MODELING THE INTERDEPENDENCE BETWEEN FOREIGN EXCHANGE AND CONSUMER PRICE INDEX IN MALAWI

MASTER OF SCIENCE (MATHEMATICAL SCIENCES) THESIS

MOSES THOMAS

UNIVERSITY OF MALAWI

JUNE, 2024

MODELING THE INTERDEPENDENCE BETWEEN FOREIGN EXCHANGE AND CONSUMER PRICE INDEX IN MALAWI

Master of Science (Mathematical Sciences) Thesis

By

Moses Thomas

BEd(Science) - University of Malawi

BCom (Accountancy) - University of Malawi

Submitted in partial fulfilment of the requirements for the degree of Master of Science in Mathematics

University of Malawi

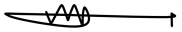
June, 2024

Declaration

I the undersigned hereby declare that this thesis is my own original work which has not been submitted to any other institution for similar purposes. Where other people's work has been used acknowledgements have been made.

Moses Thomas

Full Legal Name



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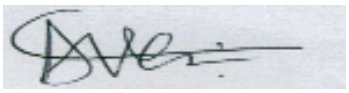
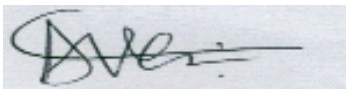
Signature:  Date: 17^{th} July 2024

Dr Nelson Dzupire, Phd (Senior Lecturer)

Main Supervisor

Signature:  Date: 17^{th} July 2024

Ms Ellen Gondwe, MSc (Lecturer)

Co-Supervisor

Dedication

This thesis is dedicated to my family for encouraging me to work extra hard to finish the project. Special gratitude to my loving parents, Mr/Mrs J T Mwamadi who always stand by me in all my academic endeavors.

Acknowledgements

I wish to express my utmost gratitude to God Almighty for blessing me with wisdom, strength, guidance and peace to successfully complete my thesis. I also want to extend overwhelming gratitude to my supervisors, Dr. N dzupire and Ms Ellen Gondwe for their constant guidance, commitment and support throughout the entire process. I could not have attained this milestone without their endless and constructive feedback. I also appreciative my family for the emotional and physical support they provided to me, from the conception to the completion of this thesis.

Abstract

Malawi's unrestrained over-reliance on imports continues to expose the country to vulnerabilities in price variability and foreign exchange rate volatility. Several studies have combined data from many African countries to analyse the relationship between foreign exchange and consumer price index and some studies on the subject fails to take into account the causal relationship between these two fundamental macroeconomic variables. This study goes beyond analysis of the relationship between these variables by producing a model for the interdependence between foreign exchange and consumer price index specifically in Malawi using vector auto regressive model and granger causality test. The study used time series monthly data from 2012 to 2022 to estimate the VAR model. VAR model employed shows that there is a direct relationship between foreign exchange and consumer price index in Malawi. The results shows that about 79% change in consumer price index is in response to change in foreign exchange rate. On the other hand, about 72% change in foreign exchange rate in Malawi is caused by changes in consumer price index. This interdependence is also reflected in granger causality test results which reveals that consumer price index and foreign exchange granger-cause each other. Based on this correlation, a model is developed linking foreign exchange and consumer price index in Malawi. The study recommends to policy makers to cushion the effect of inflation on the economy that arises from the exchange rate movement as it explores measures to reduce importation of domestically substitutable goods in the economy.

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Abbreviations and Acronyms

AR	Autoregressive
VAR	Vector Autoregressive
CPI	Consumer Price Index
FX	Foreign Exchange
PPP	Purchasing Power Parity
IRP	Interest Rate Parity
USD	United States Dollar
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
DCC	Dynamic Conditional Correlation
BEKK	Baba-Engle-Kraft-Kroner
AIC	Akaike Information Creterion
SIC	Schwarz Information Criterion
HQIC	Hannan-Quinn Information Criterion
BIC	Bayesian Information Criterion
SBC	Schwarz Bayesian Criteria
FPE	Final Prediction Error
ARIMA	Autoregressive Integrated Moving Average
IRF	Impulse Response Function
CEIC	Census and Economic Information Center
ACF	Autocorrelation Function
PACF	Partial Autocorrelation Function
ADF	Augmented Dickey-Fuller
RSS	Residual Sum of Squares
IPI	Import Price Index
EPI	Export Price Index
PPI	Producer Price Index
GDP	Gross Domestic Product

Chapter 1

Introduction

1.1 Background

Consumer price index plays a crucial role in defining the overall health of an economy. The consumer price index measures the weighted average prices of several consumer goods and services taking into account changes of prices of each item. Typically, prices may rise over time called inflation but prices of goods and services may also fall over time which is called deflation. The consumer price index is therefore a well known indicator of inflation in a particular country. Literature asserts that the consumer price index is an economic indicator as it has a direct impact on the state of economy through adjustments in interest rates, financial instruments and foreign exchange (Abdurehman & Hacilar, 2016). The adverse movement in consumer price index has far reaching consequences on the well-being of the citizenry.

Exchange rate on the other hand is the value of a country's currency in relation of another country's currency (Mankiw, 2011). Exchange rate can be broken down into two namely: nominal and real exchange rate. Nominal exchange rate is the relative price of two currencies; that is, the price of a foreign exchange expressed in terms of a home or domestic currency (Feenstra, 2014). For Instance, if the nominal exchange rate between the dollar and the Kwacha is K1,200, then one dollar would purchase K1,200. The real exchange rate, however, looks at the price of foreign goods relative to the price of domestic goods.

For a home country, a high normal rate may give the impression that their currency is able to afford several foreign goods. Nonetheless, it is the real exchange rate that determines the purchasing power of the currency. This proves that besides prices of domestic goods, imports and exports prices are also key drivers of growth and development.

The Malawian economy has in many years been plagued by a severe foreign exchange crisis, fueled in part by a steadily rising import bill, sharp successive declines in tobacco export prices, the suspension of direct government budget support from several development partners in 2011, and the dwindling investments by the international investors (Mæhle et al., 2013). Up until the regime change in April 2012, the government resisted calls for a devaluation, arguing that devaluation would lead to inflation and thus harm poor Malawians. The government then offered no alternative solution to the foreign exchange crisis and continued to borrow from abroad to cover the balance-of-payments shortfall and pay for essential imports(Pauw et al., 2013). Contrary to the fears of inducing inflation most commentators sounded an alarm that if the fundamental macroeconomic imbalances (that is, the trade deficit in particular) were not addressed, the governments vision of a vibrant economy was simply not achievable. The change in government in 2012 led to an instant devaluation of 50 percent and subsequent conversion to a floating exchange rate for the Malawian currency, known as the kwacha (Pauw et al., 2013).

Most central banks, especially in developing countries like Malawi, use foreign exchange market intervention as a policy tool for macroeconomic stabilization.

Thus, exchange rate-consumer price index relationship is vital, especially in emerging economies as the two variables constitutes two important elements of measuring macroeconomic performance of a country (Goldberg & Knetter, 1996).

The impact of exchange rate to domestic prices has been investigated using a wide range of domestic indexes from IPI to CPI, PPI and even EPI using both disaggregated and aggregated data levels. Various studies have employed a single equation and a cointegration method to investigate the degree of impact of exchange rate to domestic prices (Dinh et al., 2019). However, this approach does not take into account the casual relationship between inflation and exchange rates (Momo et al., 2021). Recently, researchers and practitioners have become interested in using multiple equation approaches, such as the vector autoregressive model. This new approach has many benefits, such as enabling a dynamic feedback between inflation and exchange rates, testing the simultaneous impact of monetary policy shocks and exchange rate fluctuations on price levels in an integrated model, and enabling the tracking of pass-through to domestic prices in the ordering of a chain of distribution (Sasaki et al., 2022).

The purpose of the study is to develop a model for the interdependence of foreign exchange rate and consumer price index that takes into account the causality effect of the two variables. Findings from this paper are expected to provide policy makers with an appropriate framework for formulating and implementing policies for the economy.

1.2 Problem Statement

Fluctuations in exchange rates directly influence the cost of imported goods and services, while changes in consumer prices reflect shifts in purchasing power and inflationary pressures within an economy. However, the complex interplay between these two variables remains inadequately understood, posing significant challenges for decision-makers seeking to navigate volatile currency markets and manage inflationary risks effectively.

The weakening of exchange rate raises the price of imported inputs, which are usually pushed on to the final consumers through increased prices of outputs. However, impact of fluctuating foreign exchange on the price of outputs differs from country to country. According to Agarwal (2022), Malawi is a net importer of goods and services. Munthali et al. (2021) found out that the total value of food imports in Malawi more than doubled between 1998 and 2018 reaching about MK70 billion (USD94 million).

A country with high dependency of imported goods for its economy may be hit hard by the weakening of its foreign currency unlike the one with minimal dependence (Krugman & Taylor, 1978). Studies like those of Loungani and Swagel (2001) combines data from many African countries to analyse the relationship between foreign exchange and consumer price index. This combined approach fails to take into account the different economic environment of each country like Malawi which may have different susceptibility to domestic prices variation due to changes in foreign currency because of its dependency on imports.

Furthermore, studies by Vo (2019), Usman and Musa (2018), Nortey et al. (2015) and Barhoumi (2006) on the analysis of the relationship between foreign exchange and consumer price index does not take into account the casual relationship between foreign exchange rate and consumer price index.

This study is therefore aimed at addressing this gap by developing a model depicting the interdependence between foreign exchange and consumer price index, specifically in Malawi.

1.3 Research Objectives

1.3.1 Main Objective

The main study objective is to model the interdependence between foreign exchange and consumer price index in Malawi.

1.3.2 Specific Objectives

The following are the specific objectives of this study:

1. Investigate the direction of causality between foreign exchange and consumer price index .

2. Develop a model for the interdependence between foreign exchange and consumer price index.

3. Analyze how temporary or persistent shocks in FX impact the CPI and vice versa.

1.4 Significance of the Study

Policy-making: By understanding the interdependence between foreign exchange and the consumer price index, policymakers can make more informed decisions regarding economic policies. This knowledge allows them to predict and address the impact of changes in one variable on the other, leading to more precise policy measures. For instance, one typical objective of monetary policy for central banks is to target inflation rates. Central banks can benefit from knowing how changes in exchange rates affect domestic consumer price index in order to successfully adjust interest rates or use other monetary policy tools to achieve their inflation targets.

Economic stability: The ability to predict changes in FX and CPI enables governments to devise strategies to maintain economic stability. With a clearer understanding of how these variables interact, policymakers can implement measures to mitigate potential risks and fluctuations in currency exchange rates and inflation. Exchange rate fluctuations can affect investment decisions, purchasing habits, and overall economic activity by causing uncertainty for both consumers and businesses. In order to reassure stakeholders and foster stability in the business environment, policymakers can communicate more effectively with them if they have a comprehensive grasp of how exchange rates affect consumer price index and vice versa.

Individual financial planning: Knowledge of expected price levels derived from the interdependence between FX and CPI empowers individuals to make better financial decisions. Understanding how exchange rate and consumer price index affect each other helps individuals budget and save more effectively.

For example, if a currency depreciates, causing imported goods to become more expensive (leading to inflation), individuals may need to allocate more of their budget to cover higher costs or adjust their savings goals accordingly.

Academic contribution: This study adds to the existing literature on the relationship between FX and CPI in the context of Malawi. By providing additional insights and analysis, it contributes to the academic understanding of these economic variables and their relationship, potentially informing future research and policy discussions.

Overall, this study's significance lies in its potential to enhance policy formulation, foster economic stability, empower individuals in financial decision-making, and contribute to the body of knowledge surrounding the relationship between FX and CPI.

1.5 Scope of the Study

The country under study is Malawi found in southern africa. It is an agro-based economy as it derives 60%-70% of its foreign exchange from Tobacco (Kachulu et al., 2018). This study aims to develop a model for the interdependence between the foreign exchange rate and the consumer price index in Malawi. The scope encompasses a comprehensive analysis of the dynamics between these two variables, considering both with much emphasis in the short-term fluctuations. The study utilized historical data on foreign exchange rates and CPI in Malawi, examining trends, patterns, and correlations over a specified time period.

Various statistical and econometric techniques were employed to analyze the data, including time series analysis, Granger causality tests and auto-regressive modeling.

The sample size of 11-year data for each variable was the limitation of this study. According to the Central Limit Theorem, the larger the sample size, the more representative the sample is of the population. Hence a small sample size makes it difficult to make statistical inference. Unfortunately, the variables in question only had limited data available for the country under study.

1.6 Structure of the Thesis

The subsequent sections of the thesis are structured as follows: Chapter two provides a comprehensive review of the relevant literature, Chapter three presents the methodology employed in the study, Chapter four presents the results and discussions, and finally, Chapter five concludes the thesis.

Chapter 2

Literature Review

2.1 Overview

In this chapter, literature pertinent to the study is reviewed. The first part of the chapter looks at the theoretical literature establishing the relationship between consumer price index and exchange rate and the second segment is empirical framework that explores this relationship.

2.2 Theoretical Framework

2.2.1 Purchasing Power Parity

The purchasing power parity theory suggests that in the long run, the exchange rates between two currencies should equalize the prices of a basket of goods and services across different countries (Martinez, 2021). According to the theory, changes in exchange rates should reflect the relative changes in the consumer price index of the two countries. If a country's consumer price index rises faster than that of its trading partners, its currency should depreciate to maintain parity in purchasing power (Chen & Hu, 2018). The opposite also hold if the consumer price index is getting lower.

Mathematically, denote S_{ct} as the nominal exchange rate in country c in year t, defined as the domestic currency cost of a US dollar, P_{ct} and P_t^* express the domestic and foreign price levels, proxied by the CPIs.

The relative version of purchasing power parity can be represented as:

$$\triangle logS_{ct} = \triangle logR_{ct} \tag{2.1}$$

Where $\triangle logS_{ct} = logS_{ct} - logS_{c,t-1}$ is the log-change in the exchange rate from the previous to the current year t, and $\triangle logR_{ct} = (logP_{ct} - logP_{c,t-1}) - (logP_t^* - logP_{t-1}^*)$ is the inflation differential. This relationship has been applied in United States and Australia (Vo & Vo, 2023).

Illustratively, if a basket of goods costs USD95 in the United States and an equivalent basket of goods costs K104,500 in the Malawi Kwacha, then according to PPP, the exchange rate between the US dollar and the Malawi Kwacha should be 1,100 (USD1 = K1,100) to maintain purchasing power parity.

The origins of PPP can be traced to the sixteenth century, by the Salamanca school in Spain, however its contemporary usage could be attributed to Gustar Cassel, a Swedish economist who recommended the theory as a way of amending the exchange rate parities in pre-World War I, for countries who were to return to the gold standard system after the fights (Adedoyin et al., 2016). Nevertheless, modifications to the theory was required as countries still experienced different rates of inflation during and after the war. The most practical form of the purchasing power parity; absolute PPP, was then devised based on the law of one price (Edwards, 2019). It stipulates that due to arbitrage, exchange rate would adjust such that the price of baskets of goods of services between two countries would be equal. Hence, the main argument proposed by Cassel was that relative price levels are necessary to determine exchange rate and a change in price level would result in a change in exchange rate consequently.

2.2.2 Interest Rate Parity

Interest rate parity theory establishes a link between interest rates, exchange rates and expected return on investment(Burnside, 2019). According to IRP, there should be a relationship between the interest rate differential between two countries and the forward premium or discount on their currencies. The interest rate differential includes both nominal interest rates and inflation differentials. This can be presented as follows:

$$F_0 = S_0 \times \frac{1 + i_x}{1 + i_y} \tag{2.2}$$

Where:

F_0 =forward rate

S_O = spot rate

i_x = interest rate in country x

i_y = interest rate in country y

The theory of IRP is based on the principle of interest arbitrage. Interest arbitrage involves borrowing money in one currency, converting it into another currency, investing it in the foreign country, and simultaneously entering into a forward exchange contract to convert the investment back into the original currency at a future date (Ubi & Nyiputen, 2020). The objective is to take advantage of interest rate differentials and exchange rate expectations. For instance, if interest rates are high in America as compared to Malawi, then most Malawian will be motivated to borrow in Malawi and covert the borrowings in USD and invest the same in America to benefit from high interest rates. The high interest rates in America stimulates demand for the USD, causing its value to appreciate.

As a result, the exchange rate will adjust in such a way that the interest rate differentials are offset by expected exchange rate changes.

However, it is important to note that the benefits of interest rate parity are foiled by transaction costs, capital controls, and market imperfections (Costa & Marcal, 2019). Additionally, other factors like risk premium, inflation expectations, and economic conditions can influence exchange rates and interest rates, causing deviations from the theoretical IRP relationship. Nevertheless, IRP is a concept widely used in international finance and helps explain the relationship between interest rates and exchange rates in the context of global financial markets.

2.2.3 Monetary versus Structuralist Theories

The argument of the main causes of inflation has been a major debate between monetarists and structuralists. Monetarists believe that the main cause of inflation in an economy is the excess money supply that exceeds output. They contend that, without a corresponding growth in supply of money beyond that of real output, secular inflation cannot persevere. Hence, inflation can only be curbed if growth in money supply is decelerated which would subsequently lead to stable price levels as well as a more balanced economy (Danlami et al., 2020). Thus:

$$\frac{\triangle P}{P} = \frac{\triangle M}{M} - \frac{\triangle Y}{Y} \tag{2.3}$$

Where:

P = price level

M = money supply

Y = output level

On the other hand, the structuralist hold the view that inflation can be attributed to the structural factors within the economy. According to the structural theory, inflation arises from imbalances or distortions in the structure of an economy. These imbalances can be induced by various factors, such as changes in production costs, supply constraints, changes in market power, government regulations, or changes in the composition of demand (Odonye et al., 2014). In their regard, money supply is an effect of inflation and not the cause. They believe that inflation has two main causes which are food supply rigidities and the inconsistency in exports purchasing power (Fischer et al., 2002). Supply of food is inelastic and as such, there is flexibility in prices with regards to changes in demand and resources shifts between these two sectors when needed. More generally, the structural view can be presented as follows:

$$P_t = f(P_c, S_c, M_c, G_r, \triangle D) \tag{2.4}$$

Where:

P_t = price level at time t

P_c = production costs

S_c = supply constraints

M_c = changes in market power

G_r = government regulations

$\triangle D$ =changes in demand

According to Stiglitz et al. (2017) industrialization shift resources from the agricultural sector to the manufacturing sector which result in rigidities in supply in the agricultural sector.

These blockages in the agricultural sector detrimentally affect food production, coupled with inadequacies in purchasing power of exports resulting in low food imports, prices of food would increase respectively, which would in turn affect cost of living and wages. Hence if prices of food or exports react more rapidly than prices in the rest of the economy then the inflation rate will be affected not only by the excess supply of money, but also by the change of relative prices reflecting sectoral excess demand. Barriers in sectors lead to low productivity which subsequently increases prices and then result in an increase in money supply.

Having examined the three theories above, the purchasing power parity is considered an appropriate theoretical framework for the current study. The purchasing power parity is based on the fundamental economic principle that currencies should eventually equalize the price of an identical basket of goods and services between two countries. It is therefore considered the most appropriate theoretical framework for modeling consumer price indices and foreign exchange rates. This theory provides a solid basis for comprehending changes in exchange rates since it supports the notion that the relative values of currencies are established by the relative price levels among nations. PPP establishes a direct connection between price levels (inflation) and exchange rates, which is crucial for forecasting and examining global economic interactions(Nagayasu, 2021).

The purchasing power parity is also necessary to comprehend inflation differences and how they affect exchange rates. PPP theory states that nations with greater rates of inflation will see a decline in the value of their currencies in comparison to those with lower rates of inflation. More precise modeling of the long-term effects of consumer price index on exchange rates is made possible by this relationship(Xu, 2003).

Researchers may forecast future movements and pinpoint times when currencies are overvalued or undervalued by including PPP into exchange rate models. This allows researchers to provide important insights for economic policy, strategy, and investment decisions.

2.3 Empirical Literature Review

Loungani and Swagel (2001) carried out a study to determine the causes of inflation in fifty-three developing countries. The sources of inflation were grouped into fiscal imbalances, balance of payment deficits, exchange rate depreciation, and government budget constraints. Countries under study were also grouped into their respective region to account for dynamics in each subgroup which can enable a deeper analysis. The study used a modified version of Montiels (1989) vector autoregressions model instead of estimating individual VAR for each country hence data from across different countries was combined.

The results from their study showed that in many African and Asian countries, sources of inflation are quite diverse with most dominant being fiscal variables, money growth and exchange rates in high inflation countries. However other instruments like oil and non-oil commodities prices as well as output gap had moderate effects on inflation in these regions (Adu, 2020). In many low to moderate inflation, inertial inflation was more significant, and the recommendation was that countries should focus on structural matters like labour market rigidities and inflation forecasting schemes when building anti-inflationary policies .

It was also discovered that for developing countries with fixed exchange rate regimes, money growth seemed to be the major source of inflation compared to those with floating exchange rate regimes (Loungmani & Swagel, 2001).

Adetiloye (2010) examined the relationship between exchange rate and inflation in Nigeria, using the Johansen co-integration test, vector error correction model and a Correlation coefficient analysis. The dependent variable under study was inflation while exchange rate, money supply and real gross domestic product were the independent variables employed. Their findings from the Johansen co-integration test revealed that in the long run, there is an equilibrium relationship between the dependent and independent variables and the vector error correction model estimated that on average, a 1% increase in exchange rate would lead to a decline in inflation rate by 24.9% in Nigeria. However this result was rendered statistically insignificant (Onyekachi & Onyebuchi, 2016). The partial correlation coefficient analysis also demonstrated a weak negative correlation between the predicted variable and exposure variables. Based on their findings, they highly recommended that policymakers pay attention to the parallel movement of exchange rate and inflation when trying to stabilize price levels and overall, improve macroeconomic performance.

The results above echos findings by Ocran (2007) who modelled inflation rates in Ghana within the time period of 1960 to 2003 using the Johansen co-integration test to determine the long-term relationship between inflation and other macroeconomic variables. Error correction model was used as an aid to explain the relationship. The study findings identified exchange rate, price of foreign goods and terms of trade as the main drivers of inflation in Ghana in the long run.

Nevertheless, the study failed to establish a relationship between money supply and inflation rate in the country in the long run. Per his research however, in the short run the main causes of inflation in Ghana are money growth, inflation inertia, changes in interest rates and exchange rate, with inflation inertia being the dominant determinant.

In their study on evaluation of the relative strength of exchange and monetary expansion in propagating inflation in ten Africa countries, Canetti and Greene (1991) concluded that exchange rate movement explains the inflationary trend in these Africa countries. The two used vector auto regression analysis to separate the influence of money supply growth from exchange rate changes on prevailing and predicted rates of inflation in Africa. The study found out that both exchange rate movements and monetary expansion affect consumer price changes in a number of sub-saharan African countries. Significant causal impact of exchange rates on consumer price index was observed in countries like Sierra Leone, Tanzania, and the Congo. These observations are also echoed by London (1989) who examined money supply and exchange rate, in the inflationary process of twenty three Africa countries. The application of pure monetarist model on supply, expected inflation and real income were significant determinants of inflation for the period between 1974 and 1985. The exchange rate was later included as one of the explanatory variables in pure monetarist model and the result shows that exchange rate movement had remarkable influence on the inflationary process in 1980s.

In 2014, Blessing Mandizha also conducted a study on the relationship between inflation and exchange rate depreciation using data from Zimbabwe during periods of hyperinflation, that is from 2001 to 2005.

The results showed that in the short run, increases in consumer price index was in fact as a result of depreciation in the local currency. The granger causality test proved a statistically significant positive correlation between exchange rate depreciation and average price levels only in the short run. In the long run, there was only a feedback relationship between inflation and exchange rate (Mandizha, 2014). The findings also showed that instruments like interest rate and inflation rates are positively correlated to economic growth, hence an increase or decrease in either variable would correspond to a respective change in growth in the economy.

Chibber and Shafik (1990) modelled inflation in Ghana and found out that inflationary surge was not as a result of official devaluation. This was because at the time of devaluation, prices in Ghana had already reflected the parallel exchange rate which was higher than the official rate of exchange. Emphasis was placed on inflation mostly being a monetary phenomenon although past inflation rates had been as a result of structural deficiencies in the economy (Chhibber & Shafik, 1990). Nonetheless, Dordunoo (1994) stipulated that depreciation of exchange rate in a rapid manner, as well as hikes in prices of imports, were inflationary in nature and hence should not be left out when looking at the factors that influence average price levels in an economy.

Nortey et al. (2015) modelled inflation and exchange rate in Ghana using multivariate GARCH, DCC and BEKK models and found a positive correlation, both conditionally and unconditionally, between inflation and exchange rates, between interest rate and inflation rates, and lastly between exchange rate and interest rates. Their analysis proved that when there is stability in general price levels, interest rates are expected to be stable as well.

Nevertheless, with exchange rate and inflation rate, when price levels are stable, depreciation in the Ghanaian currency is expected, but at a slower rate. Generally, they discovered that a positive performance of the Ghanaian currency would yield positive inflation and interest rates in the long run.

Using annual data, Hendry general to specific modeling method and vector autoregression model, Monfared and Akin (2017) studied the relationship between between exchange rates, money supply and inflation in Iran. The results of the study revealed a direct relationship as an increase in exchange rate and money supply triggers an increase in inflation with contribution of the money supply on inflation being greater than the exchange rate.

Another study by Kamas (1995) on Colombia extended the works of Montiel(1989) and Dornbusch et al. (1990) on the drivers of inflation. The study concluded that exchange rates did not play an important role in explaining the variation in inflation in Colombia and that inflation appeared to be primarily inertial with respect to the foreign exchange rate. Instead, the study found out that inflation is largely a function of demand shocks which skyrocket whenever there is an exponential demand for some products.

The foregoing discussions clearly points to diverse conclusions on the relationship between exchange rate and consumer price index. For some countries, there is no clear relationship between these two macroeconomic variables in either case. Some studies like those of Loungani and Swagel (2001) combines data from many African countries to establish the relationship between foreign exchange and consumer price index. The results may not therefore reflect the macroeconomic dynamics for each country.

Furthermore, the studies examined above are unidirectional and fails to take into account that inflation can also affect the independent variables such as foreign exchange.

2.4 Chapter Summary

This chapter has given the theories that underpin this research. It has also given insights on how previous researchers dealt with the subject of foreign exchange and consumer price index in different countries. These countries have different condition as compared to Malawi and the nature of relationship established in those countries may not apply to Malawian settings. For instance Malawi has been described as a predominately importing nation and using the principles of demand and supply of foreign currency, this may have adverse impacts on consumer price index in Malawi.

Various studies that have been analyzed in this study focused on the unidirectional nature of the relationship between foreign exchange and consumer price index. Specifically, most studies have focused on the impact of fluctuating foreign exchange on the consumer price index in a particular country. Thus, the nature of relationship between these two macroeconomic variables, can be presented $FX \rightarrow CPI$.

Although fluctuating foreign exchange has been found to trigger inflation in many countries, studies in other countries like Colombia found out that changes in inflation is not a function of fluctuating foreign exchange.

The foregoing discussion has shown that studies on the relationship between foreign exchange rate and consumer price index fails to model the causal relationships between these two macroeconomic variables as the techniques used are unidirectional, focusing on the effect of exchanges rate on consumer price index and not vice versa. Furthermore, studying the relationship between foreign exchange rate and consumer price index by combining data from many African countries fails to appreciates the fact that different countries are exposed to different economic environments and the results may not be a true reflection of the prevailing situations in a particular country like Malawi.

Chapter 3

Methodology

3.1 Overview

This section outlines the methods employed during the study of the problem. The methodology encompasses the research design, study population, sampling technique and sample size, data collection and analysis methods.

3.2 Research Design

The approach used in this study is a quantitative research design. The aim of the research is to model the cause-and-effect relationship between foreign exchange rate and consumer price index, and hence usually involves more than one explanatory variables and their relationship to one dependent variable (Oppewal, 2010). Given that the main objectives of this study is to model the interdependence of foreign exchange rate and consumer price index, the most fitting research design to test the hypothesis was a causal research design approach. The study starts by analyzing the trend of foreign exchange rate and and consumer price index in Malawi. This is followed by the application of vector autoregressive models, Granger causality tests,impulse response functions (IRFs) to capture the dynamic interplay and causal effects between forex rates and consumer price index.

3.3 Sampling Technique and Sample Size

The population under study is the foreign exchange rates and consumer price indices. In the period between 2012 and 2022, Malawi experienced drastic movement in the foreign exchange rates. For instance, the reserve bank of Malawi announced a devaluation of the Malawi currency by 33% in 2012 and the country also experienced another currency devaluation in 2022 (Kampanje, 2022). Furthermore, the ongoing war between Ukraine and Rusian which started in 2022 created scarcity of some basic items on the international market and many countries of the world including Malawi lamented over increase in the consumer price index. Considering the period of Malawi currency volatility and price instability as well as data availability, the study used 2012-2022 (11 years) data of foreign exchange rates and consumer price indices.

3.4 Data Collection

The study used secondary data from Census and Economic Information Center (CEIC), an organization comprising a team of expert economists and analysts. The organization works closely with specialized agencies, think tanks, research companies and associations covering newly emerged alternative sources with a global and local perspective to generate the data. It provides the most expansive and accurate data insights into both developed and developing economies around the world including Malawi. This data can be accessed on http://www.ceicdata.com /en/indicator/malawi/exchange-rate-against-usd. The site offers unlimited and unconditional access to data.

3.5 Augmented Dickey-Fuller test

This is a technique for determining data stationarity. Many time series analysis techniques presuppose data stationarity and it is therefore important to ensure that time series must be stable before analysis. For instance, ARIMA and VAR models as time series models for forecasting are based on the assumption that the data is stationary (Chidzalo et al., 2023). The model may not faithfully reflect the underlying patterns in the data if it is non-stationary, and the findings will be erroneous.

The fact that non-stationarity might result in incorrect or misleading results is another justification for the necessity of time series to be stationary before analysis. As an illustration, a non-stationary time series could give the impression that there is a high connection between two variables, but in reality, the correlation is only there because of a trend or a seasonal element in the data (Aunsri, 2019).

The Dickey-Fuller tests whether the dataset has a constant mean and standard deviation or not. Therefore for an auto-regressive model with lag p, we should have, the Augmented Dickey-Fuller test given by:

$$
\begin{aligned}
Y_t &= \beta + \sum_{i=1}^{p} \phi_i Y_{t-i} + \varepsilon_t \\
Y_t - Y_{t-1} &= \beta + \phi_1 Y_{t-1} + \sum_{i=2}^{p} \phi_i Y_{t-i} + \varepsilon_t - Y_{t-1} \\
Y_t - Y_{t-1} &= \beta + (\phi - 1) Y_{t-1} + \sum_{i=2}^{p} \phi_i Y_{t-i} + \varepsilon_t \\
\triangle Y_t &= \beta + \delta Y_{t-1} + \sum_{i=2}^{p} \phi_i Y_{t-i} + \varepsilon_t \\
t_{\hat{\phi}_i} &= \frac{\hat{\phi}_i}{sec\hat{\phi}_i}
\end{aligned} \tag{3.1}
$$

Where:

β = constant term

Y_t = observed time seris value atv time t

ϕ = coefficient of a time trend in regression model

$Y_t - Y_{t-1}$ = difference of two consecutive observations at time t

ε = independent error term

The reason for checking stationarity was the requirement of the Granger causality test, which assumes that the data is stationary.

The ADF test has the following hypotheses:

H_0: $\phi = 0$ meaning the time series contain a unit root

H_0: $\phi < 0$ meaning the time series does not contain a unit root

The test follows an asymmetric t-distribution where most of the values will be negative (Maddala & Kim, 1998). After the t-value is calculated it is compared to the simulated critical values provided by Fuller (1976).

The null hypothesis is rejected for small values which can be seen from the hypotheses where the alternative is that ϕ is less than zero.

The autocorrelation function and partial autocorrelation function plots were utilized to explore stationarity. The ACF measures the correlation between a time series and its lagged values, revealing the relationship between each observation and its preceding ones. Thus:

$$ACF(p) = Corr(y_t, y_{t-p}) \tag{3.2}$$

Similarly, PACF measures this correlation between observations in a time series, after accounting for the contributions of the intermediate observations. In other words, it measures the correlation between a time series and its own lagged values, but after removing the effect of correlations at shorter lags. This is mathematically presented below:

$$PACF(p) = Corr(y_t, y_{t-p}|y_{t-1}, y_{t-2}, y_{t-3}...) \tag{3.3}$$

If the PACF or ACF values exhibit a rapid decline or exponential decay to zero after a few lags, it indicates that the time series is stationary. Conversely, if the ACF displays a sinusoidal or wave-like pattern or if the values fail to diminish, it suggests non-stationarity. Furthermore, if the PACF values decay slowly or persistently differ from zero over numerous lags, it indicates non-stationarity.

3.6 Techniques for Determining Lag Length

Running the vector auto-regressive model requires one to find the optimal lag length which is the minimum number of earlier time periods that are incorporated

into a model in order to forecast or interpret the series' current value. It is essential for models like moving average and autoregressive, in which the current value is regressed on previous values or previous error terms respectively. The selection of lag lengths in auto-regressive models can sometimes be guided by economic theory. However, there are statistical methods that are helpful to determine how many lags should be included as regressors. In general, too many lags inflate the standard errors of coefficient estimates and thus imply an increase in the forecast error while omitting lags that should be included in the model may result in an estimation bias. The following are some of the techniques used in lag selection:

3.6.1 Akaike Information Criterion

Akaike Information Criterion (AIC) is a widely used statistical criterion for model selection in time series analysis, including determining the appropriate lag length. It provides a measure of the relative quality of competing models, taking into account both the goodness of fit and the complexity of the model. This is mathematically presented as follows:

$$\begin{aligned} AIC &= -2 \times \frac{l}{n} + 2 \times \frac{k}{n} \\ &= 2(-\frac{l}{n} + \frac{k}{n}) \\ &= 2(-\frac{k-l}{n}) \end{aligned} \tag{3.4}$$

Where,

n is the number of observations

k is the number of model parameters

l is the likelihood function computed by the equation:

$$l = -\frac{n}{\pi}(2 \times \pi) + \ln\left(\frac{1}{n} \times \sum_{i=1}^{n}(y_i - \mu)^2\right) \tag{3.5}$$

Where y_i is the observed value.

3.6.2 Schwarz Information Criterion

The Schwarz Information Criterion (SIC), also known as the Bayesian Information Criterion (BIC), is another statistical criterion commonly used for determining the lag length in time series data. It is similar to the AIC but includes a penalty term for model complexity, which is particularly useful when dealing with small sample sizes. In general, this is given as:

$$SIC = -2 \times \frac{l}{n} + \frac{k \times \ln(n)}{n} \tag{3.6}$$

3.6.3 Hannan-Quinn Information Criterion

The Hannan-Quinn Information Criterion (HQIC) is another statistical criterion used for determining the lag length in time series analysis. Like AIC and SIC/BIC, HQIC provides a measure of model fit while considering the complexity of the model (Deka & Resatoglu, 2019). It is particularly useful when dealing with medium-sized sample sizes. In general, the HQIC is given by:

$$HQIC = -2 \times \frac{l}{n} + 2 \times \frac{k \times \ln(\ln(n))}{n} \tag{3.7}$$

Although there these several techniques for optimal lag selection, the Akaike Information Criterion was employed in this study because it accounts for both model complexity and goodness of fit, rather than focusing solely on the correlation between the time series and its lagged values. Furthermore, AIC is simple as it does not require specifying prior distributions or hyper parameters, making it broadly applicable across different models and datasets (Cavanaugh & Neath, 2019).

3.7 Granger Causality Test Algorithm

The Granger causality test is a statistical test used to determine the causal relationship between two time series variables. It helps to determine whether one variable (X) can be used to predict another variable (Y).

In this context, the Granger causality test is used to examine whether one variable (such as the foreign exchange rate) can be used to predict or influence another variable (such as the consumer price index). By analyzing the time series data and applying the Granger causality test, researchers can assess the direction and strength of the causal relationship between these variables.

The test helps in understanding the interdependence and potential causal linkages between variables. If a significant causal relationship is found, it provides evidence that changes in one variable can be used to predict or explain changes in the other variable. This information is valuable for policymakers, economists, and researchers in making informed decisions, formulating appropriate policies, and understanding the dynamics of the studied phenomena.

The formula for the Granger causality test depends on the specific method being used, but the general approach involves estimating two different regression models and comparing their predictive power.

Assume that we have two time series, Y and X, and we want to test whether X Granger-causes Y. The basic steps involved in the test are as follows:

(1) Estimate a univariate autoregressive model of Y using its own lagged values, denoted by $Y_{t-1}, Y_{t-2}, \cdots, Y_{t-p}$, where p is the number of lags included in the model. This model is represented as:

$$Y_t = a + b_1 Y_{t-1} + b_2 Y_{t-2} + \cdots + b_p Y_{t-p} + \varepsilon_1(t) \tag{3.8}$$

where $\varepsilon_1(t)$ is the error term.

(2) Estimate a bivariate autoregressive model of Y and X using their own lagged values, denoted by $Y_{t-1}, Y_{t-2}, \cdots, Y_{t-p}, X_{t-1}, X_{t-2}, \ldots, X_{t-p}$. This model is represented as:

$$Y_t = a + b_1 Y_{t-1} + b_2 Y_{t-2} + \cdots + b_p Y_{t-p} + c_1 X_{t-1} + c_2 X_{t-2} + \cdots + c_p X_{t-p} + \varepsilon_2(t) \tag{3.9}$$

where $\varepsilon_2(t)$ is the error term.

(3) Calculate the F-statistic for the joint significance of the X variables in the bivariate model, compared to the univariate model of Y alone. This test statistic is based on the idea that if X Granger-causes Y, then the inclusion of X in the bivariate model should improve the accuracy of the predictions of Y. The formula for the F-statistic is:

$$F = \frac{(RSS_1 - RSS_2)/p}{RSS_2/(n - 2p - 1)} \tag{3.10}$$

Where RSS_1 is the residual sum of squares from the univariate model of Y, RSS_2 is the residual sum of squares from the bivariate model of Y and X, p is the number of lags included in the models, and n is the sample size.

(4) Compare the calculated F-statistic to a critical value from the F-distribution with p degrees of freedom in the numerator and $(n-2p-1)$ degrees of freedom in the denominator, at a chosen level of significance (usually 5% or 1%). If the calculated F-statistic is larger than the critical value, then we reject the null hypothesis that X has no Granger causality on Y, and conclude that X Granger-causes Y (Inoue & Kilian, 2013).

Note that there are several variations of the Granger causality test, including the vector autoregression (VAR) model and the modified Wald test. The formulas and procedures for these methods may differ slightly from the basic approach described above (Götz et al., 2016).

3.8 Vector Autoregressive Model

Vector autoregressive model is a statistical time series model used to analyse the dynamic relationship among variables. The model is an extension of the autoregressive model, which only considers the relationship between a single variable and its lagged values. Estimating a VAR model involves determining the lag order (p) and estimating the coefficient matrices using techniques like least squares or maximum likelihood.

Once estimated, the VAR model can be used for various purposes, such as forecasting future values of the variable, analyzing impulse response functions to understand the dynamics effects of shocks, and conducting variance decomposition to measure the contribution of each variable to the forecast error variance.

In this study, we are using VAR model to analyze the the dynamic relationship between consumer price index and foreign exchange. Vector autoregressive model works on the assumption that variable X cause variable Y. The vector autoregressive model offers significant advantages for analyzing time series data, primarily due to its ability to handle multiple interrelated time series simultaneously. In contrast to univariate models such as ARIMA, which analyze each time series independently, VAR models capture the dynamic interdependencies between multiple variables. By including past values of all variables in the system, VAR models provide a comprehensive framework to understand and forecast the behavior of each variable in the context of its interactions with others. This multivariate approach not only improves forecasting accuracy but also allows for a deeper understanding of the underlying relationships and mechanisms driving the observed data. Again unlike AR model, each variable in a system depends on its own lagged values and the lagged values of all other variables and the system can be represented as a vector (Solari & Gelder, 2011). Besides capturing simultaneous interactions and feedback effects among the variables, VAR models can also detect relationships between variables in the equation system (A'yun & Fatwa, 2022). The Mathematical representation of this statement is given in equations (3.11) and (3.12) which were used and validated in a study by Amaral et al. (2022).

$$Y_t = \alpha_1 - \alpha_2 X_t + \lambda_1 X_{t-1} + \lambda_2 Y_{t-1} + \varepsilon_{yt} \tag{3.11}$$

$$X_t = \alpha_3 - \alpha_4 Y_t + \lambda_3 X_{t-1} + \lambda_4 Y_{t-1} + \varepsilon_{xt} \tag{3.12}$$

Where,

Y_t is the consumer price index today

Y_{t-1} is the consumer price index for previous period

X_t is the foreign exchange today

X_{t-1} is the foreign exchange for previous period

ε_{yt} is the standard error term for determining CPI

ε_{xt} is the standard error term for determining FX

α_1 and α_3 are the constants of the model

$\alpha_2, \alpha_4, \lambda_1, \lambda_2, \lambda_3$ and λ_4 are the coefficients or parameters of the model to be estimated.

Rearranging equations 3.11 and 3.12, we get:

$$Y_t + \alpha_2 X_t = \alpha_1 + \lambda_1 X_{t-1} + \lambda_2 Y_{t-1} + \varepsilon_{yt} \tag{3.13}$$

$$\alpha_4 Y_t + X_t = \alpha_3 + \lambda_3 X_{t-1} + \lambda_4 Y_{t-1} + \varepsilon_{xt} \tag{3.14}$$

Equations 3.13 and 3.14 can be transformed into matrices as follows:

$$\begin{pmatrix} 1 & \alpha_2 \\ \alpha_4 & 1 \end{pmatrix} \begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_3 \end{pmatrix} + \begin{pmatrix} \lambda_1 & \lambda_2 \\ \lambda_3 & \lambda_4 \end{pmatrix} \begin{pmatrix} X_{t-1} \\ Y_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{yt} \\ \varepsilon_{xt} \end{pmatrix} \tag{3.15}$$

Using the notations,

$$\beta = \begin{pmatrix} 1 & \alpha_2 \\ \alpha_4 & 1 \end{pmatrix}, \theta_t = \begin{pmatrix} Y_t \\ X_t \end{pmatrix}, \omega = \begin{pmatrix} \alpha_1 \\ \alpha_3 \end{pmatrix}, \gamma = \begin{pmatrix} \lambda_1 & \lambda_2 \\ \lambda_3 & \lambda_4 \end{pmatrix}, \delta = \begin{pmatrix} \varepsilon_{yt} \\ \varepsilon_{xt} \end{pmatrix}$$

Equation 3.6 can be expressed as follows:

$$\beta\theta_t = \omega + \gamma\theta_{t-1} + \delta \tag{3.16}$$

To make θ_t the subject of the formula, we multiply each term of equation 3.7 by the inverse of β to obtain

$$\theta_t = \beta^{-1}\omega + \beta^{-1}\gamma\theta_{t-1} + \beta^{-1}\delta \tag{3.17}$$

If we let,

$$\Omega_1 = \beta^{-1}\omega, \Omega_2 = \beta^{-1}\gamma, \tau = \beta^{-1}\delta$$

Then, equation 3.17 becomes

$$\theta_t = \Omega_1 + \Omega_2\theta_{t-1} + \tau \tag{3.18}$$

3.8.1 Assumptions required in VAR Model

1. **Linear in Model Parameters**

   This assumption holds true that the time series process, which is stochastic in nature, follows a model that is linear in its process such that;

   $$Y_t = \beta_0 + \beta_1 x_{t1} + \beta_2 x_{t2} + ... + \beta_n x_{tn} + \mu_t \tag{3.19}$$

   Where,

   β_j, $j = 0, 1, 2, 3, ..., n$ are the parameters to be estimated

   x_{t1}, x_{t2},....,x_{tn} are the independent variables for time periods $1, 2, ..., n$

   μ_t is the sequence of errors (Wooldridge et al., 2016).

2. **No perfect Collinearity**

   No independent variable in the sample is constant, neither are they a perfect linear combination of others.

This assumption allows for correlation among the independent variable, however it rules out perfect correlation in the sample (Wooldridge et al., 2016).

$$x_1 \neq x_2 \neq x_3 \neq x_4 \neq \ldots \neq x_t \tag{3.20}$$

$$x_1 \neq \lambda_1 x_2 \neq \lambda_2 x_3 \neq \lambda_3 x_4 \neq \ldots \neq \lambda_t x_t \tag{3.21}$$

3. **Zero Conditional Mean**

   The zero conditional mean assumption states that the expected value of the error term (μ_t) for each t given any value of the independent variable(s) (X) is zero. Thus;

$$E(\mu_t|X) = 0, t = 1, 2, 3, \ldots, n \tag{3.22}$$

4. **Homoskedasticity**

   This assumption states that the variance of the error term in a regression model is constant across all levels of the independent variables. In other words, the variability of the dependent variable around the regression line is the same for all values of the predictors. Mathematically, this is represented as follows:

$$Var(\mu_t|X) = Var(\mu_t) = \sigma^2, t = 1, 2, 3, \ldots, n \tag{3.23}$$

5. **No Serial correlation**

   Conditional on X, the disturbances or errors in two separate time periods are not correlated (Wooldridge et al., 2016), such that,

$$Corr(\mu_t, \mu_s) = 0, \forall t \neq s \tag{3.24}$$

3.9 Impulse Response Function

Impulse response analysis is one of the important steps in econometric analysis, which employs vector auto regressive models. The main purpose is to describe the evolution of a model's variables in reaction to a unit impulse shock in one or more variables. This feature allows to trace the transmission of a single shock within an otherwise noisy system of equation and, thus makes them very useful tools in the assessment of economic policies. This research provides insights on the response of consumer price index in response to change in foreign exchange.

The impulse response function can be derived using the mathematical framework of linear-invariant systems. Assume we have a time series variable y_t and a shock or impulse X_t at time $t = 0$. The Impulse function at lag $h(h \geq 0)$ is denoted as IRF_h and represents the effect of the shock on y_t after h period. The impulse response function is given as:

$$IRF_h = \sum_{t=0}^{\infty} \phi_{h,t}.x_{t-h} \tag{3.25}$$

Where $\phi_{h,t}$ represents the coefficient of auto regressive representation of the time series variable x_t.

Hence the formula states that the impulse response at lag h is the sum of the product of the shock x_{t-h} and the corresponding coefficient $\phi_{h,t}$ over the time period t starting from t =0 to infinity (Jamil, 2022).

3.10 Ethical Consideration

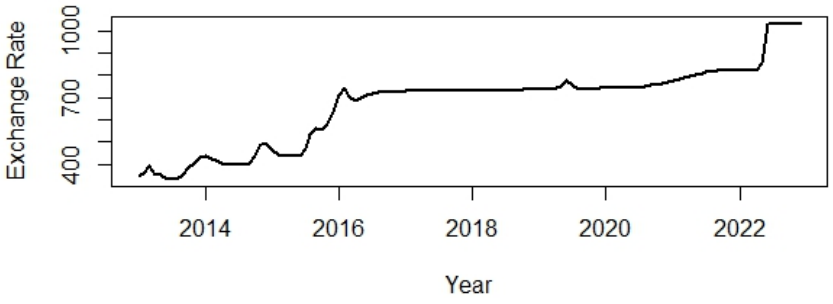
One of the fundamental principle guiding a credible research is the need to maintain integrity throughout the research process (Zhaksylyk et al., 2023). Several ethical considerations were taken into account to ensure that the study was conducted in an appropriate manner. The researcher maintained accuracy and honesty in data representation, with transparent documentation of sources and methodology. Consideration of the societal and economic implications of findings is vital to avoid potential harm, ensuring that policy recommendations are based on unbiased analysis. For this reason, findings from this study were strictly from the analysis made and as such interpretations, conclusions and recommendations were also based on these results, regardless of the opinions of the researcher.

Chapter 4

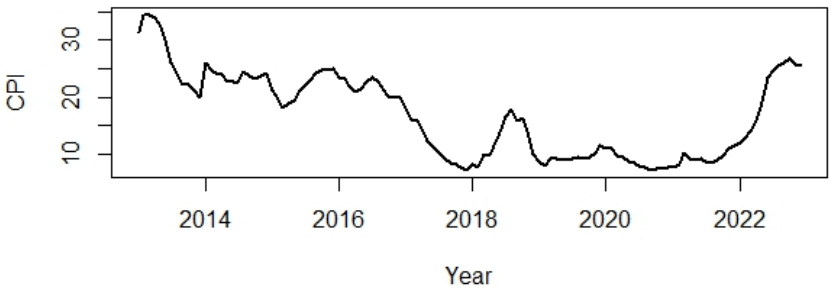
Results and Discussion

4.1 Trend of Consumer Price Index and Foreign Exchange

In this section, we start by presenting graphs showing trend of the movement of foreign exchange rate and consumer price index in an uni-variate fashion.



(a) Trend of exchange rate



(b) Trend of consumer price index

Figure 1: Trend of exchange rate and consumer price index

Figure 1a shows plot of foreign exchange from 2012-2022. From the graph, exchange rate has been increasing since 2012. However, it remained relatively stable in the early parts of 2017 and 2020, possibly due to stability in the USD during that period. There was an upward jump in the exchange rate in 2021 and 2022, potentially influenced by the economic recession following the war in Ukraine.

Figure 1b shows that the consumer price index has been declining from 2012 to 2015. This decrease is due to stability in the exchange rate as depicted in Figure 1a. This aligns with studies on purchasing power parity, as conducted by Usman and Musa (2018) and Chen and Hu (2018), which indicate that countries with high balance of payments and lower exports are likely to witness a lowered CPI when exchange rates stabilize. After this decline, the CPI slightly increased between 2015 and 2016, dropping again in 2017 and 2018. It remained relatively stable between 2019 and 2020 and thereafter increased exponentially during 2022 in response to an adverse movement in exchange rate in 2021 and 2022 as shown in Figure 1a .

Considering the shapes of the graphs in Figures 1a and 1b, the overall trend in the foreign exchange and consumer price index in Malawi has been increasing. The insatiable appetite for imports in Malawians is likely to make this trend continue (Bank, 2020).

Clearly, Figures 1a and 1b shows that the time series data of foreign exchange and consumer price index is not stationary and this must be corrected before any statistical and econometric analysis to avoid spurious output and, therefore, misleading interpretation.

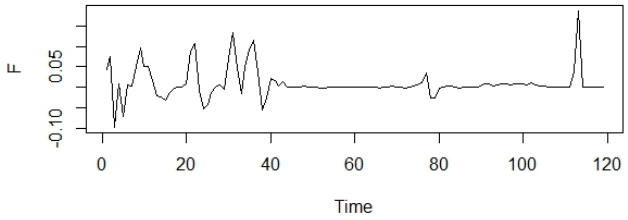
The model being employed in this study requires data to be stationary.

The solution to transform non-stationary data to stationary is to take the log of the variables to normalize them and then apply a lagged differencing methodology as follows:

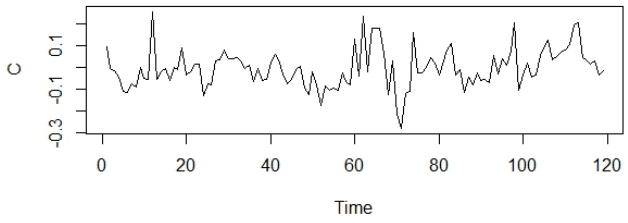
$$\ln Y = \ln Y_t - \ln Y_{t-n} \tag{4.1}$$

$$\ln X = \ln X_t - \ln X_{t-n} \tag{4.2}$$

Data was therefore transformed using equations 4.1 and (4.2) and then tested for stationarity using Augmented Dicky-Fuller Test.



(a) Trend in foreign exchange movement



(b) Trend in consumer price index

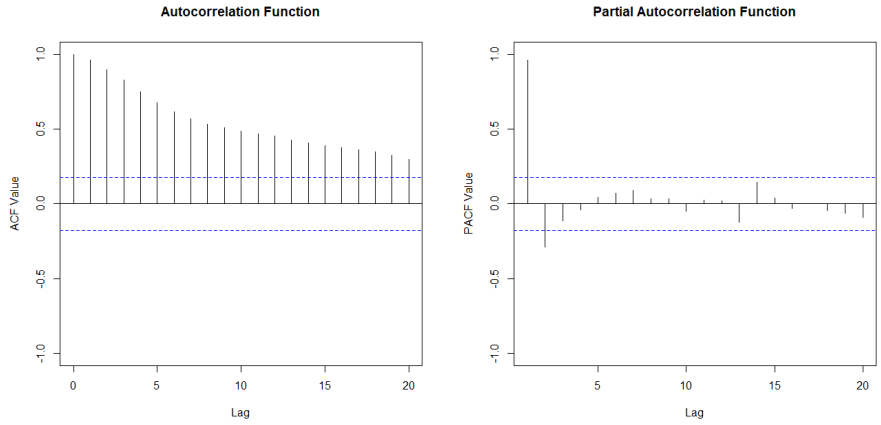
Figure 2: Plot of transformed data

Where $F = \log(FX)$ and $C = \log(CPI)$.

After transforming the data using equations 4.1 and 4.1, the plot of the transformed data in Figures 2a and 2b displays signs of data stationarity as major slumps depicted in Figures 1a and 1b have been corrected. This means that the mean, variance and autocorrelation structures of the time series are constant over time. Stability of the data permit time series analysis so that meaningful relationships of the times series data can be extracted (Granger & Hatanaka, 2015).

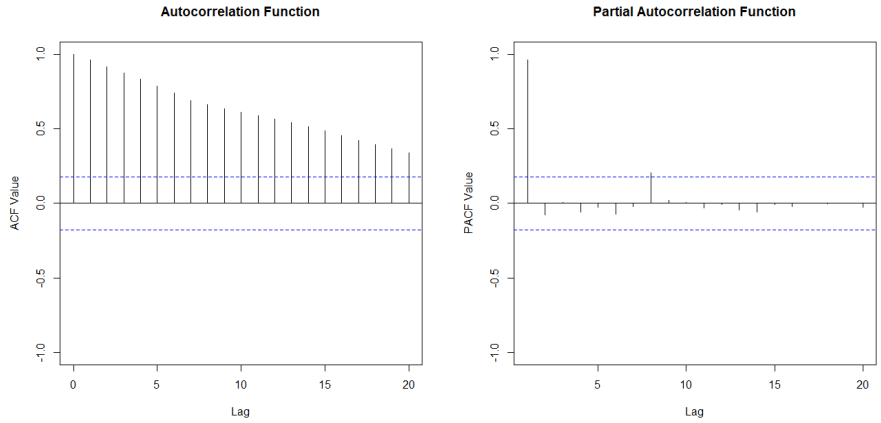
4.2 Augmented Dickey-Fuller test Results

The results of the auto-correlation function in CPI show a delay in the decay of values to zero (Figure 3a), despite the fact that the partial auto-correlation function shows an immediate drop after the second lag (Figure 3b). The failure of the auto-correlation function to decay and the incomplete decay of the partial auto-correlation function after the second lag suggest that the CPI is not stationary. Similar results were obtained for forex data (Figure 4a, 4b).



(a) ACF for CPI (b) PACF for CPI

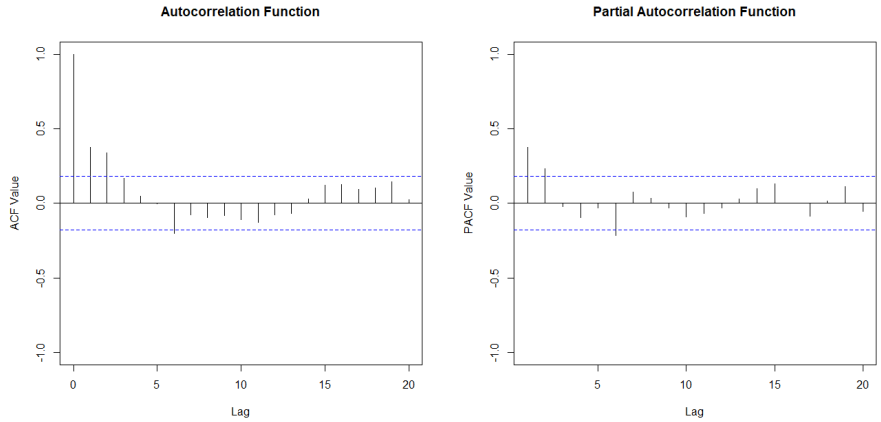
Figure 3: Exploring sationarity in CPI



(a) ACF for forex (b) PACF for Forex

Figure 4: Exploring sationarity in forex

Applying the transformation using equations 4.1 and 4.2 to the data led to an improved pattern in both the auto-correlation and partial auto-correlation functions. For instance, the auto-correlation and partial auto-correlation functions for the transformed CPI showed a rapid drop to insignificant values (Figure 5a, 5b). This suggests that the transformed data is stationary.



(a) ACF for transformed CPI (b) PACF for transformed PCI

Figure 5: Exploring sationarity in transformed CPI

To investigate it from the data, we applied the Augmented Dickey-Fuller test to both the transformed and raw data.

The results show that the raw data was not stationary. In each case, the magnitude of the Dickey-Fuller statistic was smaller than the lag order of 4 (Table 1), and the p-value was significantly greater than 0.05. However, the transformed data was found to be stationary, as the p-value was less than 0.01 and the magnitude of the Dickey-Fuller statistic was much larger than the lag order of 4 (Table 1).

Table 1: Augmented Dickey-Fuller test, lag order=4

Data	**Statistic**	**De-trended**	**p-values**	**Decision**
CPI	-1.2276	no	$p = 0.8974$	Not stationary
Forex	-1.8629	no	$p = 0.6333$	Not stationary
CPI	-4.3549	yes	$p < 0.01$	stationary
Forex	-5.1202	yes	$p < 0.01$	stationary

This results are consistent with the with shape of the graphs as shown in Figure 2.

4.3 Finding the Optimal Lag length

The lag selection criteria options are Akaike Information Criterion, Schwarz Information Criterion, Human-Quinn Information Criterion and Final Prediction Error. According to Table 2 below, the optimum lag length is two (2), which is the most frequent number among the selection criteria. Ivanov and Kilian (2005) showed that AIC produces the most accurate impulse response for realistic sample sizes.

Table 2: Lag information criterion

Akaike Information Criterion (AIC)	**Hannan Quinn (HQ)**	**Schwarz Information Criterion (SC)**	**Final Prediction Error (FPE)**
2	2	1	2

Results from Table 2 shows that the historical values of all variables are important in estimating the relationship between foreign exchange exchange and consumer price index using VAR model. Specifically, a lag length of two as determined by the AIC in the time series analysis indicates that the best model for the data incorporates the preceding two observations as predictors. With a lag length of two, the best balance is achieved by including values at times $t-1$ and $t-2$, which increases the model's predictive ability. This choice suggest that in order to predict the present value of the time series with any degree of accuracy, data from the two most recent previous observations is essential. Thus, the time series remembers information for up to two periods, after which the impact of observations starts to diminish. Once the lag-length of two has been determined, the VAR model can be built using R-software.

4.4 Granger Causality Test

Variables in the VAR model must be set endogenously and exogenously. Economic relations can be so complex that endogenous and exogenous discrimination of variables may not be possible. This section test for causality between consumer price index and foreign exchange using Granger causality test.

The Variable X is said to Granger cause Y if variable X helps in the prediction of variable Y , or equivalently if the coefficients on the lagged X's are statistically significant (Granger 1969). The causation in two ways is frequently used. Thus X Granger cause Y and Y Granger cause X.

The null hypothesis of the Granger causality test, H_0, is that foreign exchange rate does not Granger cause consumer price index and vice versa.

Running Granger causality test on the VAR model produces the results depicted in Table 3.

Table 3: Granger causality test results

Data	Variable	DF1	DF2	p-value	Null Hypothesis
VAR Model	FX	112	114	0.0135	FX does not Granger cause CPI
VAR Model	CPI	112	114	0.040	CPI does not Granger cause FX

DF= Degrees of Freedom

Results from Table 3 shows that the null hypothesis should be rejected with 95% confidence level. This is justified by the lower than 5% p-values of 0.0135 and 0.040. Therefore the results shows that foreign exchange does Granger cause consumer price index and similarly, consumer price index Granger cause foreign exchange with the same confidence level. Thus, the causality between foreign exchange and consumer price index is bidirectional in Malawi as illustrates in Figure 6.

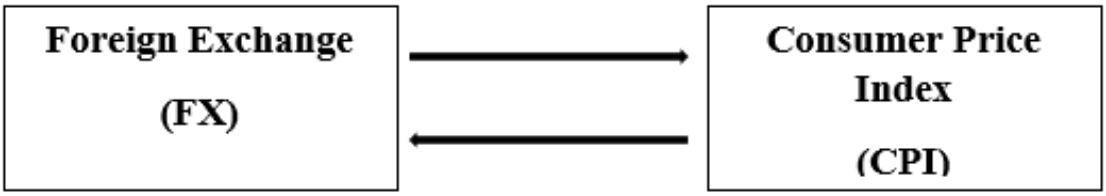


Figure 6: Direction of Causality Between CPI and FX

The Granger causality test shows that foreign exchange has a significant Granger causality effect on the consumer price index, and vice versa. This finding aligns with studies conducted by Jongwanich et al. (2019), which suggest that Granger causality has a high likelihood of being positive when the dependency in the VAR model is established to be significant, as it has been in this study.

This therefore means that today's exchange rates and consumer price index can be explained by the changes of these two macroeconomic variables in the past two months.This is crucial as it enables consumers and business to properly plan for the effects of variations in foreign exchange rate and consumer price index.

4.5 Vector Auto regressive Model Estimations

Having determined the lag length of two, the VAR model can be applied to the dataset transformed from stationary to non stationary.

4.5.1 VAR Estimation of Foreign Exchange

Table 4 shows VAR estimation of foreign currency using consumer price index as endogenous variable. From Table 4, the "Estimate" refers to the estimated value based on the correlated variable and its lag. The "Standard Error" is the standard deviation of the statistical sample, "T value" measures how far each estimated par value deviates from the hypothesis value and "p-value" measures the statistical significance.

Table 4: VAR estimation of foreign exchange

Variable	**Estimates**	**Std error**	**T value**	$Pr(>\|t\|)$	**Sig**
FX 1	1.0960	0.0935	3.9171	0.0015	Yes
CPI 1	0.0912	0.0379	0.5593	0.0371	Yes
FX 2	-0.0902	0.0934	-1.4561	0.1483	No
CPI 2	0.0911	0.0378	0.1902	0.0499	Yes
Constant	0.0783	0.0212	0.7694	0.0362	Yes

Roots of polynomial : 0.6472, 0.3675, 0.3601, 0.3601

Residual Std Error : 1.0381 on 112 degrees of freedom

Multiple R-Squared : 0.7246

Adjusted R-Square : 0.7181

F-Statistics : 4.256 on 4 and 112 DF

p-value : 0.003038

FX1 represents the foreign exchange rate in the previous month. The estimated coefficient of 1.096 indicates that the current rate is a multiple of the previous month's rate. With a p-value of less than 5%, this estimate is significant, which means that the previous month's rate needs to be considered when determining the rate today or in the future. However, for FX2, the estimated value is not significant in determining the current rate. The CPI of the previous month does also play a significant role in determining today's exchange rate. This is also true for the CPI of previous two months with an estimate of 0.0911 though the p-value is close to 5%. The results, therefore, indicate that the foreign exchange rate depends on the rate from one month ago and the CPI from the previous two months.

The adjusted R-Square is 72% meaning that the variations in foreign exchange can be attributed to the past values of consumer price index and its own past values at lag 1. This implies that the other 28% variations in foreign exchange can be explained by changes in other variables such as gross domestic growth and interest rates among others (Kilicarslan, 2018).

4.5.2 VAR Estimation of Consumer Price Index

Table 5 shows VAR estimation for consumer price index on endogenous variables of foreign exchange and consumer price index.

Table 5: VAR estimation of consumer price index

Variable	**Estimates**	**Std error**	**T value**	$Pr(>\|t\|)$	**Sig**
FX 1	4.4713	0.2276	3.0481	0.0017	Yes
CPI 1	0.4690	0.0923	3.1007	0.0424	Yes
FX 2	2.8462	0.2273	3.0832	0.0681	No
CPI 2	0.2397	0.0919	2.6093	0.0833	No
Constant	0.3864	4.0627	2.3560	0.0202	Yes

Endogenous variables : FX and CPI

Roots of polynomial : 0.6472, 0.3675, 0.3601, 0.3601

Residual Std Error : 1.298 on 112 degrees of freedom

Multiple R-Squared : 0.7971

Adjusted R-Square : 0.7923

F-Statistics : 25.56 on 4 and 112 DF

p-value : 3.77e-05

From Table 5, VAR estimation of CPI shows a relationship between the consumer price index of today and the past values of foreign exchange at lag 1, equivalent to one month. The p-values at lag 1 is 0.0017 with estimated value of 4.4713. This p-value is lower than α of 5% and therefore the null hypothesis of no relationship between the two variables is rejected. The alternative hypothesis should therefore hold meaning that there is a relationship between consumer price index and foreign exchange at lag 1. Similarly, Table 5 shows a relationship between CPI of today and its past values at lag 1 with an estimated value of 0.4690.

The adjusted R-Square is 79% meaning that the variations in consumer price index can be attributed to the past values of foreign exchange and its own past values at lag 1.

This implies that the other 21% variations in consumer price index can be explained by changes in other variables such as taxes and monetary policies put in place by the government (Mangani, 2020).

Using equations 3.17 and 3.18 as well as results in Tables 4 and 5, the model is:

$$\beta^{-1} = \begin{pmatrix} 1 & \alpha_2 \\ \alpha_4 & 1 \end{pmatrix}^{-1} = \begin{pmatrix} 1 & 4.0627 \\ 0.0212 & 1 \end{pmatrix}^{-1}$$

$$\omega = \begin{pmatrix} \alpha_1 \\ \alpha_3 \end{pmatrix} = \begin{pmatrix} 0.3864 \\ 0.0783 \end{pmatrix}$$

$$\gamma = \begin{pmatrix} \lambda_1 & \lambda_2 \\ \lambda_3 & \lambda_4 \end{pmatrix} = \begin{pmatrix} 4.4713 & 0.4690 \\ 1.0960 & 0.09115 \end{pmatrix}$$

$$\delta = \begin{pmatrix} \varepsilon_{yt} \\ \varepsilon_{xt} \end{pmatrix} = \begin{pmatrix} 1.2980 \\ 1.0381 \end{pmatrix}$$

Now,

$$\Omega_1 = \beta^{-1}\omega = \begin{pmatrix} 1 & 4.0627 \\ 0.0212 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 0.3864 \\ 0.0783 \end{pmatrix}$$

$$= \begin{pmatrix} 0.0682 \\ 0.0701 \end{pmatrix}$$

$$\beta^{-1}\gamma = \begin{pmatrix} 1 & \alpha_2 \\ \alpha_4 & 1 \end{pmatrix}^{-1} \begin{pmatrix} \lambda_1 & \lambda_2 \\ \lambda_3 & \lambda_4 \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 4.0627 \\ 0.0212 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 4.4713 & 0.4690 \\ 1.0960 & 0.0912 \end{pmatrix}$$

$$\therefore \Omega_2 = \begin{pmatrix} 0.0186 & 0.0987 \\ 1.0011 & 0.0812 \end{pmatrix}$$

Also,

$$\beta^{-1}\delta = \begin{pmatrix} 1 & \alpha_2 \\ \alpha_4 & 1 \end{pmatrix}^{-1} \begin{pmatrix} \varepsilon_{yt} \\ \varepsilon_{xt} \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 4.0627 \\ 0.0212 & 1 \end{pmatrix}^{-1} \begin{pmatrix} 1.2980 \\ 1.0381 \end{pmatrix}$$

$$\therefore \beta^{-1}\delta = \begin{pmatrix} -2.9195 \\ 1.0105 \end{pmatrix}$$

Hence equation 3.18 becomes:

$$\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \begin{pmatrix} 0.0682 \\ 0.0701 \end{pmatrix} + \begin{pmatrix} 0.0186 & 0.0987 \\ 1.0011 & 0.0812 \end{pmatrix} \begin{pmatrix} X_{t-1} \\ Y_{t-1} \end{pmatrix} + \begin{pmatrix} -2.9195 \\ 1.0105 \end{pmatrix}$$

$$\begin{pmatrix} Y_t \\ X_t \end{pmatrix} = \begin{pmatrix} -2.8513 \\ 1.0806 \end{pmatrix} + \begin{pmatrix} 0.0186 & 0.0987 \\ 1.0011 & 0.0812 \end{pmatrix} \begin{pmatrix} X_{t-1} \\ Y_{t-1} \end{pmatrix} \tag{4.3}$$

The main aim of this study was to model the interdependence between foreign exchange and the consumer price index in Malawi.

To achieve this, the study utilized the vector autoregressive model. The detrending transformation of logarithmic differencing, which achieved stationarity for smooth fitting in the vector autoregressive model, is rarely applied in similar studies. However, authors such as Taveeapiradeecharoen et al. (2019) and Aunsri and Taveeapiradeecharoen (2020), demonstrate that this method is appropriate for non-unique economies like Malawi. Additionally, they show that most models do not go beyond lag 1, while interestingly, our study has achieved this higher lag.

The analysis revealed major sudden departures from stability in both exchange rate and consumer price index data between the periods of 2012 and 2022. This finding is in line with studies conducted in unique economies by authors like Jamil (2022) and Pham (2019), which suggest that non-unique economies, such as Malawi, can be significantly affected by recessions as in unique economies like the USA.

Using the VAR model, we have demonstrated a significant dependence between foreign exchange and the consumer price index up to lag two. This means that a shock in the forex within a two-month period is likely to cause an immediate shock in consumer price index. Thus, the results of the vector autoregressive model indicate that changes in the CPI pattern, as explained above, are due to changes in the stability of the forex rate. Therefore, the variations in the dataset are highly explained by the interdependence between CPI and the foreign exchange rate, which has been demonstrated by the fitted VAR model.

More specifically, it has been established that variations in CPI can be attributed to the foreign exchange rate and its own value within the previous one month giving the coefficient of determination of 79%. The VAR model has also shown that the current foreign exchange rate is a function of consumer price index of the previous two months and foreign exchange rate of the previous month. This agrees with the purchasing power parity theory which postulates that changes in exchange rates ought to correspond with changes in the two nations' respective consumer price indices. A nation's currency should weaken to preserve parity in buying power if its CPI increases more quickly than that of its trading partners

The study was able to produce a model with monthly foreign exchange and consumer prices indices. This differs from study carried by Monfared and Akin (2017) who used annual data and Hendry General to Specific Modeling method and VAR model to analyse the relationship between exchange rates and inflation without necessarily producing a model linking the two variables. The use of annual data may not provide reliable results in this ever-changing business environment. The coefficient of determination in our study shows that 79% of the variation in consumer price index is caused by changes in foreign exchange. This is a significantly different from finding by Monfared and Akin (2017) who established that money supply has greater contribution to inflation than exchange rate. Furthermore, the results also differs to results obtained by Lafrogne-Joussier et al. (2023) who established a conditional pass-through of foreign input prices into domestic prices of 30%.

The study results also differs to the results obtained in Nigeria by Adetiloye (2010) who established that 24.9% variations in consumer price index in Nigeria arises due to changes in the exchange rate. These differences therefore speak to the different economic environments that these countries are sailing through.

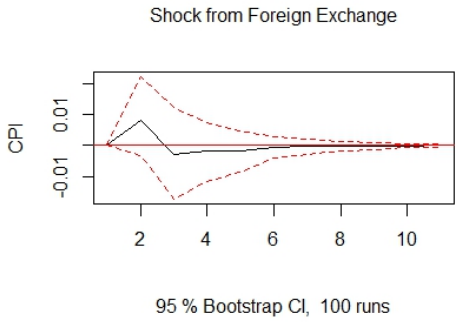
This means that studying the interdependence between exchange rate and consumer price index by using combined data from African countries as advocated by Loungani and Swagel (2001), Canetti and Greene (1991) and London (1989) may produce results which can potentially subdue the economic situations facing different countries like Malawi.

Although the results of the study are consistent with Adu (2020), Ocran (2007), Ilzetzki et al. (2020),Vo et al. (2020) and Nortey et al. (2015) among other authors, the results unearthed by this study are in sharp contrast to results obtained by Kamas (1995) which established that exchange rates did not play any significant role on inflation in Colombia and that inflation appeared to be primarily inertial with respect to the foreign exchange rate. Instead, the study found out that inflation is largely a function of demand shocks which skyrocket whenever there is an exponential demand for some products.

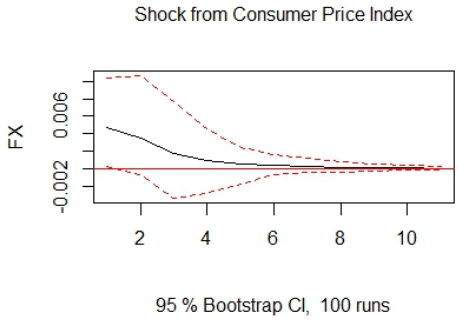
4.6 Impulse Response

The impulse response function is the change of a dynamic system in its output when presented with a brief input signal called an impulse or shock ($\delta(t)$). The impulse response describes the reaction of the system as a function of time or a function of some other independent variables that parametrizes the dynamic behavior of the system (Inoue & Kilian, 2013). Therefore in this section, we investigate the impact of the change in variable Y in response to a change (Impulse) in variable X and vice versa.

Figures 7a and 7b show the results of impulse response for both foreign exchange and consumer price index for ten periods. It should be pointed out that the data has been structured monthly, then ten(10) periods corresponds to 10 months.



(a) Consumer price index



(b) Forex

Figure 7: Impulse response

Using Figure 7a, one standard deviation in foreign exchange causes a positive response in consumer price index in the first two months but slowly eases off until it is almost zero. Thus, the impact of any change in foreign exchange can be experienced in the first two months after the change before dying out in the next six to ten months. Figure 7b shows a clear positive impact on the foreign exchange for one standard deviation in the consumer price index.

A decrease in consumer price index triggers a decrease in foreign exchange within the fist two before easing off between 6th and 10th month.

The results from the impulse response function also align with the study results from the VAR model. It indicates that the shocks produced by foreign exchange rates or changes in consumer price indexes are strong and significant in their ability to cause sudden rises in consumer price indexes or foreign exchange rates in Malawi, particularly within a two-month period when the shock is experienced. This finding agrees with studies conducted by López-Villavicencio and Mignon (2017), Pham et al. (2022) and Deka and Resatoglu (2019), which suggest that this phenomenon is more likely to be within weeks in a developing nations like Malawi.

Chapter 5

Conclusions and Recommendations

5.1 Conclusion

This section recaps the results discussed in the prior chapter and makes fitting conclusions per the findings. This chapter also provides recommendations to assist economists, individuals, firms and policymakers when addressing foreign exchange rate and consumer price index concerns.

The study focused on modeling the interdependence between foreign exchange and consumer price index. The results of the VAR model and Granger Causality test show that changes in consumer price index are greatly explained by the changes in foreign exchange, and variations in foreign exchange are a function of changes in consumer price index. Hence, the study concludes that these two time series variables are interdependent.

The lag length clearly shows that it takes a relatively short period of two months before consumers feel the impact of any change in foreign exchange. Using foreign exchange to predict consumer price index or using consumer price index to predict foreign exchange would be the most accurate due to the high relationship between the two variables, as evidenced by the estimates in Tables 4 and 5. The high Adjusted R-Squares also attest to this claim. Foreign exchange explains 79% of the variation in consumer price index, while 72% of variations in foreign exchange can be explained by the consumer price index.

5.2 Recommendations

It is imperative that policy makers, businesses, and consumers alike understand the link between foreign exchange rates and the consumer price index . To reduce uncertainty in exchange rate fluctuations, policymakers should first adopt transparent and consistent monetary and fiscal policies. This is because exchange rate volatility can intensify inflationary pressures by increasing the cost of imported goods and services. Furthermore, when deciding on monetary policy, central banks should keep a careful eye on exchange rate developments and take into account how they may affect domestic pricing. Price stability can be maintained by central banks by taking a proactive approach and using tools like exchange rate intervention to reduce the risk of the CPI becoming unstable.

Businesses that operate in global markets ought to implement efficient risk management tactics to protect themselves from variations in exchange rates and minimize possible negative effects on their pricing policies and profit margins. This could entail signing long-term contracts with suppliers or using financial instruments like currency futures or options. Furthermore, it is imperative for firms to regularly monitor fluctuations in consumer prices and modify their pricing strategies as needed to sustain competitiveness and safeguard consumer purchasing power.

5.3 Suggestions for future work

Further studies on the interdependence between foreign exchange rates and the consumer price index could explore several avenues to deepen our understanding of this complex relationship.

Firstly, researchers could investigate the differential impacts of exchange rate movements on various components of the CPI basket, such as imported goods versus domestically produced goods or basic need versus luxurious needs. By analyzing how different sectors of the economy respond to changes in exchange rates, researchers can uncover nuanced effects on consumer prices and inflation dynamics.

Apart from the above, researchers can model the interdependence of foreign exchange rate and consumer price index under different exchange rate regimes of floating and fixed. Comparative studies across countries with different exchange rate regimes can shed light on how institutional arrangements affect the pass-through of exchange rate movements to consumer prices and the effectiveness of monetary policy in controlling inflation. By addressing these research gaps, future studies can contribute to a more comprehensive understanding of the interplay between foreign exchange rates and the consumer price index and inform policy decisions aimed at promoting price stability and economic growth.

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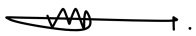

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