KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF STATISTICS AND ACTURIAL SCIENCE

CHANGE POINT ANALYSIS OF THE CEDI-DOLLAR EXCHANGE RATE

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A THESIS SUBMITTED TO THE DEPARTMENT OF STATISTICS AND ACTURIAL SCIENCE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE

OF

BACHELOR OF SCIENCE

(STATISTICS)

AUGUST, 2024

Declaration

We hereby declare that, the thesis is the result of our own research towards the award of the Bachelor of Science degree in Statistics and that, to the best of our knowledge, it contains no material previously published by another person nor material which had been accepted for the award of any degree of the university, except where due acknowledgment had been made in the text.

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Dedication

We dedicate this work to our families , friends and the few ones who helped to see me through this research. We love them very much.

Abstract

This study used change point process to detect changes in the exchange rate data between the cedi and dollar. The exchange rate data was also modelled using ARIMA and forecasted the data using prophet model. ARIMA model was developed using Box and Jenkins method of Time Series Analysis on the monthly data collected from January, 2019 to June 2024. The results showed that ARIMA (2,1,0) was the best model with AIC (155.9718),BIC (162.495), and AICc (143.9718). The ARIMA model had errors of metrics as: MASE (0.2189052), MAE (0.3658338) and MAPE (4.266775). The multiple mean changes point using binary segmentation and BIC penalty term was used. Three(3) changes was detected in our exchange rate data, thus , 37, 44 , and 61. We estimated the parameter (mean) for each segment of change point and had 5.572614 for the first, 7.292071 for the second, 11.89682 for the third and with the last one we had 13.466240. The error metrics for the change point model was also calculated and we had MASE (1.353253), MAE (0.4069087) and MAPE (5.018955). We then compared the error of metrics of the ARIMA and the change point model and the ARIMA model appeared to be the best. We forecasted our exchange rate data using the prophet model which automatically detects twenty five changes in datasets. We adjusted the changepoint prior scale which has default of 0.05, and we added 0.1 and 0.2. The error of metrics was computed for the different changepoint prior scale and 0.2 appeared to be the best among them.

Acknowledgements

Our sincere appreciation to God Almighty for watching over us during this four-year period and guiding us through this work.

We are extremely grateful to all the lecturers and most especially our supervisor, Associate Prof. Nana Kena Frempong, Postgraduate Coordinator, Department of Statistics and Actuarial Science, KNUST, for his time spent on us, patience and guidance throughout this work. .

Finally, We want to express my appreciation to our family and friends who supported us throughout this work. Your enthusiasm and encouragement have been invaluable in accomplishing this task.

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Kumasi, August 2024

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Chapter 1

INTRODUCTION

1.1 Background of study

The exchange rate represents the relative price of one currency in terms of another currency, impacting economic activity, inflation, and a nation's balance of payments. It reflects the value of one currency compared to another and plays a crucial role in international trade and investments. The accuracy of exchange rates is a key factor influencing the economic growth of developed countries. Studies have highlighted the significant threat posed by high volatility to the economic progress of many African nations, including Ghana. Exchange rates are influenced by various factors such as interest rates, inflation, political stability, and the economic performance of different countries. In developing countries like Ghana, exchange rates are determined by foreign exchange markets. Since the year 2000, the Ghanaian cedi has experienced volatile exchange rates against leading currencies. A wide array of forecasting tools has been utilized to predict economic growth and other key indicators. The study of exchange rates is a vital component of international finance and economics.

Researchers have extensively analyzed the factors influencing exchange rates and their impact on international trade, investments, and economic stability. They scrutinize economic indicators like interest rates, inflation rates, and GDP growth to comprehend their effects on exchange rates. Various theories and models, such as the purchasing power parity theory and the interest rate parity theory, are employed to grasp the dynamics of exchange rate movements. This research aids businesses, governments, and individuals in making informed decisions regarding currency exchange, hedging strategies, and international financial transactions.

Exchange rate dynamics in Africa have been the focus of numerous studies. Researchers like Umoru David have explored the dynamic interaction between exchange rate regimes, import prices, and foreign holdings in developed countries, highlighting their impact on reserve holdings. Studies have revealed a significant relationship between exchange rate fluctuations and their effects on the overall economy. In Anglophone West African countries, researchers like Dung and Okereke have identified factors such as inflation rates, interest rates, current account balances, and terms of trade that depreciate exchange rates in Sub-Saharan African countries. The study emphasizes the unstable exchange rate management policies that lead to excessive depreciation of currencies, lack of international competitiveness in tradable goods, and inconsistent fiscal policies. Notably, the research by David Umoru utilizing GARCH models has provided insights into exchange rate dynamics in developing countries, forecasting significant increases in exchange rates in Ghana. The study also highlights the persistence of volatility in Nigeria and the turbulence in exchange rates experienced by countries like Kenya, Ghana, and Mauritius. Currently, the exchange rate stands at 1 USD = 15.56 GHS (BOG,2024).This exchange rate serves as a crucial benchmark for trade, investments, and economic activities between Ghana and the United States, highlighting the importance of exchange rate stability for sustainable economic growth and development.

In January 2024, the average exchange rate between the Ghanaian cedi and the US dollar was 11.934 (USD/GHS), showing an increase from the previous month's rate of 11.651 USD/GHS. Exchange rate data between Ghana and the US dollar is regularly updated on a monthly basis, spanning from January 1957 to January 2024. The historical data reveals that the exchange rate reached its peak at 13.073 in November 2022 and hit a record low of 0.000 in June 1967. The data on the average exchange rate against the USD is extended by CEIC, sourced from the Bank of Ghana, with information before July 1971 obtained from the International Monetary Fund. Recent research has indicated that the exchange rate between the Ghanaian cedi and the US dollar is non-stationary, implying that the governing probability law of the process changes over time, leading to a forecasted depreciation of the cedi against the dollar.

Volatility in exchange rates is a key concern for financial markets globally, prompting the use of tools like change point processes to analyze time series data and identify structural breaks that drive currency fluctuations. The study aims to analyze the exchange rate between the Ghanaian Cedi and the US Dollar using change point processes to uncover trends and shifts in exchange rate dynamics over time. By employing this analytical framework, the research seeks to provide a deeper understanding of the factors influencing the Cedi-Dollar rate and their implications for Ghana's economy. These shifts in exchange rates could signify changes in economic fundamentals, monetary policy decisions, geopolitical events, or market sentiments affecting the value of the Cedi relative to the Dollar.

1.2 Problem Statement

Exchange rates play a significant role in international economics, in influencing trade between countries, in investment, and how stable the econonomy would be. The exchange rate between the Ghanaian cedi (GHS) and the US dollar (USD) is particularly significant for Ghana's economy, this is becacuse of the country's dependence on imports, exports, and foreign investment. The exchange rate between the cedi and the dollar has experience a frequent and significant changes (highly volatile) in recent years, causing the economy to be unstable and making investors feel uncertain whether to invest their money into businesses or not. This frequent changes poses challenges for trade, inflation control, and economic planning. Over the past decade, the cedi has experienced significant depreciation against the dollar. Factors such as fluctuating commodity prices, changes in foreign investment flows, and varying levels of foreign exchange reserves have contributed to this trend. The cedi has declined more than 55% between January and October 2022, among the steepest declines of any currency in the world this year. For the year 2022, the Ghana cedi depreciated by 30.0 percent against the US dollar, after reversals of some of the losses in December.This compares with 4.1 percent depreciation in 2021. In the year to January 26, 2023, the Ghana Cedi cumulatively depreciated by 19.1 percent against the US dollar. In comparison with the same period of last year, the Ghana Cedi had depreciated by 1.5 percent against the US dollar(BOG,2024). All this is affecting the cost of import and driving investors away and overrall affecting the economic stability of Ghana. Over the years, ARIMA have been used to analyze the cedi's performance, they are inadequate for detecting structural changes in the exchange rate dynamics. This study seeks to fill this gap by utilizing change point analysis to identify and analyze significant changes in the exchange rate.

1.3 Main Objective

The main objective of the study is to employ change point process to detect shifts in the exchange rate between the Ghanaian cedi and the US dollar . In the context of exchange rates, these processes can help in identifying specific time points where there are notable changes in the dynamics of the exchange rate between the cedi and the dollar. The main objective of utilizing change point process is to enhance the understanding of the exchange rate behavior between the Ghanaian cedi and the US dollar by detecting specific time periods where significant changes in the exchange rate dynamics occur.

1.4 Specific Objective

Specific objectives for this study includes:

- Monitoring factors that influence the exchange rate between the dollar and the cedi, such as inflation, interest rates, and trade balances.
- Forecast the exchange rate between the cedi and dollar for two years
- Analyze trend patterns in the exchange rate over time
- Compare the ARIMA model to the change point model
- Compare the different change-point prior scale of the prophet model

1.5 Significance of Study

The examination of exchange rate dynamics between the Ghanaian cedi and the US dollar through change point processes holds importance for policymakers, market participants, and researchers alike. It offers crucial insights into currency fluctuations, aiding in policy formulation and improving decision-making and risk management within the exchange market. Through the analysis of exchange rate fluctuations on economic indicators, the study plays a role in enhancing Ghana's economic stability. Additionally, it boosts the precision of exchange rate forecasting and propels advancements in exchange rate modeling, contributing to a more profound understanding of global economics.

1. Economic Stability: The exchange rate between currencies reflects the economic strength and stability of the respective countries. By studying and monitoring the exchange rate between the cedi and the dollar, policymakers and stakeholders can gauge the economic health of Ghana and its relationship with the global economy.

2. International Trade and Investments: The exchange rate directly influences international trade and investments. A stable exchange rate fosters confidence among investors and facilitates smoother trade relations between countries. Analyzing the exchange rate dynamics helps in predicting trends and making informed decisions regarding trade and investments.

3. Policy Formulation: The study of exchange rates assists policymakers in formulating effective economic policies. By understanding the factors influencing the fluctuation of the exchange rate, governments can implement measures to stabilize the currency and promote economic growth.

1.6 Organisation of the Study

The study is structured into five chapters. Chapter one provides the background, problem statement, main and specific objectives, significance of the study, the organization of the research and limitation of the study. Moving on to Chapter 2, the study delves into a detailed exploration of the introduction, structure, and history of the exchange rate market in Ghana. This section provides a thorough overview of the historical evolution of exchange rates in Ghana, the structure of the exchange market, and key factors influencing exchange rate dynamics in the country. Additionally, Chapter 2 includes a review of empirical studies on exchange rates and financial time series with a focus on volatility, offering insights from existing literature to contextualize the research within the broader academic landscape. In Chapter 3, the study likely transitions into the methodology section, where the research design, data collection methods, and analytical techniques employed in the study are elaborated upon. This chapter outlines the specific approach taken to analyze exchange rate dynamics using change point processes, detailing the steps involved in data collection, model selection. By providing a transparent account of the methodology, this section ensures the rigor and reliability of the research findings. Chapter 4 is dedicated to the presentation and analysis of the research findings. Here, the study showcases the outcomes of applying change point processes to examine exchange rate trends between the Ghanaian cedi and the US dollar. Through detailed data analysis, visualization of trends, and interpretation of results, this chapter offers valuable insights into the patterns and shifts in exchange rate dynamics over time. The findings presented in this section contribute to a deeper understanding of the factors influencing the cedi-dollar exchange rate and their implications for Ghana's economy. Finally, Chapter 5 concludes the study by summarizing the key findings, discussing their implications, and offering recommendations for policymakers, market participants, and future research directions. This section encapsulates the significance of the study's contributions to the field of exchange rate dynamics and underscores its relevance for informing economic policies and decision-making processes in Ghana.

1.7 Limitation of the study

The study on exchange rate dynamics between the Ghanaian cedi and the US dollar using change point processes may face limitations related to data availability and quality, model assumptions, and external factors influencing exchange rates. Generalizability of findings to other contexts, time constraints in analysis, and potential methodological limitations in capturing the full complexity of exchange rate dynamics are also key considerations. Addressing these limitations is essential for ensuring the reliability and validity of the research outcomes.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The exchange rate between the cedi and the dollar is a subject of crucial interest due to its impact on the economic growth, policy making and others important reasons. This chapter aims to explore various analysis conducted on exchange rate between the cedi and the dollar data, highlighting the methodologies, findings and impact of each study

2.2 Exchange Rate

The exchange rate of a country's currency is the value of its money for an international trade in goods, services and finance and, therefore, it is a part and parcel of the monetary condition of a country. Therefore, the central banks being the monetary authorities have been given discretionary powers under the relevant statutes to decide appropriate foreign exchange policies along with its monetary, financial and economic development policies. In macroeconomic perspective, foreign exchange rate policies are instrumental in the mobilization of foreign savings and capital to fill the domestic resource gap and investment expansion. Various public views are often expressed as to how the central banks should decide exchange rate policies and what factors should be taken into consideration. The exchange rate is a key determinate of a nations economy and its also an important factor investors need to consider in a country's economy due to it propensity to affect the real value of their currency.

2.2.1 Factors Affecting The Exchange rate

In this section emphasis is on various factors affecting currency movement and their characteristics. We have included important factors which can affect the valuation of FOREX. We have also indicated positive and negative effect of each factor on currency valuation. These factors include:

- Inflation

  In economics, inflation is defined as a sustained increase in the general price level of goods and services in an economy over a period of time. It is measured as an annual percentage of increase. Inflation plays an important role in valuation of currency of any country. If the rate of inflation in the Ghana is lower than other countries comparatively, then Ghana's exports will increase. There will be an increase in demand for Rupee to buy Ghana goods. Also foreign goods become cheaper and so Ghanaian citizens will pay less ultimately import decreases. Therefore lower inflation rates tend to see an appreciation in the currency value of any country. A higher inflation rate in a Ghana will decrease the demand for the Ghana's currency since the value of the currency depreciates relatively faster over time than other foreign currencies

- Interest Rate

  An interest rate is a cost of borrowing money, expressed as a percentage of the amount borrowed (ABC Finance,2024). If rate of interest in Ghana increase relatively to other countries, it will become attractive to invest money in Ghana. Investor will get a higher return from saving in the Ghana banks. Therefore, demand for Ghana goods will rise. Higher interest rate is an appreciation for money inflow which will have negative impact on local businesses of the country. Higher interest rate reduces purchase power of the consumer while the loan borrowers have to pay more interest. However, in practice, it is balanced out by inflationary pressures

- Gross Domestic Product

  The gross domestic product of a country is a measure of all of the finished goods and services that a country generated during a given period. GDP gives best measure of health of country's economy. It is the number calculated by consolidation of total expenses of government, money spent by business, private consumption and exports of the country. Increment in GDP indicates economic growth. Foreign investors get attracted towards the countries with economically strong countries with good GDP. It leads to better valuation of the currency of the country because more and more money comes to the country.

- Macroeconomic and Geopolitical Events

  In the case of events like elections, wars, monetary policy changes, financial crisis, currency of the country is highly affected. Such macroeconomic and geopolitical events also affect other parameters. These events have the ability to change or reshape of the country including fundamentals of the country. For example, wars can put a huge economic strain on a country and greatly increase the volatility in a region, which could impact the value of its currency. It is important to keep up to date on these macroeconomic and geopolitical events.

- Political Stability and Economic Performnace

  Countries with stable government can give better growth in economy through completion of the projects in hand. Investors invest their money in the countries with strong economic performance. As India has coalitions government and no party has got full majority so there are lot of problems for stability of the government and the government can't take decisions strongly. So, it causes loss of confidence in foreign investors. It affects economic growth and money moves out of the country.

2.2.2 Importance of exchange rate on economic activies

The exchange rate plays a crucial role in shaping various aspects of economic activity and its includes;

- Trade and Export Competitiveness

  The exchange rate directly impacts Ghana's export competitiveness. A depreciation of the Ghanaian cedi can make Ghanaian goods more affordable in international markets, potentially boosting exports and improving the country's trade balance. On the other hand, an appreciation of the cedi may make exports more expensive, affecting the competitiveness of Ghanaian products.

- Inflation and Import Prices

  Exchange rate movements can influence inflation in Ghana. A depreciation of the cedi may lead to higher import prices, which can contribute to inflationary pressures in the economy. This, in turn, affects the purchasing power of consumers and the overall price levels of goods and services in the domestic market

- Foreign Direct Investment (FDI)

  Exchange rate stability is crucial for attracting foreign direct investment to Ghana. Investors often consider exchange rate fluctuations when making investment decisions. A stable exchange rate can provide a conducive environment for FDI inflows, contributing to economic growth and development

- Monetary Policy Implications

  The Bank of Ghana may use exchange rate movements as a factor in determining monetary policy. Fluctuations in the exchange rate can influence interest rates and inflation targeting strategies. The central bank's interventions in the foreign exchange market can impact the exchange rate and overall economic stability

- Balance of Payments

  Exchange rate movements affect the balance of payments in Ghana. Changes in the exchange rate can impact the country's current account balance, capital flows, and reserves. A strong or stable exchange rate can help maintain a favorable balance of payments position, while excessive volatility may pose challenges for external accounts

2.3 History Of Exchange Rate System In Ghana

Prior to European colonialism, there was no established monetary system in use in Ghana. The Gold Coast, which is now Ghana, utilized a form of a fixed exchange rate system during the time when it was under colonial rule. Before the West African Currency Board (WACB) was created in 1912 and began issuing the West African Pound, the Bank of British West Africa, which was a private bank and had a branch in Accra, was responsible for the distribution of the British pound, which did not require an exchange mechanism. After 1912, when the WACB pound was first introduced, its value was pegged to that of the British pound sterling at par (thus, one to one). When Ghana gained its independence in 1957, it immediately instituted its own independent monetary policy and currency. A lengthy period of time was spent under the system with a fixed exchange rate until 1983, when it was replaced with a regime that allowed for greater exchange rate flexibility. The Ghana pound was the country's official currency from 1957 through 1965, and it had a value that was equivalent to that of the British pound at that time. The Ghana pound was replaced with a brand-new currency known as the first cedi, which was created by the Bank of Ghana in 1965. The exchange rate for one Ghana pound was set at 2.4 Cedis. Additionally, it was equivalent to one pound of sterling (2.4 Cedis equaled one pound of sterling). The National Redemption Council decided to replace the first cedi with the second cedi in 1967. This took occurred (NRC). The exchange rate for this was determined to be 2 Cedis to 1 Ghana pound. The value of one Ghana pound was equivalent to that of one British pound. Later on, in 1967, the US dollar was used instead of the pound as an intermediate or intervention currency, and the exchange rate was set at 1 cedi = 0.98 US dollars. The value of the cedi was reduced to $0.55 in 1971, after which it was revalued to $0.78 in 1972 and to $0.8696 in 1973 before the currency was allowed to float in 1978. After then, the value of one dollar in Cedis was set at 2.75 Cedis. The period known as the PNDC regime and the Economic Recovery Programme were responsible for the implementation of the controlled floating exchange rate system in 1983. The auction exchange rate mechanism was first made available to importers in August of 1986 and was organized by the Treasury Department. In February of 1987,the Bank of Ghana centralized the Auction and gave formal permission to exchange bureaus to purchase and sell foreign money. At the beginning of 1992, the auction system was done away with and replaced with the interbank exchange rate system. Under this new system, the (official) exchange rates are established by the market that exists between different banks. Therefore, as of right now, the systems of foreign exchange rates that are in use are those of forex bureau and interbank exchange rate systems.

2.4 Trends in foreign exchange rate in Ghana

The effective exchange rate has been steadily falling against the world's primary trading currency, the dollar, ever since the floating exchange rate changes were first put into place in 1983. This is an indication that a greater number of Ghana Cedis are required to trade for a single dollar. Since Ghana made the transition from using a fixed exchange rate regime to using a floating exchange system in 1983, the value of the Ghana cedi has substantially decreased by a huge amount each year. In 2016, one dollar in US currency was equivalent to GHS 3.992. As of the 24th of February, in 2017,one US dollar was equivalent to GHS 4.552.On Tuesday, June 14 2022, the USD against GHS exchange rate fell from 7.8000 in the previous trading session to 7.6700. This is a fall of 0.1300, or 1.67 percent. According to research, the value of the cedi began toincrease from the start of the year 2022 and only had a slight drop in the month of June 2022. As of today July 16th 2024, one US dollar is GHS 15.45. The conclusion is that more Ghana Cedis are required to trade for a dollar,which is not good news for Ghana because the country imports more than fifty percent of its goods and services from other dollarized nations.The vast majority of developing nations are extremely reliant on imported inputs for production, and Ghana is not an exception to this rule. The regular depreciation of the Ghana cedi, in accordance with the conventional theory of trade, is anticipated to stimulate exports while simultaneously discouraging imports. However, in practice, this is not the situation for Ghana, despite the fact that it is found that a unit depreciation of the Ghana cedi creates a 0.3109 improvement in Ghana's trade balance as a result. The reason for this is that Ghana's imports have consistently been higher than her exports over the whole accounting period. According to research, a one unit rise in Ghana's GDP (income), while maintaining other parameters equal, results in around a 0.5333-point worsening of Ghana's trade balance. This is evidence that Ghana buys more than she exports at the present time.It is also found in research that the amount of food that is produced in Ghana is less than the amount of food that is demanded, and that the gap is supplied by imports. This results in a weaker balance of payments and a greater depreciation rate in Ghana. In Ghana, a very worrisome problem is the regular devaluation of the cedi, particularly when measured against the dollar. This is due to the fact that it has a detrimental impact on her prices, wages, interest rate, production levels, job prospects, and a wide variety of other macroeconomic phenomena according to research.This results in an increase in the price of final products and services priced in Cedis when these goods and services are imported from a country with a lower value of the cedi relative to the dollar. As a result of rising cedi prices for imported commodities, production costs have grown, and these higher costs have been passed on to local pricing levels. The growth in domestic prices, without a commensurate rise in the nominal wage rate of the people of Ghana, results in a reduction in the real wage, and families are need to spend more money in order to maintain the same quality of living. This opens the door for labor to advocate for increases in pay and benefits to the company . Additionally, the sudden increase in the costs of imported supplies might discourage new investments in commercial endeavors, while the upkeep and repair of existing equipment would also represent a major financial strain on contemporary enterprise . Regular drops in the value of the cedi contribute to an increase in the overall level of inflationary pressure. Between June 2008 and June 2009, Ghana was subjected to pressures associated with inflation, which were partially caused by the devaluation of the cedi. Inflation reached its all-time high of 20.7 percent year on year in June of 2009. According to research, the primary factors that influence inflation in Ghana are the devaluation of the country's currency and the rise in the wholesale prices of food crops. According to the findings of research, there is a significantly positive link that holds between the parallel exchange rate and the overall price level in Ghana. The instability of the currency exchange rate has a negative impact, not only on Ghana's national income, but also on employment. According to the Monetary Policy Report (2016) published by the Bank of Ghana, the real growth of the nation's GDP was 3.9% in 2015, down from 4.1% the previous year. The depreciation of the Ghana cedi as well as persistent power supply difficulties, both of which severely impacted the manufacturing sector, were the root causes of shortfall. Research shown that Ghana's exchange rate has a detrimental impact on the country's GDP growth over the course of several years. This indicates that a one percent increase in Ghana's exchange rate will result in a 0.0025 percent decline in Ghana's GDP growth. Additionally, research discovered that a one percent rise in the exchange rate volatility results in a 0.8 percent reduction in economic growth in Ghana. According to findings, the performance of the manufacturing sector in Ghana improves whenever the currency rate appreciates, and if it depreciates, the industry is badly affected, which in turn has a negative impact on the amount of employment in the nation .According to findings, the depreciation of the Ghanaian cedi in comparison to the United States dollar considerably reduces the rate of job growth in the manufacturing sector in Ghana. Since Ghana does not collect its income in dollar terms,but rather in cedi terms, the rapid depreciation of the Ghana cedi boosts the value of Ghana's foreign debt and the cost of repaying that debt. In 2005, Ghana's total external debt was 7.17 billion dollars in US currency. In 2007, this was reduced to \$3.68 billion US dollars. The reason for this was that because of the redenomination of the Ghana cedi during this time period, the exchange rate managed to remain reasonably constant. In 2009, Ghana's external debt was valued at 7.2 billion US dollars; the following year, it rose to 9.3 billion US dollars. It reached a record high of \$15.8 billion US dollars in 2013, according to research In terms of United States dollars, the increase in Ghana's external debt represented a 79 percent increase from US \$7,103.41 million in September 2011 to US \$12,712.02 million; however, in terms of Ghana cedi, the increase represented a 275 percent increase from GH10,814.23 million to GH40,644.15 million. As at the year 2022 Ghana's debt was \$28.14 billion and provisional gross public debt at end Q1-2023 stood at GH569.35 billion (US\$51.67 billion), representing 71.1 percent of GDP, a slight decrease of 20 basis points from 71.3 percent recorded at the end of Q4-2022. Rises in Ghana's foreign debts are matched by increases in the amount of money that must be paid to service such loans. The interest payment on Ghana's foreign debt was

139.6 2024b the debt is million US dollars in 2009; it climbed to 335.7 million US dollars in 2013, up from 128.7 million US dollars in 2011 and 219.9 million US dollars in 2012. This increased contribution toward debt service has a tendency to compete with other areas of spending, notably capital investment. Increases in wages as a consequence of inflationary pressures through the exchange rate depreciation have the potential to raise public outlays: the rise in government expenditure generates budget deficits when the revenue collected is insufficient to meet the expansion in expenditure. This is the case in many developing countries, including Ghana, where the government is the primary employer of labor. In 2015, total revenue and grants amounted to GHS31.1 billion, which represented 22.2 percent of GDP, while total expenditures amounted to GHS37.3 billion, which represented 26.7 percent of GDP. Those figures are in Ghana Cedis (GHS) (Bank of Ghana monetary policy report, 2016). In addition, the unstable currency rate that Ghana has been experiencing for the past three decades makes it difficult for the government, companies, and individuals to plan. One of these proofs is the fact that it causes delays in timely repayments. For example, the recent fall in the value of the cedi makes it impossible for those who want to buy home with mortgages to do so since house prices have risen to unaffordable levels.In addition, the present quick depreciation of the cedi is a sign that Ghana's fiscal or monetary policy posture is unwell. This depicts that either Ghana's fiscal policy is more expansionary or her monetary policy is not as tight as policy makers are anticipating it to be.The reason for this is because in an open economy such as Ghana, monetary and fiscal policies need to be consistent in order to maintain stability in the country's overall economy.Imports, exports, investments, knowledge transfer, and eventually economic growth might all suffer as a result of these policies on exchange rates, which are incorrect. The advocates of a fixed exchange rate have argued that a flexible exchange rate increases trade uncertainty and may reduce trade volumes because it exposes importers to greater risks as a result of fluctuations. However, positive effects could result in the short term if the flexible exchange rate is implemented . Floating exchange rates have the potential to be both effective and efficient in some contexts, given the right conditions and regulations.As can be seen from the numerous budget statements of Ghana, the goal of Ghana is to achieve and then sustain stable and competitive real exchange rates. The rationale for this is that foreign exchange may be utilized as a weapon to bring about development and stability in economic conditions.On the other hand, the Ghanaian government's efforts to keep the value of the cedi constant in relation to the US dollar have continued to run into obstacles.

2.5 Empirical Review

Empirical studies conducted in Ghana and other countries have revealed the underlying causes of the fluctuations in a country's currency relative to those of its key trade partners. By comparing the Ghanaian cedi to various global currencies, researchers have sought to understand these mixed tendencies. For instance, a study conducted between 1980 and 2022 investigated the impact of exchange rate fluctuations on Ghana's economic development. The primary aim of the research was to identify the causes of exchange rate volatility and its long-term effects on Ghana's economic growth. Using the co-integration approach, the study found correlations between the real exchange rate and factors such as terms of trade, real GDP, trade openness, money supply, domestic credit, and exports. It was also noted that terms of trade significantly impacted real exchange rate volatility. The researchers concluded that higher productivity reduces long-term volatility, while terms of trade negatively impact real exchange rate volatility. Additionally, foreign direct investment (FDI), government expenditure, and money supply were found to have a positive and significant relationship with long-term exchange rate volatility. The study determined that the primary driver of exchange rate volatility in Ghana is the country's output.

Another study examined the factors influencing fluctuations in the Ghanaian cedi's exchange rate from 1985Q1 to 2006Q4 using the Johansen co-integration approach. The model included variables such as nominal GDP, government spending, domestic credit, imports, the consumer price index, and the nominal exchange rate as regressors. The findings highlighted that government expenditure in Ghana played a crucial role in predicting currency fluctuations, along with the country's historical experience with currency changes.

Further analysis of Ghana's real exchange rates and misalignments was conducted from 1980 to 2010, utilizing the Error Correction Model (ECM). The study used the real effective exchange rate as the dependent variable and included explanatory factors such as productivity, trade openness, real relative interest rate, government spending, terms of trade, and foreign reserves. The results indicated that real exchange rate depreciation was associated with productivity, trade openness, real relative interest rate, and foreign reserves, while government spending, terms of trade, domestic credit, and fiscal deficit had a positive (appreciating) effect on the real exchange rate. However, domestic credit and budget deficit were found to have no statistically significant impact on the real exchange rate.

In another research , the real effective exchange rate of Ghana from 1965 to 2004 was investigated, with the primary goal of identifying the fundamental factors influencing the equilibrium exchange rate in Ghana. Variables such as terms of trade, net capital inflow, and commercial policy (openness) were considered in estimating the equilibrium exchange rate. The findings indicated that a decline in terms of trade, increased openness, and higher capital inflows led to currency devaluation.

A study was also conducted where they used the Monetary Approach to examine the factors influencing the Cedi/Dollar exchange rate from December 1992 to November 2003. They employed co-integration and error correction modeling, considering variables like Ghana's money supply, US money supply, Ghana's GDP, US GDP, and the real interest rate disparity between the two countries. The study found that monetary growth was correlated with currency depreciation, with a 1 percent increase in the real interest rate differential leading to a 0.23 percent depreciation in the cedi/dollar rate. Additionally, a 1 percent increase in domestic inflation relative to foreign inflation resulted in cedi/dollar depreciation.

Researchers have identified various underlying causes contributing to the mixed trends of a country's currency in relation to those of its key trading partners, through empirical studies conducted in Ghana and other countries. By comparing the Ghanaian cedi to US dollar worldwide, they examined the effects of exchange rate fluctuations on Ghana's economic growth from 1980 to 2022. The primary objective of these studies was to uncover the factors causing exchange rate volatility and to understand its long-term impact on economic development. They employed the co-integration approach, revealing correlations between the real exchange rate and several factors including terms of trade, real GDP, trade openness, money supply, domestic credit, and exports. The studies found that higher productivity reduces volatility in the long term, while terms of trade have a negative and significant relationship with real exchange rate volatility. Foreign Direct Investment (FDI), government expenditure, and money supply all positively correlate with long-term exchange rate volatility. Ultimately, the researchers concluded that Ghana's exchange rate volatility is primarily driven by the country's output.

In another analysis, the Monetary Approach was used to study the factors affecting the Cedi/Dollar exchange rate between 1992:12 and 2003:11. They employed co-integration and error correction modeling, including variables like Ghana's money supply, US money supply, GDP for both countries, and the real interest rate disparity. The results showed a correlation between monetary growth and currency depreciation. A 1 percent increase in the real interest rate differential resulted in a 0.23 percent depreciation of the cedi/dollar rate, and a 1 percent increase in domestic inflation relative to foreign inflation caused further depreciation.

The empirical findings suggest that the relationships between key factors and exchange rate performance in Ghana may have evolved over time, with some variables that previously influenced the cedi's exchange rate now having different impacts. The main aim of the present study is to identify significant changes in the Ghanaian cedi and the US dollar. The Ghanaian cedi has experienced frequent devaluation over time, raising concerns about the stability of the currency. This investigation focuses on detecting changes in the cedi and the US dollar which in turn gives as in dept understanding in economic fundamentals, monetary policy decisions and other factors. Most studies employ the ARIMA model in modelling the exchange rate of the cedi and dollar which fail to detect shift in the exchange rate data. Our studies however will employ multiple mean change point to detect significant changes in our exchange rate data which inform decision making.

Chapter 3

METHODOLOGY

3.1 Introduction

The determination of exchange rate between currencies is an important aspect of the global economics, influencing trade, investment and economic policies. In this study, we centre on understanding the dynamics of exchange rate between the cedi and the dollar. The fluctuation of this exchange rate impacts Ghana's economy and also reflects the trends in global financial markets. In this chapter, we explore the methodology employed to analyse the cedi-dollar exchange rate, with our gear on change point analysis. Change point analysis is a powerful new tool for detecting whether a change has taken place in a time series data. The main objective of this chapter is to provide a detailed explanation of how change point analysis will be applied to the cedi- dollar exchange rate. The methodologies detailed include data collection, statistical methods

3.2 Research Design

The study adopts a quantitative research design, centering on the statistical analysis of time series data. This approach allows thorough study of the exchange rate fluctuations and identification of change points in the time series data

3.3 Target Population

The target population for this study includes all data points that represent the exchange rate between the Ghanaian cedi (GHS) and the United States dollar (USD) over a specified time period. This population includes historical exchange rate data sourced from financial databases, specifically the Bank of Ghana website.

3.3.1 Defintion and Scope

The target population consist monthly exchange rate data between the cedi and the dollar. These data points reflect the fluctuations and trends in the exchange rate over time. The scope includes data from January 2019 to June 2024. This broad timeframe ensures a comprehensive analysis of long-term trends and significant events that may have influenced the exchange rate.

3.4 Sample size and Sampling Technique

The sample size in this study refers to the number of data points collected and analysed to understand the exchange rate dynamics between the cedi and the dollar. The sample size is determined by the frequency and duration of the collected data. The study will analyse exchange rate data from January 2019 to June 2024. Data points will be collected on a monthly basis. The sampling technique employed in our studies is the time series sampling which involves which collecting data at regular intervals over a period of time.

3.5 Data Collection

For our analysis, we used secondary data which was obtained from the Bank of Ghana official website. The data is known to be univariate because exchange rate between the cedi and the dollar were observed over time.

3.6 Research Methodology

Time Series Models

A time series is a set of observations X_t , each one being recorded at a specific time t. Time series arises in a variety of fields including in business where we observe the daily stock prices, in agriculture where we observe the daily crop prices, in engineering to the voltage measurements and more of different fields. **Autoregressive (AR) Model**

In an autoregression model, we forecast the variable or series of interest using a linear combination of past values of the variable. This means in autoregression, the current value of the variable or series depends on the past or history values. The term autoregression indicates that it is a regression of the variable or series against itself. The order of the model is denoted as "p", which determines the number of past observations studied for the forecast. The autoregressive model is given as:

$$X_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + \cdots + \phi_p X_{t-p} + \epsilon_t$$

where:

- X_t is the value of the time series at time t,
- $\phi_1, \phi_2, \ldots, \phi_p$ are the parameters of the model,
- ϵ_t is white noise error term at time t.

Moving Average (MA) Model

A moving average is a statistical calculation used to analyse data over a certain period. Rather than using past values of the forecast variable in a regression, a moving average model uses past forecast errors in a regression-like model. The moving average is calculated by taking an average of a specified number of data points within a given time frame and then moving forward one data point at a time and recalculating the average. The order of the moving average is given by "q" . The moving average model is given as:

$$X_t = \mu + \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \cdots + \theta_q \epsilon_{t-q}$$

where:

- X_t is the value of the time series at time t,
- μ is the mean of the series,
- ϵ_t is white noise error term at time t,
- $\theta_1, \theta_2, \ldots, \theta_q$ are the parameters of the model.

Autoregressive Integrated Moving Average (ARIMA) Model

The models discussed above so far are based on stationary assumptions, that is, the mean and variance are constant over time but the autoregressive integrated moving average deals with non- stationary data. It helps to analyse and forecast data with time dependent format. It is known to consist of both the Autoregressive (AR) and Moving Average components of time series. It handles non- stationary data by differencing. In Autoregressive (AR) part, we forecast the variable or series of interest using a linear combination of past values of the variable and the Moving Average (MA) uses past forecast errors in a regression-like model and the Integrated part deals with non-stationarity of the time series. The Autoregressive

Integrated Moving Average (ARIMA) Model is given as;

$$\Delta^d X_t = \phi_1 \Delta^d X_{t-1} + \phi_2 \Delta^d X_{t-2} + \cdots + \phi_p \Delta^d X_{t-p} + \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \cdots + \theta_q \epsilon_{t-q}$$

where:

- X_t is the value of the time series at time t,
- $\Delta^d X_t$ is the d-th differenced series, defined as $\Delta^d X_t = (1 - B)^d X_t$, where B is the backshift operator,
- $\phi_1, \phi_2, \ldots, \phi_p$ are the parameters of the autoregressive part of the model,
- ϵ_t is the white noise error term at time t,
- $\theta_1, \theta_2, \ldots, \theta_q$ are the parameters of the moving average part of the model.

In the ARIMA model, the series X_t is first differenced d times to achieve stationarity. The resulting series is then modeled as an ARMA(p, q) process.

3.7 Hypothesis Trend Test

The trend in the time series data can be seen by ploting the data to see if it is increasing, decreasing or it is constant over time. After your observation, it can be confirmed using the Mann-Kennall trend test, the cox and stuart trend test and the Theil–Sen trend test. But we would only talk about the Mann Kendall trend test.

Mann- Kendall trend test is a non – parametric statistical test used to determine if there is a trend in a dataset over time. It is given as;

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \tag{3.1}$$

where;

sgn is the signum function

3.7.1 Test for Stationarity

Differencing

The presence of a trend indicates non-stationarity; therefore, the time series data must be differenced to achieve stationarity. Differencing can be performed once, twice, thrice and so on if necessary. But in our study, we perform first and secondary differencing.

First Differencing

The first difference is calculated by subtracting the previous observation from the current observation which is computed as:

$$\Delta y_t = y_t - y_{t-1}$$

where;

- y_t is the value of the time series at time t.
- y_{t-1} is the value of the time series at time $t-1$, which is the previous time period.
- Δy_t is the first difference of the time series at time t, representing the change from y_{t-1} to y_t.

Second Differencing

The second differencing is calculated by subtracting the first difference at time t-1 from the first difference at time t. It is given as;

$$\Delta y_t = y_t - y_{t-1}$$

$$\Delta^2 y_t = \Delta y_t - \Delta y_{t-1} = (y_t - y_{t-1}) - (y_{t-1} - y_{t-2}) = y_t - 2y_{t-1} + y_{t-2}$$

where:

- y_t is the value of the time series at time t.
- y_{t-1} is the value of the time series at time $t-1$, which is the previous time period.
- y_{t-2} is the value of the time series at time $t-2$, which is two periods ago.
- Δy_t is the first difference of the time series at time t, representing the change from y_{t-1} to y_t.
- $\Delta^2 y_t$ is the second difference of the time series at time t, representing the change in the first differences.

Unit Root Test

When there is a trend in time series data, the presence of the trend indicates that the time series data is not stationary. Therefore, stationarity must be achieved to carry on the analysis. The unit root tests such as Augmented Dickey-Fuller (ADF), Philips-Perron (PP), and Kwiatkowski- Phillips – Schmidt – Shin (KPSS) were used to test for stationarity. The ADF and PP tests have the same null and alternative hypothesis, which states that the series is not stationary for the null and the series is stationary for the alternative. The KPSS has a null hypothesis which states that the series is stationary and the alternative hypothesis is not stationary. The decision is either to reject or fail to reject the null hypothesis if the p-value is less or greater than the 5% level of significance respectively.

The Augumented Dickey Fuller (ADF) test is given by:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \epsilon_t$$

where:

- Δy_t is the first difference of the time series.
- α is a constant.
- βt is a trend term (optional).
- y_{t-1} is the lagged value of the time series.
- p is the number of lagged difference terms.
- δ_i are the coefficients of the lagged difference terms.
- ϵ_t is the error term.

The Philips-Perron test is computed as:

$\frac{\text{t-statistic}-\sigma}{\text{se}}$

where:

t-statistics is the test statistics from the ADF regression.

σ is a constant that depends on the sample size and the presence of deterministic terms.

se is the standard error of the test statistics.

The Kwiatkowski- Phillips – Schmidt – Shin (KPSS) test is given by:

KPSS $=\text{T}\times \sum_{i=1}^{k}[\frac{1}{k+1} \times \sum_{t=1}^{T} \frac{(y_t-\mu)^2}{\sigma^2}]$

Where:

T is the number of observations in the time series.

K is the truncation lag parameter.

y_t is the observation at time t.

µ is the estimated mean of the time series.

σ^2 is the estimated variance of the time series.

Model Selection

After achieving stationarity at various orders of differencing, competing models are built and the best model is selected based on the least values of the three information criteria which are the Akaike Information Criterion (AIC), Corrected Akaike Information Criterion (AICc) and Bayesian Information Criterion (BIC).

The AIC is a measure of the goodness of fit of a model. It also balanced the fit of the model by penalizing models with more parameters.

The AIC is given as:

$\text{AIC} = -2\ln L(\hat{\theta}_k) + 2K$

Where;

$\ln L(\hat{\theta}_k)$ is the likelihood of the fitted model.

K is the number of unknown parameters free to vary.

The AICc is a modification of AIC that adjusts small sample sizes. It is used when the number of observations is relatively small compared to the number of parameters in the model.

The AICc is computed as:

$\text{AICc} = -2\ln L(\hat{\theta}_k) + \frac{2kn}{n-k-2}$

Where:

$\ln L(\hat{\theta}_k)$is the likelihood of the fitted model.

k is the number of unknown parameters.

n is the total number of observations.

The BIC is similar to AIC but the only difference is that the BIC places a stronger penalty on the models with more parameters.

The BIC is given by: $\text{BIC} = -2\ln L(\hat{\theta}_k) + k\ln n$

Diagnostic Checking and Forecasting

Diagnostic checking also known as residual analysis, is a vital stage in time series analysis to check if the selected models are appropriate. There are several ways to check for auto-correlated but in this study, we use the ACF plot of the residuals. If the lag spikes from the ACF plot of residuals are insignificant, then the errors are not correlated. The Ljung Box test is used to determine if the model is appropriate or not. It has a null hypothesis which states that the model is appropriate and the alternative hypothesis is not appropriate. The decision is either to reject or fail to reject the null hypothesis if the p-value is less or greater than 5% level of significance and conclude that the model is not appropriate or the model is appropriate respectively.

The Ljung Box test is given as:

Q $= n(n+2)\sum_{k=1}^{h-1} r_k^2 \frac{1}{n-k}$

Where:

n is the sample size.

r_k is the sample auto-correlation at lag k.

h is the number of lags being tested.

Forecasting Accuracy Measures

At this stage, we evaluate the performance of the model. There are several error metrics available, but due to our study, we selected Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE). In this study, the best fitting model was selected based on the least values of these errors. The MASE measures the performance of a forecast in relation to the performance of benchmark model.

3.8 Change Point Model

Multiple Mean Change Model

The Multiple Mean Change Point Model aims to detect multiple points in a time series where the mean level or trend level shifts in our data.

3.8.1 Model Formulation

Consider a time series $\{y_t\}_{t=1}^{n}$. The goal is to identify K change points $\tau_1, \tau_2, \ldots, \tau_K$ such that the series can be divided into K+1 segments, within each of which the mean is constant but can differ between segments. The mean within each segment i can be estimated as:

$$\hat{\mu}_i = \frac{1}{\tau_i - \tau_{i-1}} \sum_{t=\tau_{i-1}+1}^{\tau_i} y_t$$

And now our model can be expressed as:

$$y_t = \mu_i + \epsilon_t, \quad \tau_{i-1} < t \leq \tau_i$$

where:

- μ_i is the mean of the i-th segment,
- ϵ_t is the error term, often assumed to be i.i.d. normal with zero mean and constant variance,
- $\tau_0 = 0$ and $\tau_{K+1} = n$.

3.8.2 Cost Function

The cost function evaluates the goodness-of-fit of the model with given change points. For the our , it is typically the sum of the residual sum of squares (RSS) for each segment:

$$C(y_{1:n}, \tau_1, \ldots, \tau_K) = \sum_{i=0}^{K} \sum_{t=\tau_i+1}^{\tau_{i+1}} (y_t - \mu_i)^2$$

The overall residual sum of squares is then:

$$\text{RSS} = \sum_{i=0}^{K} \sum_{t=\tau_i+1}^{\tau_{i+1}} (y_t - \hat{\mu}_i)^2$$

3.8.3 Penalty Term

To avoid overfitting by detecting too many change points, a penalty term is added to the cost function. We consided using the bayesian information criterion which is also known as schwarz criterion. It is based on likelihood function and is given by:

$$\text{BIC} = n \log(\hat{\sigma}^2) + k \log(n)$$

Where:

- n is the number of observations in the dataset.
- $\hat{\sigma}^2$ is the maximum likelihood estimate of the variance of the errors.
- k is the number of parameters in the model.

The penalized cost function combining RSS and BIC penalty is:

$$\text{BIC} = n \log\left(\frac{\text{RSS}}{n}\right) + K \log(n)$$

3.8.4 Detection Method

Binary Segmentation

We begin by initially applying this detection method to the whole data. If no changepoint is detected we stop, otherwise we split the data into two segments (before and after the changepoint), and apply the detection method to each segment. If a changepoint is detected in either, or both, segments, we split these into further segments, and apply the detection method to each new segment. This procedure is repeated until no further changepoints are detected. An advantage of this method is that it is computationlly efficient resulting in This considers a general test statistic $\Lambda(\cdot)$, estimator of changepoint position $\hat{\tau}(\cdot)$, and rejection threshold C. The idea is that the test statistic is a function of data, such as the likelihood ratio statistic, and we detect a changepoint in data $y_{s:t}$ if $\Lambda(y_{s:t}) > C$. If we detect a changepoint, our estimate of its position, such as the maximum likelihood estimate, is $\hat{\tau}(y_{s:t})$. Within the code, $\mathcal{C}$ denotes the set of detected changepoints, and $\mathcal{S}$ denotes a set of segments of the data that need to be tested for a changepoint.

One iteration chooses a segment from $\mathcal{S}$, and performs the test for a changepoint. For a negative result, the segment is removed from $\mathcal{S}$. Otherwise, a changepoint is detected and added to $\mathcal{C}$, and the segment is replaced in $\mathcal{S}$ by two segments defined by splitting the original segment at the changepoint.

The r is just the position of the changepoint in the original dataset, calculated from $\hat{\tau}(y_{s:t})$, the position of the changepoint in the segment $[s, t]$. The algorithm is given by:

- **Input:** A set of data of the form, $(y_1, y_2, \ldots, y_n)$.
- A test statistic $\Lambda(\cdot)$ dependent on the data.
- An estimator of changepoint position $\hat{\tau}(\cdot)$.
- A rejection threshold C.

Initialise:

- Let $\mathcal{C} = \emptyset$, and $\mathcal{S} = \{[1, n]\}$.

Iterate while $\mathcal{S} \neq \emptyset$

(a) Choose an element of $\mathcal{S}$; denote this element as $[s, t]$.

(b) If $\Lambda(y_{s:t}) < C$, remove $[s, t]$ from $\mathcal{S}$.

(c) If $\Lambda(y_{s:t}) \geq C$ then:

i. remove $[s, t]$ from $\mathcal{S}$;

ii. calculate $r = \hat{\tau}(y_{s:t}) + s - 1$, and add r to $\mathcal{C}$;

iii. if $r \neq s$, add $[s, r]$ to $\mathcal{S}$;

iv. if $r \neq t - 1$, add $[r + 1, t]$ to $\mathcal{S}$.

Output the set of change points recorded $\mathcal{C}$.

3.9 Model Evaluation

Common metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and Mean Absolute Percentage Error (MAPE) will be used to assess the model's performance on a testing data set. The average difference between expected and actual attendance values is measured by these indicators. An objective division of the data will be made into training and testing sets. Ninety percent of the data, or the training set, will be used to train the model, and the remaining ten percent, or the testing set, will be used to assess the model's adaptability to new information. To evaluate the model's accuracy in capturing trends and seasonality, the computed error metrics (MAE, RMSE, and MAPE) will be examined. Improved model performance is indicated by lower error levels (Bekkar et al., 2024).

These Metrics are given by:

- Root Mean Squared Error (RMSE):

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(X_t - \hat{X}_t)^2}$$

where n is the number of observations, X_t is the observed value, and $\hat{X}_t$ is the predicted value.

- Mean Absolute Percentage Error (MAPE):

$$\text{MAPE} = \frac{1}{n}\sum\left|\frac{A-F}{A}\right| \times 100$$

  where

  - N is the number of fitted points
  - A is the actual value
  - F is the forecast value

- Mean Absolute Error (MAE):

$$\text{MAE} = \frac{\sum|y_i - x_i|}{n}$$

  where y_i is the predicted value and x_i is the actual value.

3.10 Prophet Model

The Prophet model was used in detecting change point and forecasting our time series data. Prophet is a method for predicting time series data using an additive model. It fits non-linear trends with seasonality on a daily, weekly, and annual basis, together with the effects of holidays. Strong seasonal effects in time series and multiple seasons of historical data are ideal for its effectiveness. Prophet usually handles outliers well and is adaptable to missing data and trend changes. It is designed such that parameters can be adjusted without knowing the details of the underlying model. Prophet also works best with long term predictions and more historical data. Facebook's Core Data Science team released Prophet as open source software. Kaggle. Prophet is an open source software in both R and Python. The Prophet model is a decomposable time series model (Harvey and Peters, 1990) as cited by Taylor and Letham (2017) with three main model components: trend, seasonality, and holidays. It has the equation,

$$y(t) = g(t) + s(t) + h(t) + \epsilon(t)$$

where $y(t)$ is the predicted value of the target variable at time t, $g(t)$ describes a piecewise-linear trend, $s(t)$ describes the various seasonal patterns, $h(t)$ captures the holiday effects, and $\epsilon(t)$ is a white noise error term.

Trend

The time series' overall long-term growth or fall is represented by this component. Prophet models the trend using a piecewise linear function, which takes into account possible changes in the trend's direction over time.

Seasonality

This component identifies reoccurring patterns in the data at particular intervals of time. Prophet has the ability of simulating various forms of seasonality, such as:

• Daily seasonality: Takes into account day-of-week effects (for example, increased attendance on weekdays).

• Weekly seasonality: Describes effects that occur every week of the year (e.g., reduced attendance during holidays).

• Yearly seasonality: Identifies impacts that occur once a year (e.g., seasonal fluctuations in exchange rate)

Holiday

You can include the impact of recognized holidays on the time series by using this component.You can give Prophet a schedule of holidays along with the dates they fall on.

Error Term

This represents the difference between the actual value and the predicted value.

• If not specified explicitly, the knots (or changepoints) for the piecewiselinear trend are selected automatically. Creating an upper bound on the trend can also be achieved using a logistic function.

• The Fourier terms of the corresponding periods form the seasonal component. Order 3 is used for weekly seasonality while Order 10 is used for annual seasonality by default.

• Simple dummy variables are included to account for holiday effects.

• A Bayesian technique is used to estimate the model, which allows the changepoints and other model parameters to be automatically selected.

3.10.1 Model Specification

Prophet employs a Bayesian technique, which means that previous information about the trend and seasonality is incorporated into the model. When compared to ordinary time series models, this may result in more reliable forecasts. The model's specific seasonality types are determined by the properties of your data. You may explore various seasonality choices and assess how they affect the performance of the model. Although holidays are not required, they may be advantageous if you are convinced they have some effect. Exponential smoothing takes the same technique to modeling seasonality as an additive component (Gardner, 1985). A log transform can be used to achieve multiplicative seasonality, in which the seasonal effect is a factor that multiplies g(t). Despite the fact that we opt out some important benefits of employing a generative model such as ARIMA, this approach offers several useful benefits:

• Flexibility: By using various periods, we can easily account for seasonality and allow researchers to make different assumptions about trends.

• Unlike ARIMA models, there is no need for regular spacing or interpolation of missing values after removing outliers. Because fitting happens very quickly, the researcher can interactively examine a wide range of model specifications, as in the Shiny application (Chang et al., 2015).
• The forecasting model features easy-to-understand parameters that may be adjusted by researchers to meet their assumptions. Furthermore, researchers may simply expand the model to add new components because they usually have familiarity with regression. With several techniques developed over the years for particular kinds of time series, automatic forecasting has a long history (Tashman and Leach (1991), De Gooijer and Hyndman(2006)).

3.10.2 The Trend Model

Two trend models have been implemented, that is, a saturating growth model and a piecewise linear model.

Linear Trend with Change Point

An effective approach is offered by a piece-wise constant rate of growth for forecasting issues that do not show saturating expansion. The trend model in this instance is:

$$g(t) = (k + a(t)^T \delta)t + (m + a(t)^T \gamma)$$

where k is the growth rate, δ has the rate adjustments, m is the offset parameter, and γ_j is set to $s_j \delta_j$ to make the function continuous (Bekkar et al., 2024).

3.10.3 Automatic Changepoint Selection

The analyst may choose the changepoint s_j automatically from a list of possibilities, or they may be defined using known dates of product launches and other events that impact growth.(Bekkar et al., 2024)

3.10.4 Holiday Effect

Holidays and events can cause significant and unpredictable fluctuations in business time series, making smooth cycles unsuitable for modeling their effects. For example, Thanksgiving in the United States takes place on the fourth.Thursday, November. The Super Bowl, one of the biggest broadcast events in the US, takes place on a difficult to schedule Sunday in January or February.Many countries around the world celebrate major holidays according to the lunar calendar. Holidays typically have a consistent impact on time series, making it crucial to factor them into forecasting.

Chapter 4

DATA COLLECTION AND ANALYSIS

4.1 Introduction

In this chapter a univariate time series model called Autoregressive Integrated Moving Average Model (ARIMA) was used to forecast the excahnge rate data. Also we used Bayesian Multiple Change point to detect changes and also predict the exchange rate data. The Bank Of Ghana website provided us with data from January 1,2019 to June 30,2024

4.2 Examining the trend of the exchange rate data from January 2019 to June 2024

4.2.1 Graphical Aprroach

From Figure 4.2 below, the time series shows slow upward trend from 2019 to early 2022 and from there a sharp upward trend to late 2022, At the ending of 2022 and early January of 2023, there is a sharp decline of the exchange rate and from there it begins to increase again till 2024. Since there is and increasing and decreasing trend in the exchange rate data, the mean of the data is not constant and therefore our data is not stationary.

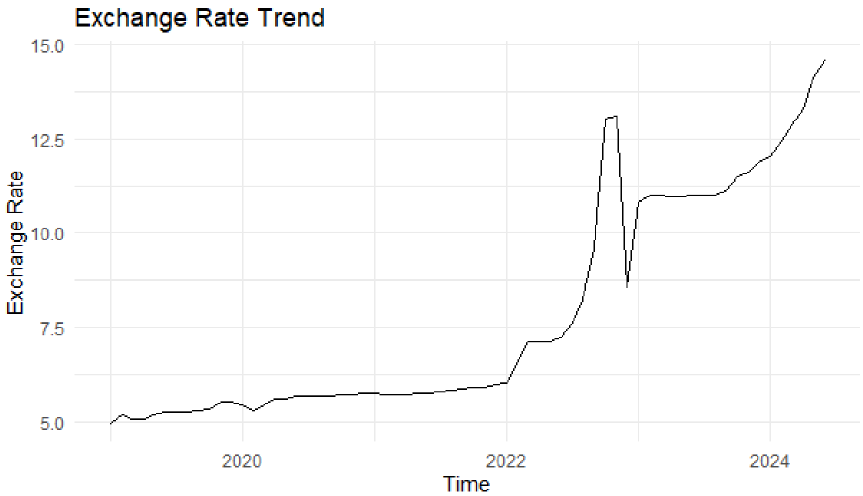

Figure 4.1: Time series plot of the exchange rate data from January 2019 to June 2024

4.2.2 Hypothesis Test

The Man Kendall trend test was used to confirm what the graph above is saying that there is a trend in our exchange rate data. The null hypothesis of the Man Kendall trend test says there is no trend in our data and the alternative hypothesis says there is a trend in our data. From our calculation we had a p_value which is less than 5% and so we have enough evidence to reject the null hypothesis and conclude that there is a trend in our data. Also the value of the S statistics was 2145 which indicate that there are more pairs of observations where the later observation is greater than the earlier one, suggesting an increasing trend in our data.

4.3 The most suitable model for our exchange rate data should be identified

With our data, stationarity was achieved with the first differencing our data for ADF test, PP test,and KPSS test, only one model was generated from the results of the minimum information criterion (AICc,AIC,BIC). The best overall model was ARIMA (2,1,0)

4.3.1 Test for Stationarity

For us to be able to forecast our exchange rate data , we need the best ARIMA model. And for it to be generated, we need to achieve stationarity of the exchange rate data and this is done through differencing. The ADF and PP tests have the same null hypothesis which states that exchange rate data are not stationary and the alternative hypothesis states that it is stationary. On the other hand, the KPSS has a null hypothesis stating that the exchange rate data is stationary and the alternative hypothesis is not stationary. As can be seen in Figure 4.2 above, the increasing trend in the exchange rate data indicates that the series is not stationary and the unit root tests, ADF, PP, and KPSS confirm this observation. From Figure 4.1,the unit root ADF test has a p-value is which 0.8702 which is greater than 5% level of significance and so we reject our null hypothsis and conclude that the series is not stationary. Also, the PP test has a p-value of 0.6257 which is greater than 5% level of significance and so we reject our null hypothesis and conclude that the series is not stationary. Lastly the KPSS test also has a p-value of 0.01 which is less than 5% level of significance and so we fail to reject the null hypothesis and conclude that the series is not stationary.

Test	P-value	Conclusion
ADF	0.8702	The series is not stationary
PP	0.6257	The series is not stationary
KPSS	0.01	The series is not stationary

Table 4.1: Unit root test for the exchange rate data

From 4.2, the exchange rate data is differenced once, the ADF and PP tests had the same p-values of 0.01 which is less than a 5% level of significance and therefore we reject fail to the null hypothesis and conclude that it is stationary. The KPSS also has a p-value of 0.1 which is greater than 5% significance level and so we reject our null hypothesis and conclude that the seies is stationary.

Test	ORDER OF DIFFERENCING	P-value	conclusion
ADF	[01]	0.01	The series is stationary
PP	[01]	0.01	The series is stationary
KPSS	[01]	0.1	The series is stationary

Table 4.2: Unit root of first differencing for the exchange rate data

From our table the exchange rate data was differenced once in order to achieve stationarity for all the unit root tests.

4.3.2 Model Selection

The minimum information criteria in statistical model building refer to the standard practice of fitting several candidate models to a dataset before selecting the "best" model. When modeling with the Arima model, the ADF, and PP tests and KPSS all together suggested a differencing order of "1", information about stationarity. As a result, only one set of competing models are constructed using the differencing order, and the information criteria for each model are calculated. The best model is selected based on the minimum value of the AIC, AICc, . Results are shown in table 4.3 with a differencing order of "1" and with some non-differencing order according to the AICc, AIC which have 155.9718 and 143.9718 respectively indicates ARIMA(2,1,0) as the best model with drift.

Table 4.3: Competing Models and thier Information Criterion

Model	AIC	BIC	AICc
ARIMA(0,0,0)	333.2339	337.6133	321.2339
ARIMA(0,0,1)	265.5784	272.1474	253.5784
ARIMA(0,0,2)	234.3291	243.0877	220.9957
ARIMA(0,1,0)	158.1293	160.3036	inf
ARIMA(0,1,1)	159.688	164.0368	147.688
ARIMA(0,1,2)	156.7165	163.2397	144.7165
ARIMA(1,0,0)	164.5312	171.1002	152.5312
ARIMA(1,0,1)	169.037	177.7956	155.7037
ARIMA(1,1,0)	159.9379	164.2867	147.9379
ARIMA(1,1,1)	160.4527	166.9759	148.4527
ARIMA(1,1,2)	158.1445	166.842	144.8111
ARIMA(2,0,0)	169.1943	177.953	155.861
ARIMA(2,0,1)	169.6247	180.573	154.6247
ARIMA(2,0,2)	167.6498	180.7877	150.8498
ARIMA(2,1,0)	**155.9718**	**162.495**	**143.9718**
ARIMA(2,1,1)	157.7764	166.4739	144.443
ARIMA(2,1,2)	159.7204	170.5923	144.7204

Residual Diagnosis Analysis for ARIMA(2,1,0) with drift

Our selected model, ARIMA(2,1,0) with drift was diagnostically tested to determine whether it is an appropriate model. The test is based on determining whether the residuals do not violate any of the assumptions for the residuals to be an appropriate time series model.

Ljung-Box Test

H_0: The model is appropriate.

H_A: The model is not appropriate.

From Table 4.4, since the p-value is 0.9948 and is greater than the critical value being used for the comparison which is 0.05, it gives us enough evidence to fail to reject the null hypothesis and conclude that the ARIMA(2,1,0) with drift is an appropriate model.

Table 4.4: Ljung-Box Test

Variable	Test statistics	P-value
Residuals of exchnage rate	0.1888111	0.9948

From Figure 4.2, the ACF plot demonstrates that the residuals of the

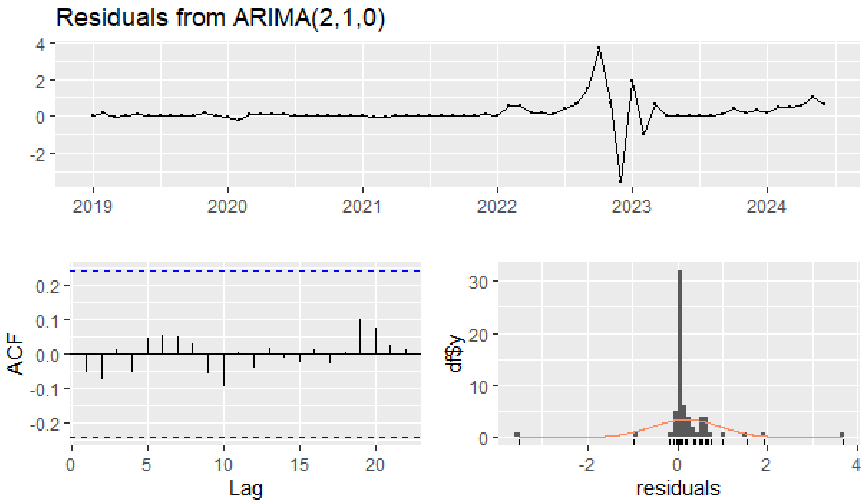

Figure 4.2: Diagnostic check on the residuals of ARIMA(2,1,0)

exchange rate data level do not exhibit any significant lags, which suggests that the errors are not correlated. Therefore it is an appropriate model.

4.3.3 Forecast Accuracy Measures for ARIMA Model

With our data only, only one model was generated so we compute the accuracy measures for this model. The three error metrics were used to calculate their accuracy (MASE, MAE, and MAPE).

ARIMA Model	RMSE	MAE	MAPE
ARIMA(2,1,0) with drift	0.7324099	0.3658338	
ARIMA(2,1,0) with drift	0.7324099	0.3658338	4.266775

Table 4.5: Error metrics for ARIMA Model

4.4 Change Point Model

4.4.1 Change Point Detection

From our analysis, changes were detected at three different positions,thus , 37 , 44 , and 61. These changes suggest that the mean level of the series changes at these points. What this imply is that the statistical property specifically the mean, have shifted at these points. Between these change

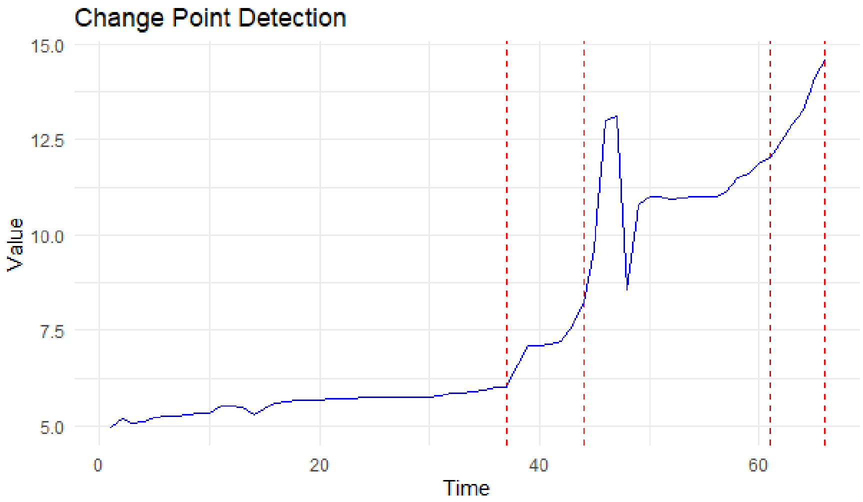

Figure 4.3: Change point detection in the time series data

points, the seies can be divided into segments where the mean is constant but is different from segment to segment. The first segment spans from postion 1 to 37 which represent 1st January 2019 to 1st January,2022 and is characterised by a constant mean from 4.6. This segment represents the first stable period before any significant change in the mean occured. The second segment spans from position 38 to 44 which represent 1st Febraury,2022 to 1st August,2022 which indicates a shift in mean. From 4.6 there is an increase in the mean level in this segment as compared to the first one which is constant.The third segment also starts from position 45 to 61 which represent 1st September,2022 to 1st January,2024 and the last segment starts from position 62 to 66 which represent 1st February 2024 to 1st June 2024 . The change point 61 indicates a final shifts in mean suggesting that the series has entered a new regime with distant mean level.

4.4.2 Parameter Estimation

With our analysis, the paramter we considered is the mean. From the start of our series, thus, before a change point was detected has a mean of GHC 5.57. The mean from the first change point to the second change point is GHC 7.29. The mean from the second change point to the third change point is GHC 11.89. The mean of the series in the fourth segment GHC is 13.47. The penalty value for BIC was 12.56896.

4.4.3 Forecast Accuracy Measures for Change Point Model

With our data, we computed for the accuracy measures of the change point model. Three error of metrics were used to calculate its accuracy (MASE, MAE, and MAPE).

Change Point Model	RMSE	MAE	MAPE
Multiple Mean Change Point	0.846623	, 0.4069087	5.018955

Table 4.6: Error metrics of Change Point Model.

4.4.4 Prophet Model

Using our excahnge rate data, the prophet model was used to estimate rate of our data with a 95% confidence interval, from July 2024 to June 2026 (or the next 24 months).The primary columns in the Prophet model was renamed to ds and y . Predicting the future prices and plotting them on the graph, the Date column was taken as 'ds' and the 'rate' column as y.

4.4.5 Forcasted values from July 2024 to June 2026

Date	yhat(0.1)	yhat(0.2)	yhat(0.05)
2024-07-01	13.955512	13.391066	13.643967
2024-08-01	14.048132	13.291861	13.7927
2024-09-01	14.580818	13.834038	14.311590
2024-10-01	15.943653	15.278887	15.525302
2024-11-01	15.467337	14.805409	15.110675
2024-12-01	14.997675	14.305687	14.681493
2025-01-01	15.697109	14.934162	15.273849
2025-02-01	16.619264	15.576553	16.157780
2025-03-01	16.724553	15.801814	16.336823
2025-04-01	16.632275	15.707445	16.198707
2025-05-01	16.615891	15.508698	16.232037
2025-06-01	16.704772	15.629263	16.311440
2025-07-01	17.247750	16.043111	16.714957
2025-08-01	16.793764	15.542074	16.306772
2025-09-01	17.528794	16.231366	17.008642
2025-10-01	18.627922	17.299699	18.014666
2025-11-01	19.287969	17.900778	18.697824
2025-12-01	17.894932	16.603408	17.318182
2026-01-01	18.518887	16.962881	17.940162
2026-02-01	18.897937	17.287045	18.285187
2026-03-01	19.267208	17.656628	18.665751
2026-04-01	19.426764	17.8337265	18.777862
2026-05-01	19.295361	17.633856	18.670930
2026-06-01	19.492589	17.823743	18.856259

Table 4.7: Forecasted values from July 2024 to June 2026

Visualization of forecasted values

The graph of the predicted values of the exchange rate between the cedi and dollar is displayed in 4.6. The dark blue line represents the predicted value (yhat), the light blue area represents the (yhat_lower) and (yhat_upper), and the black dots represent the real data. The graph displays a distinct upward trend, and the relatively narrow confidence interval demonstrate a high level of confidence in the forecasts, implying that the growth pattern will likely continue with some degree of uncertainty regarding the precise numbers.

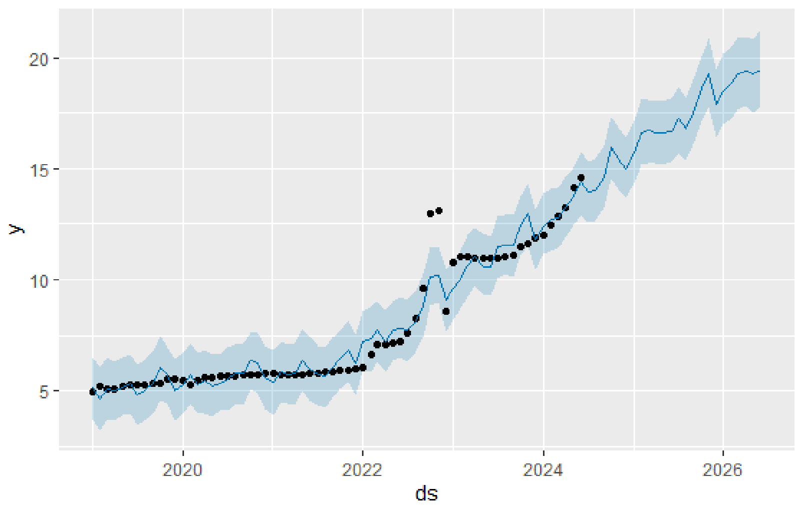

Figure 4.4: Visualization of the forcasted values from July 2024 to June 2026

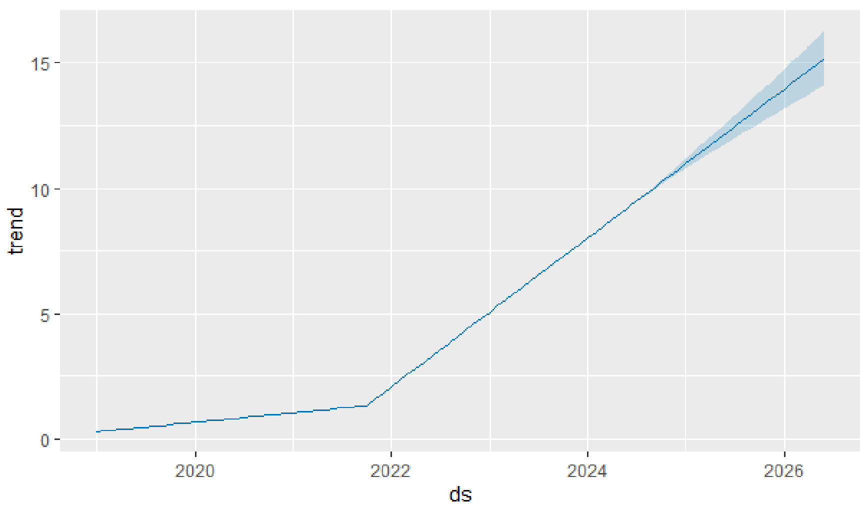

Figure 4.5: Components of the forecasted exchange rate showing trend

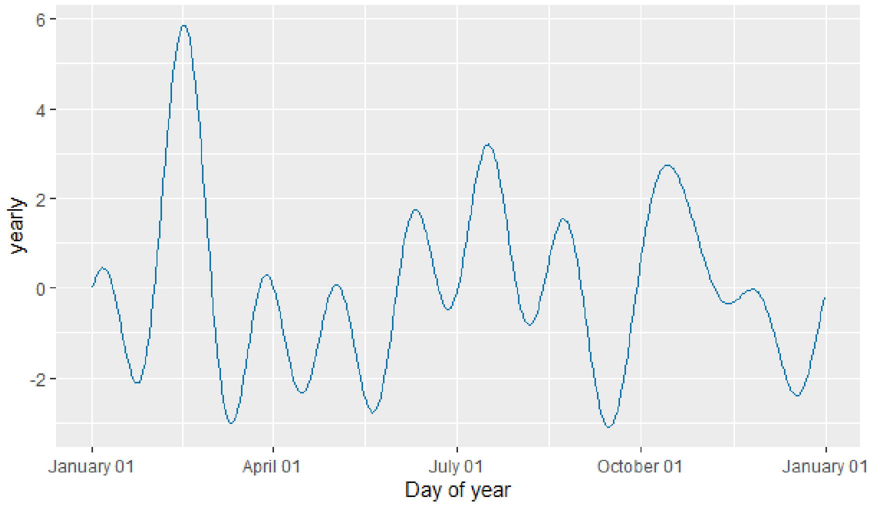

Figure 4.6: Component of forecasted exchange rate showing yearly

4.4.6 Automatic change point detected

The prophet model by default automatically detects twenty five (25) chnages in our exchange rate data.It uses a bayesian approach in detecting these changes making predictions more accurate.

Dates
2019-03-01
2019-05-01
2019-07-01
2019-09-01
2019-11-01
2020-01-01
2020-03-01
2020-05-01
2020-07-01
2020-09-01
2020-11-01
2021-01-01
2021-04-01
2021-06-01
2021-08-01
2021-10-01
2021-12-01
2022-02-01
2022-04-01
2022-06-01
2022-08-01
2022-10-01
2022-12-01
2023-02-01
2023-04-01

Table 4.8: Changepoints Detected

4.4.7 Performance of prophet model

By default, the Prophet model estimates its hyperparameters and uses a Bayesian approach to identify data changepoints. With this strategy, the model can automatically detect significant shifts in the data trend,making prediction more accurate. The changepoint prior scale, which determines the trend's flexibility, is one of the most significant aspects.Increasing the value of this parameter allows you to identify more changepoints; but, if the value is set too high, the trend may become overfit.Underfitting of the trend might occur if the value is set too low. To evaluate its trend flexibility, the prophet model was given three different Changepoint prior scale values (0.05, 0.1, and 0.2). The prophet model's performance was then assessed using a number of goodness-of fit statistics, such as the root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE) for each changepoint prior scale. When the errors of the three changepoint prior scale values were compared, the 0.2 changepoint prior scale performed best since it had the fewest errors compared to the 0.05 and 0.1 changepoint prior scales.

Changepoint Prior Scale	**RMSE**	**MAE**	**MAPE**
0.10	0.7003	0.4533	0.0569
0.05	0.7205	0.4885	0.0623
0.20	0.5927	0.4124	0.0518

Table 4.9: Performance Metrics for Different Changepoint Prior Scales

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The study's last chapter highlights and summarizes the primary findings based on the study's unique objectives. Based on the findings, recommendations are also provided. This chapter has three sections: Section one contains an overview of the investigation, the second section contains the conclusion, and the final section offers a recommendation based on the data analysis.

5.2 Summary

The major goal of this study is to employ change point process to detect shifts in the exchange rate between the Ghanaian cedi and the US dollar using time series.The Bank Of Ghana provied data monthly data from 2019 to June 2024. The R studio was used as the software program. We plotted our exchnage rate data to view the trend of our data and we observed that there was an increasing trend from 2019 and a sharp decrease in late 2022 and from there, our exchange rate data began to increase again. The hypothesis trend test the Mann-Kendall test was used to confirm there was trend in our series. The presence of trend showed that the series was not stationary and so we diferenced our series once and we achieved stationarity was all the test ADF, PP and KPSS confirmed that. After achieving stationarity one ARIMA moded came out to be the best model and it was ARIMA(2,1,0). It was obtained by using the information criteria:

AIC,AICc, and BIC. The metrics of the ARIMA model was computed and we considered:MASE,MAE and MAPE.We moved on to our main work, thus, to detect changes in our exchnage rate data. Three change point was obtained and they were 37,44 and 61, thus, four segment being obtained.The changes obtained signify that economic events, interventions by Bank Of Ghana or changes in monetry policy has caused shifts in the average rate between the cedi and the dollar. Also it could reflects changes in market sentiment or external stocks that influenced the exchange rate between the cedi and dollar over time. We used the mean multiple chnage point to obtain these changes and specified our method to be binary segmentation. Our penalty term was the bayesian information criterion. With this, we went ahead to estimate the parameter(mean) for each of the four segment. The metrics of the multiple mean was also computed using the metrics:MASE,MAE and MAPE. And comparing multiple mean point metrics to the ARIMA model metrics, the ARIMA model came out to be the best cause it had few error of metrics. We forcasted our data using the prophet model which automatically detected twenty five changes in our exchange rate data.The default values for the Seasonality mode, Seasonality, and Holidays were maintained, but the changepoint prior scale value was changed from 0.05 as the default value to 0.1 and 0.2, and the results indicated that the prophet model with 0.2 changepoint prior scale was the best as compared to the 0.05 and 0.1 because the number of goodness-of-fits statistics such as the root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE) for 0.2 changepoint was having the least error.This was done since the changepoint prior scale evaluates the trend's flexibility.This conclusion will help future studies employ the 0.2 changepoint prior scale for forecasting because it fits better than the default value given by the prophet model.

5.3 Conclusion

We examined the exchange rate data between the cedi and the dollar from 2019 to June 2024 in our analysis. We observed an overall trend of the cedi-dollar exchange rate to be increasing,this suggests a depreciation of the cedi against the dollar over the years of study. (January 2019 - December 2020) shows a relatively stable period with an average exchange rate of GHC 5.57,(January 2021 - August 2021) shows a period of moderate depreciation, with an average exchange rate of GHC 7.29, (September 2021 - December 2022) shows a period of more significant depreciation, with an average exchange rate of GHC 11.89,(January 2023 - June 2024) shows the most recent period, characterized by an average exchange rate of GHC 13.466,indicating continued depreciation of the cedi. The study evaluated the performance of different models,showing the best results when using a changepoint prior scale of 0.20.It shows that the cedi will continue to depreciate against the dollar for the next two years.

5.4 Recommendation

The analysis of exchange rate data between the cedi and dollar provides insights for us to inform decision making. Based on the results, the following recommendations are made:

- The government should regularly check and update its economic plans to make sure they are working and make changes as needed.
- The government should foster open communication with citizens and businesses to ensure a clear understanding of economic development.
- The government should encourage private sector investment in key sectors to drive economic growth and stability.

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