationship with exchange rate. The times series econometric estimations including ARDL, FM-OLS, D-OLS and IM-OLS showed evidence of significant long run relationship between exchange rate and its determinants (money suply, trade openness, GDP and inflation).

In particular, the signs were mixed for real GDP growth and money supply. On the contrary, openness to trade and inflation exhibited a positive and significant coefficient in all the frameworks in both short and long run, consistent with economic theory. It means trade openness and inflation have strong depreciating and significant relationship with exchange rate in Ghana. It was also observed that the change from fixed to flexible exchange rate has increase the volatility of the nominal exchange rate for the sample period. Essentially, we observed that any disequilibrium in the exchange rate equation is fully adjusted in approximately 20 months as the coefficient of the error correction term is 0.6078.

Th calculated continuous wavelets power spectrum and wavelets coherency spectrum were calculated for depreciation rate, inflation rate, economic growth rate, money supply rate and trade openness. The wavelets power spectrum of the variables showed clear activities in short to medium frequency band across the entire time data frame. The results from the wavelet analysis strongly corroborate with standard econometric analysis. The coherence wavelet analysis suggests that exchange rate depreciation leads (drives) the variables, with the exception of trade openness. This confirms that openness to international trade tends to increase the vulnerability of the domestic currency. There appear an existence of growth gaps in the the economy based on the variables used.

5.3 Recommendations for Policy Makers

The above discussion lends itself for an important policy prescriptions so as to ensure misalignment free in exchange rate dynamics in the Ghana. The work has demonstrated that, the economy should be scientifically formalised by restructuring it from bottom up with relevant scientific technologies that seeks to embrace exports rather than imports is the route to achieving near perfect exchange rate parity and again education on the local people to have a sense of appreciation of the effects of the misalignment. This means activities that mitigate against exports in favour for imports should be strongly discouraged since that would tilt the exchange rate misalignment in a negative direction. To achieve this, leadership should show political willingness and a lot of economic discretion in the management of the economy.

For the above reason, there should be conscious pursuit towards export promotion as part of trade liberalization drive. This can take the form of organizing regular trade fairs regionally focusing a region's economic comparative advantage. Economic export should be diversified across all sectors including traditional and non-traditional rather than focusing only on traditional exports with education and training as caveat. This can be achieved by consciously adding value to exports and the pay-off would imply attracting competitive prices on the global level. Domestic consumers should be encouraged to patronise domestic goods and services rather than imported. This can be achieved through periodic organization of rural exhibitions at the district levels to showcase the quality made in Ghana goods. As a consequence, this would reduce domestic expenditure on imported goods in other to ensure favourable balance of trade, thereby resulting in the appreciation of the exchange rate. Therefore, it is imperative on government to renegotiate favourable terms of some of the existing trade agreements which are skewed against the interest of Ghana so as to minimize the influx of goods and service that easily can be produced locally. This suggest that, government itself should show courage and intelligence by avoiding sole-sourcing deals when local contents could easily be employed.

Policy makers should aggressively embark on "made in Ghana products" Lack of interest in Ghana products stems from quality of the product. If consumers can be assured of quality of goods and services, they would patronise them. To do that, government should support private sector and impressing upon them the responsibility of improving product quality and delivery with requisite policy instrument and playing a watchdog role, but such such a policy already exist, then it should rather be strengthened. The government can also create subsidies for local producers in order to prevent increase production cost which leads to increase in general prices of goods and services which ultimately lead to depreciation of the exchange rate. When this is done, the exchange rate would experience appreciation.

The calculation results also revealed that GDP growth exhibit depreciation tendencies on the exchange rate both on the long run and short run dynamics in the model. For this reason policy makers should employ demand driven policies that would lead to growth driven by supply in the economy through increase in productivity in all sectors of the economy rather than supply driven policies.

It is important for government to have long term strategic vision of educational system that is situational in character and incorporating curricula that inculcate national pride of capabilities and consciousness. That, what is made in Ghana is of fine quality comparable elsewhere in the world. This sense of patriotic consciousness will serve as a catalytic driver to propel the sense of independence but with understanding of global interdependence.

The long run results revealed that, inflation has a depreciation and significant effect on exchange rate. One of key elements of inflation originates from central government excessive spending. This means, government should be discipline so as to create macroeconomic stabilities necessary to ensure exchange rate stability. In doing this the government can create a mild increase in inflation in the short run but should make sure there will be stability in terms of inflation in the long run. In doing this, the government should not be engaged in unnecessary overspending to inject more money or cash in the economy that create inflation.

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Appendices.

1 Appendix 1: Quantine-Quantine plot

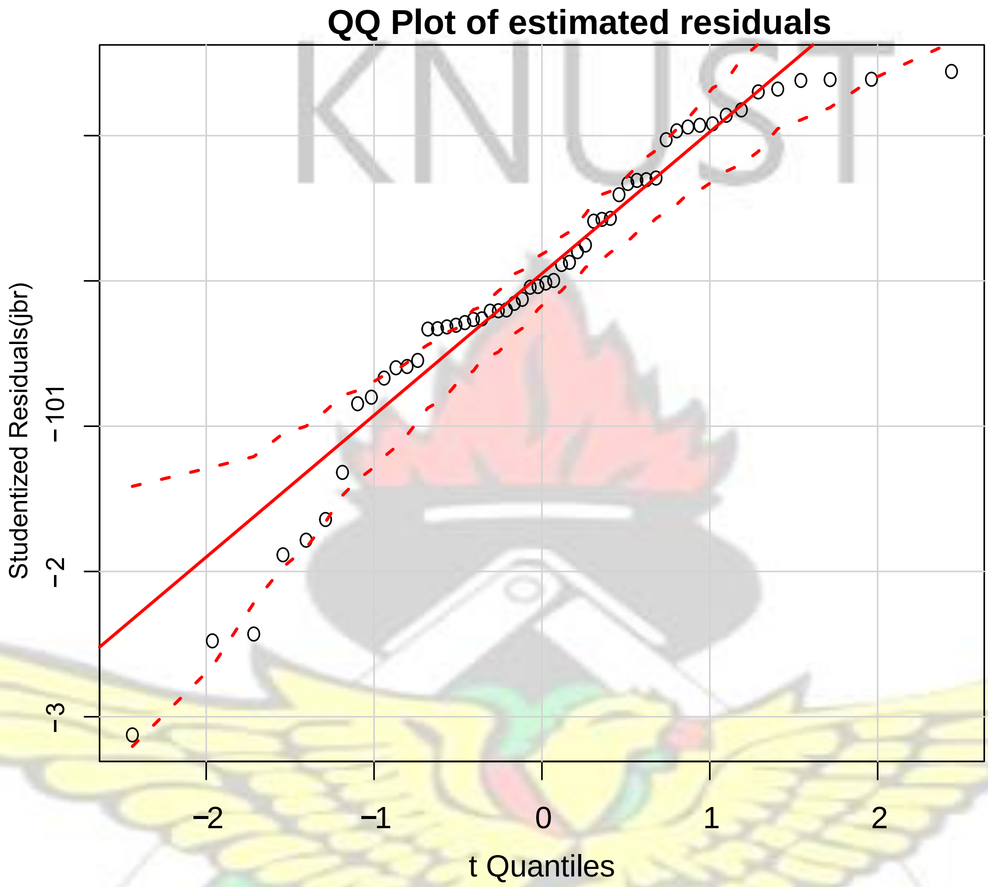

Figure 1: The normality test using quantine-quantine plot

.2 Appendix 2 :The short run granger causality

Table 1: Results of the Granger causality test for short run dynamics

Pairwise Granger Causality Tests at First Difference (Short Run) Null Hypothesis:

Null Hypothesis:	Obs	Lag 1 Prob.	Lag 2 Prob.
dlncpi does not Granger Cause dlnex		0.0487	0.2331
dlnex does not Granger Cause dlncpi	53	0.4233	0.1243
dlnm1 does not Granger Cause lncpi	53	0.1514	0.3746

dlncpi does not Granger Cause dlnm1		0.3247	0.5911
dlnm2 does not Granger Cause dlncpi	53	0.7733	0.6407
dlncpi does not Granger Cause dlnm2		0.0832	0.1019
dlny does not Granger Cause dlncpi	53	0.0225	0.0824
dlncpi does not Granger Cause dlny		0.6513	0.5904
dlntrade does not Granger Cause dlncpi	53	0.5766	0.3326
dlncpi does not Granger Cause dlntrade		0.8038	0.6553
dlnm1 does not Granger Cause dlnex	53	0.3133	0.2668
dlnex does not Granger Cause dlnm1		0.1227	0.2300
dlny does not Granger Cause dlnex	53	0.1338	0.2170
dlnex does not Granger Cause dlny		0.2343	0.4139
dlntrade does not Granger Cause dlnex	53	0.0000	0.0000
dlnex does not Granger Cause dlntrade		0.678	0.0655
dlny does not Granger Cause dlnm1	53	0.5097	0.302
dlnm1 does not Granger Cause dlny		0.4042	0.4780
dlntrade does not Granger Cause dlnm1	53	0.6687	0.6845
dlnm1 does not Granger Cause dlntrade		0.4832	0.8349
dlny does not Granger Cause dlnm2	53	0.0683	0.0231
dlnm2 does not Granger Cause dlny		0.6088	0.3321
dlntrade does not Granger Causedlnm2	53	0.7819	0.324
dlnm2 does not Granger Cause dlntrade		0.3276	0.6582
dlntrade does not Granger Cause dlny	53	0.17	0.1685
dlny does not Granger Cause dlntrade		0.9666	0.4353