THE RELATIONSHIP BETWEEN STOCK MARKET RETURNS AND INFLATION: NEW EVIDENCE FROM SUB-SAHARAN AFRICA

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ST ANDREWS UNIVERSITY

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Declaration

I, **Bekithemba Mpofu**, hereby certify that this thesis, which is approximately **74,100** words in length, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for a higher degree.

I was admitted as a research student in September, 2006 and as a candidate for the degree of **Doctor of Philosophy** in December, 2007; the higher study for which this is a record was carried out in the University of St Andrews between 2006 and 2009.

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Dedications

This thesis is dedicated to my daughter Nicole Thabisile, my real purpose for life and my late Grandmother Rhoda.

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Acronyms

Abbreviation	Meaning	First used in Page
UK	United Kingdom	1
USA	United States of America	1
VAR	Vector autoregressive	6
AR	Autoregressive	17
DF	Dickey Fuller	18
PP	Phillips-Perron	18
ADF	Augumented Dickey Fuller	18
H_0	Null hypothesis	19
OLS	Ordinary least squares	23
NLS	Nonlinear Least Squares	22
ECM	Error correction models	23
LM test	Lagrangle Multiplier test	28
VARMA	Vector autoregressive moving average	30
IMSE	Integrated mean square error	34
IFS	International financial statistic	55
CIP	Capital international perspective	55
ARIMA	Autoregressive integrated moving average	55
SUE	Standard unexpected earning	63
EPS	Earnings per share	66
AGM	Annual General meeting	70
JSE	Johannesburg stock exchange	77
JSESETS	Johannesburg stock exchange electronic trading services	80
LSE	London stock exchange	80
JET	Johannesburg equities trading	80
SEM	Stock exchange of Mauritius	80
SEMATS	Stock exchange of Mauritius automated trading system	80

Abstract

The literature investigating the relationship between stock market returns and inflation is long and has produced diverse findings. This thesis examines the nature of stock–inflation relations in Sub-Saharan countries whose stock markets were established before 1992. Evidence in this thesis shows that in the short term there is a positive relationship between stocks and inflation. Using the Johansen (1988) evidence, a long-run stock–inflation relationship is confirmed only in Nigeria and South Africa, where it is found to be negative. However, accounting for structural breaks provides evidence for a long-run relationship in Botswana, Ghana and Kenya. The evidence of the effects of regimes in the relationship is further supported by a nonparametric cointegration analysis which finds a long-run relation in countries where the Johansen (1988) method had failed. Unexpected inflation is also found to be related to stock returns in Botswana, Ghana, Kenya, Nigeria and Mauritius, which raises concerns about the use of month-end stock data in analysing this relationship. The thesis confirms the existence of hidden inflation in Kenya, Mauritius, Nigeria and Zimbabwe. Imported inflation, interest rates and the exchange rate are found to have useful information about inflation movements in Sub-Saharan Africa.

Executive Summary

The view that equities are a good hedge against the inflation rate to ensure real assets are maintained is plausible. However, empirical evidence has produced varying findings, with the negative relationship between stock market returns and inflation a worrying factor, as it infers the erosion of real values over time. Three main theories have tried to explain the nature of the relationship: first, an economic theory by Fisher (1930) hypothesised a positive relationship based on the understanding that assets ought to maintain their values against inflation. Second, Fama (1981) introduced the proxy hypothesis that sought to explain why stock market prices and inflation have a negative relationship and attributed it to an indirect relationship between both variables and economic activity. Third, Modigliani and Cohn (1979) attributed the negative relationship to inflation illusion, and thus the use of nominal interest rates by irrational investors to discount real cash flows. These theories and supporting evidence have been tested in all continents expect Africa, and this thesis provides evidence within the Sub-Saharan context. The thesis uses 20–year data from February 1987 to January 2007 where available, and considers the Botswana, Ghana, Kenya, Mauritius, Nigeria, South Africa and Zimbabwe stock markets which were operating before 1992. Econometric techniques are used to determine the short– and long–run relationship between stocks and inflation with the cointegration methods providing useful information for the conclusions thereof.

The results show that there is a relationship between stock market returns and the inflation rate in Sub-Saharan Africa. The nature of this relationship cannot be confirmed as positive or negative, given that a number of factors contribute to the nature of the relationship. First, in the short run, the relationship is found to be negative, while a positive relationship is observed when long–term techniques and data are considered. Second, the presence of structural breaks that typify the existence of different regimes

has the tendency to affect the nature of the relationship, particularly in that the direction of causality is not maintained before or after the break. The effects of the causality changes are the presence of a long–run relationship in countries where the Johansen cointegration techniques failed to confirm it. Third, the presence of different regimes questions the linearity of the relationship, and a test using a nonparametric kernel regression confirm nonlinearity in the relationship. Using the nonparametric cointegration method developed by Bierens (1997), a long–run relationship is confirmed in countries where the linear Johansen cointegration method failed.

An interesting finding about the relationship between stock returns and inflation is a significant relationship between stock market prices and unexpected inflation. These results indicate that stock market data at month end does not contain all the information about inflation expectations; thus the nature of the relationship could be altered at inflation announcement date. To arrive at inflation expectations which are used to calculate unexpected inflation, variables that have useful information about the inflation rate are determined through the analysis of forecasting results. The evidence in Sub-Saharan Africa shows that imported inflation, interest rates and the exchange rate have useful information about the movements in the inflation rate in the continent, and this is worrying since most countries review their inflation baskets every five years. There is also evidence that Sub-Saharan Africa inflation figures are not accurate, given the presence of unofficial inflation. Moreover, when poverty increases, indications in this thesis are that food weights ought to be reviewed lest the basket fails to reflect household expenditure.

CHAPTER ONE

INTRODUCTION

The essence of investment is to attain a reasonable return while preserving its purchasing power. To preserve the purchasing power of an investment while earning a reasonable return calls for such an investment to attain returns which are above the inflation rate lest the value of the investment is eroded over time, compromising its purchasing power. The economic framework that defines this plausible setting within the investment realm is a product of the theory by Fisher who sought to explain the relationship between asset returns and inflation. According to the Fisher hypothesis (Fisher, 1930) asset return should at least match the inflation rate to preserve its real value, if not move positively compared with it. This theoretical reasoning also means that stock market returns have a positive relationship with the inflation rate, a position that has been supported empirically by Boudoukh and Richardson (1993) for the United Kingdom (UK) and the United States of America (USA), using data between 1802 and 1990. In their study of 16 industrialised countries, Ely and Robinson (1997) concluded that stock market prices maintain their value in the face of inflation. In high inflation countries, Choudhry (2001), who used stochastic structural tests, provided evidence for a positive stock–inflation relationship. When analysing different sectors within the UK stock market, Luintel and Paudyal (2006) established evidence to support the Fisher economic theory, which is also known as the ‘Fisher effect’.

In light of extensive research on the stock–inflation relationship, the above plausible support for the Fisher effect only cements the continuously conflicting empirical evidence on this relationship. These inconsistencies in the findings became apparent in the 1970s when this logical explanation for the stock–inflation relationship failed empirical tests (Nelson, 1975; Jaffee and Mandelker, 1976; Bodie, 1976; Fama and Schwert, 1977; Modigliani and Cohn, 1979), as investors found this to be far from the truth since, in the short and intermediate term, stock prices were negatively related to inflation (Sharpe, 2002). Research on the relationship between stocks and inflation from then on concentrated on finding theoretic reasoning behind the evidence of a negative relationship. Feldstein (1980) argued that the taxation–inflation relationship played a pivotal role in influencing the stock–inflation relationship. However, this interpretation for the negative findings did not hold as it became apparent that the evidence was also found in other countries (Gultekin, 1983) which had different tax regimes from those of the USA.

The more logical reasoning for a negative stock–inflation relationship was attributed to the independent effect of real economic activity on stock price and inflation, with Fama (1981) arguing that the direct relationship between these two variables was spurious and could only be explained by the inferred (Proxy) arrangement between them and economic activity. Geske and Roll (1983) showed evidence that the spurious negative relationship between stock prices and inflation is driven by a chain of macroeconomic events which result in a higher rate of monetary expansion. The decrease in economic activity which negatively affects stock prices results in expected growth in money supply, and thus large increases in inflation (Stulz, 1986). James, Koreisha and Partch (1985) found evidence that stocks signal changes in both real activity and in the monetary base, which suggests a link between money supply and real activity (Lee, 1992). Emerging market evidence is also provided by Spyrou (2001), who used the regression models as well as cointegration techniques to arrive at his research conclusions. Boucher (2006), however, criticised the Proxy hypothesis and failed to find justification and support for the Fama generated explanation for the impact of inflation on stocks. Ram and Spencer (1983) also questioned the rationale of the view that inflation and real activity are negatively related in the Proxy Hypothesis, given the Phillips curve which hypothesises positive relations.

Modigliani and Cohn (1979) attributed the negative relationship between stock prices and inflation, to inflation illusion, which states that the negative relationship between inflation and stocks is a result of the use of nominal interest rates by irrational investors to discount real cash flows. Cohen *et al*. (2005) state that this behaviour of investors is due to the difficulty in estimating long–term future growth rates of cash flows, while Akerlof (2002) notes that the cost of incorporating inflation in forecasting earnings is too high relative to the benefits of improving the accuracy of the forecast. The end result is that investors fail to incorporate the effect of inflation on nominal dividend growth rates (Campbell and Vuolteenaho, 2004; Chordia and Shivakumar, 2005; Basu *et al*., 2005) and thus extrapolate historical nominal growth rates during inflation. Ritter and Warr (2002) outline four areas that make up the logic behind the inflation illusion hypothesis and these are: the debt capital gains error, the capital rate error, disintermediation and the valuation errors in the literature. The capital rate error relates the yield on stock prices to the yield on nominal bonds (Campbell and Vuolteenaho, 2004), and this relationship is now commonly known as the 'Fed Model' of stock pricing (Estrada, 2009). Estrada (2009) notes that this negative relationship between the stock market price–earnings ratio and government bond yields seems to have become conventional wisdom among practitioners. Campbell and Vuolteenaho (2004) state that practitioners argue that bond yields plus risk premium equate to nominal yield on stocks, and that actual stock yield tends to revert to this normal yield. However, Asness (2003) feels that the model erroneously compares the real magnitude of the earnings–price ratio to nominal government bond yields.

The above synopsis of literature between stock prices and inflation demonstrates the lack of common ground on the nature of the relationship as well as the theoretic reasoning applied to the relationship. Moreover, though Choudhry (2001) looked at the relationship in high inflation countries of Latin America, no one has looked at high and volatile inflation countries of Sub-Saharan African was identified. Most African stock markets are young and illiquid; thus analysing their relationship to the inflation rate brings a new dimension to the debate, more so as they experienced economic adjustments during the period of this data analysis. The presence of economic adjustments has the tendency to create structural breaks in the data and change the equilibrium plain in a relationship, and this will provide an interesting element to the analysis of stock–inflation relations. In short, the hypothesis of this thesis is: There is a relationship between stocks and inflation in Africa. Having established that such a relationship exists, the thesis will then explore this relationship with a view to ascertain if there is consistency within the continent, thus contributing to the current debate as well as filling a gap in the current literature.

Unlike other factors that influence stock market returns, inflation is usually announced monthly, and data for its calculation is predominantly collected over a period, with most prices estimated from monthly investigations carried out between the fifteenth and the end of the month. However, research to date has looked at the relationship between inflation and stocks, ignoring the fact that there is a gap between the month end and the announcement date and, as Gultekin (1983) points out, inflation figures are not end-of-month ones like stock price indices; their various components are measured at different times of the month and public announcements not made until almost the second half of the month. This concern on the use of month–end stock prices is further escalated by Adam, McQueen and Wood (2004), whose research on USA daily prices showed that stock market prices respond to inflation on the announcement date. This thesis will tackle this challenge within the African context, given that the evidence by Amihud (1996) also showed a statistically significant relationship between unexpected inflation and month–end stock prices. The significance of this relationship is that inflation expectations at month end are not fully incorporated into stock market returns hence doubt is placed on the rationale of using month end stock market data to establish the relationship. Interest rates have been used in previous research as a proxy for expected inflation. However, in this thesis there is recognition that inflation forecast models provide the best approach to forecasting inflation in Africa, which is another under-researched area. The results for the best models to forecast inflation in different countries is then used as a measure for inflation expectations.

Another research question, within the African context, that affects the analysis of inflation–stock relations is the accuracy of the inflation data. Using month end data is partly premised on the market efficiency beliefs which acknowledge that at month–end stock prices would already have contain information about the inflation rate. Now, if the inflation rate is inaccurate then there will be concerns about the relationship because stock prices would have incorporated accurate information which is not what is officially announced; hence the need for inflation announcement dates' stock data. Inflation accuracy or the existence of unofficial inflation can be determined by the presence of hidden inflation or repressed inflation. The latter was looked at by Munoz (2006) in the Zimbabwean context; thus this thesis will explore the hidden inflation component of unofficial inflation. While the presence of hidden inflation in Africa could raise questions about the robustness of the results, especially when month–end data is used, the use of the cointegration method that incorporates the vector autoregressive (VAR) system erases these concerns. The VAR system includes lagged values, and since the month–end disequilibrium is corrected every announcement date, the effect of hidden inflation on the stock–inflation relations is eliminated over time.

1.1 Thesis aims and objectives

The main aim of this thesis is to ascertain if there is a relationship between stocks and inflation in Sub-Saharan African. Having established such a relationship exists, the thesis will examine the nature of such a relationship, and this investigation will entail fulfilling the following objectives:

1.1.1 To determine current literature on the relationship between inflation and stocks with a view to ascertaining the current arguments and the economic theory that underpins the relationship.

1.1.2 To ascertain the accuracy of African official inflation rates, since this data is to be used to determine if stocks have a relationship with inflation. Any inaccuracies compromise the robustness of the findings.

1.1.3 To establish models that would best forecast inflation in Africa, mindful that the requirement to determine the relationship between inflation and stocks in the financial sector is premised on the need to make prudent stock market strategies in light of pending inflation movements.

1.1.4 To examine factors that influence the nature of the relationship between the stock market and inflation.

1.1.5 To determine the linearity of African stock–inflation relations and, where non-linearity is detected, to establish if non-parametric long-run econometric tools provide better results.

Each chapter in this thesis will explore the above objectives with a view to providing support for the acceptance or rejection of the thesis hypothesis. In addition, the expectations are that answers to the objectives will reflect the contribution of this study to current literature, both on the relationship between stocks and inflation, and on finance in general.

1.2 Expected beneficiaries

Information on the relationship between the stock market and inflation in Africa is important to academics, investors and policy makers. Academics, whose current literature is contradictory and torn between various schools of thought, will benefit from the wide, dynamic approach and analysis of this research, since it will use new and long-run data sets as well as a variety of empirical econometric techniques including both linear and non-parametric cointegration methods. The thesis will examine if there is a difference in the relationship between the short– and long–term data with a view to confirming research findings that suggest that the length of data used in the analysis has a bearing on the results. Furthermore, the research will focus on the importance of structural breaks in exploring the relationship, with a view to establishing a set of rules that could be used, thus contributing to current literature and academic work. The findings from the analysis will assist future research and provide a better understanding of why the relationship has, to date, produced conflicting results.

Information on the nature of the relationship between the stock market and inflation is also vital to international and local investors, as well as investment intermediaries who have to use it for their investment strategies. While there is disagreement on the inflation–stock relations, there is considerable theoretical and empirical evidence that there are many factors that influence the movement of stocks, and this is useful to investors. These factors range from micro factors which affect individual companies to macro factors that are mostly driven by government policies and affect the entire stock index. Monetary policy, which is one of the main government policy frameworks that affect stock prices, is now driven by inflation targeting (Bernanke and Mishkin, 1997; Benigno, 2004), hence the importance of inflation. In addition to this indirect influence which inflation has on the stock market, it also affects stock investors through its effect on the calculation of real stock returns. While most African markets are young and small, the high returns and negative correlation with major markets has provided international investors with alternative investment options for their diversified portfolios.

One reason for wanting knowledge about short– and long–term inflation–stock relations is to ensure market positioning by investors and investment intermediaries in the case of pending inflation surge or dip. Decisions about further investment, withdrawal and retaining investment levels could thus be made in light of knowledge about the impact inflation will have on stock and, where appropriate, on the advice given to the investor by intermediaries in line with future stock expectations driven by pending inflation movements. In particular, intermediaries' understanding of how inflation influences stocks might be pivotal in ensuring a competitive edge over other market players, as Branch (1976) also notes that there is a relationship between inflation and subsequent stock market performance. Consequently, looking into the future through forecasting inflation becomes part of what drives interest on the relationship between the two, as the knowledge about inflation movements provided by forecasting aids stock market stakeholders to act consistently with both the forecast know-how and researched evidence of the relationship. It is within this context that Chapter 5 of the thesis will endeavour to explore the forecasting of inflation in sub-Saharan Africa as part of the reasoning behind understanding the impact of the same on stocks, without which investors be taking a hopeless leap in the dark.

Policy makers are big players in the drive to bring inflation to satisfactory levels, and the knowledge about inflation's impact on stock prices could influence their decisions, as stock markets affect production levels, investment and reaction to interest rates which is an integral part of many monetary policies. This thesis looks at the presence of unofficial inflation, thereby helping policy makers to come up with measures to ensure an accurate announced inflation rate. Forecasting inflation findings also helps government appreciate which economic variables have useful information about the inflation rate, and such information can then be used to regulate its movement, especially in an inflation–targeting regime.

1.3 Scope of the research

This research, which is in the area of financial econometrics, will explore the relationship between stock market returns and inflation in Sub-Saharan Africa. The thesis will use twenty years of monthly data from February 1987 to January 2007, where available, for Sub-Saharan African countries. Where the twenty-year data is not available, the earliest available data will be used in pursuit of the general research objectives. There are forty-five countries in Sub-Saharan Africa, of which 18 have active stock exchanges (including one regional exchange in West Africa). However, there are only eight that were established before 1992. Given that the research will also look at long–run stock–inflation relations, and that the main empirical techniques (cointegration) to be used require long–term data for reliable results. The thesis will therefore consider countries whose stock markets were functional prior to December 1992. In this regard, the research will investigate inflation–stock relations in seven countries, namely Botswana, Ghana, Kenya, Mauritius, Nigeria, South Africa and Zimbabwe. Namibia is the only country to be excluded from this list because the consumer price index in the country changed from the Windhoek consumer price index to a national index, and there is no index that incorporates both data; hence the exclusion of Namibia from the scope of this data. Since Sub-Saharan African countries have in recent years been characterised by financial market reforms, and high and volatile inflation rates, these factors could bring a different dimension to the debate on the inflation–stock relations, especially as this relationship has not been looked at to date in this region. Using relatively volatile inflation data in Africa might also provide a clearer view of how stock market returns respond to inflation shocks. Thus, if there is either a defined positive or negative relationship, alternatively as noted by Graham (1996), if regimes and structural breaks have more influence on the nature of the relationship.

1.4 Research synopsis

Given the above thesis aims and objectives, this research will adopt a linear structure with four levels as noted in Fig 1.1 below. This chapter introduces the research, after which the research methodology is explored and then the research objectives. After the first two chapters, the next chapters mirror research objectives, of which the first three are not directly linked. Research objective 1.1.1 is looked at in Chapter Three, which intends to bring to the fore an update on research relating to the relationship between stocks and inflation; this is done through a review of past and present debates on the relationship. Currently, three main theories are still debated and these are the Fisher economic theory, the Proxy hypothesis and the inflation illusion hypothesis. The inflation illusion hypothesis has gained prominence in recent years owing to limited empirical support for the Fisher theory and proxy hypothesis. The expectations from Chapter Three are to confirm the lack of research on this relationship within the African context.

Hidden inflation is considered in Chapter Four which addresses objective 1.1.2 and seeks to ascertain if the announced African inflation rate, to be used later in the thesis, is accurate. The accuracy of the inflation rate is considered through the use of the hidden inflation approach, a concept used to determine the presence of unofficial inflation. Evidence from this chapter confirms the presence of hidden inflation in Kenya, Zimbabwe and Mauritius. Unfortunately, the analysis could not be extended to Botswana and South Africa owing to data constraints. The findings are unique, as they provide the first empirical evidence of the existence of hidden inflation in Africa.

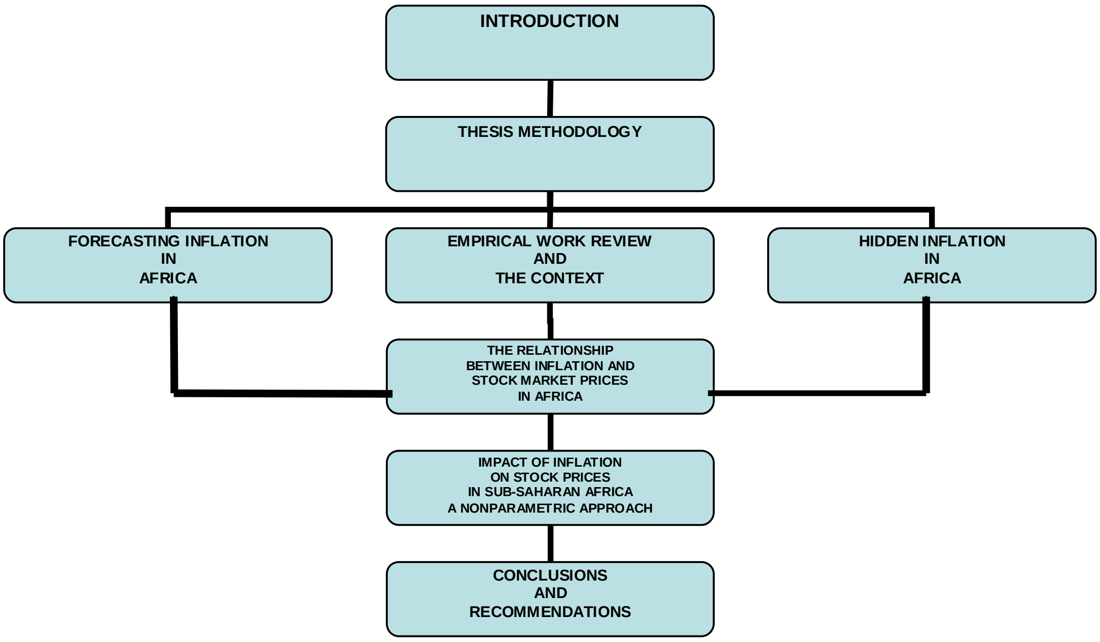

Figure 1.1 Research structure

Chapter Five will look at forecasting the inflation rate in Africa, and this tackles objective 1.1.3 of this thesis. The motivation behind this chapter is based on the understanding that the desire for knowledge about the relationship between stocks and inflation is to ensure market positioning in the face of inflation. Hence the chapter provides the tools for predicting the inflation rate within the African context. The general findings in this chapter show that multivariate and bivariate models have more power in predicting the inflation rate in Africa than their univariate counterparts. Imported inflation, interest rates and the exchange rate provide useful information about forecasting inflation in Africa. These findings are a contribution to the literature on forecasting of the inflation rate, as they provide a wider African context. Furthermore, the results provide policy makers in the continent with variables that could be useful in moderating the rate as well as a platform for inflation targeting.

Chapter Six presents the evidence on the nature of the relationship between stocks and inflation in Sub-Saharan Africa using linear techniques. In line with objective 1.1.4 of this thesis, the chapter considers factors that could influence stock–inflation relations, including the effects of structural breaks in the data. The chapter demonstrates that stock returns and inflation are related in the long run, but that this relationship depends on a number of factors and conditions. When establishing the nature of the relationship, there is a need to ascertain if such a relationship is sought for short– and long–run analysis. Unexpected inflation is also found to have a relationship with stock returns and this raises questions about the use of month–end stock data, since this would not have accounted for all inflation expectations. Failure to capture all stock expectations indicates that stock prices would move at announcement date, and such movement will be influenced by whether the inflation rate is above or below the market expectations. The effects of structural breaks and regime switch are also found to influence the nature of the relationship. Thus Chapter Seven investigates the linearity of the relationship. Linearity tests show evidence that the relationship between stock returns and inflation is not linear in most of the African countries studied and, using a nonparametric cointegration test that captures nonlinearity, a long run relationship is confirmed where linear techniques had failed to confirm this. Chapter Eight presents the conclusions and recommendations based on the empirical findings contained in the thesis.

CHAPTER TWO

THESIS METHODOLOGY

2.0 Introduction

This chapter will explore the methods adopted in order to answer the research questions noted earlier. The research adopts mainly a quantitative approach, where time series data is reviewed and analysed to arrive at the thesis conclusion and inferences about the nature of the secondary data and its interaction. The secondary data used in the following empirical chapters, including its sources, is presented in each of these chapters. This chapter deals with how the collected data is processed and used to arrive at research conclusions. Before describing the processing of the data in the empirical chapters, the data will be summarised in terms of descriptive statistics where figures corresponding to measures of central tendency and dispersion such as the mean, maximum, minimum and skewness.

The first part of processing the data will involve transforming it into seasonally adjusted figures. This is to aid relating time series data to achieve month–to–month comparability of the series, since seasonality can obscure the relationship (Bell and Hillmer, 1984), especially in short–term analysis and forecasting. Census X–12, an improvement from the initial Census X-11 developed by the US Bureau of the Census, is used on all the time series data before they are related with each other. This seasonal adjustment technique is based on software which has evolved from the 1950s to the Census X-12 of the late 1990s. Seasonally adjusting this data has, however, been criticised (Roberts, 1978; Plosser, 1978), as it looses important data for the series, with Watts (1978) noting that the aim of time series model building is to develop forecasting models that yield white-noise residuals. Thus, opting for seasonal dummies during the analysis is sometimes favoured over pre-analysis adjustments, since the latter looses important white-noise residual information.

After the data has been seasonally adjusted, the next step in processing the data is to log it, and this involves transforming the data using the natural logarithm. Logging time series data is helpful when analysing data, particularly since data in this form is easier to work with. Possibly the most important issue to consider for modelling time series data in modern times is to test for stationarity of the collected data so that it is made ready for processing. According to Brooks (2002), using non–stationary data can lead to a spurious regression where the results can seem excellent and impressive, but in reality be worthless and without meaning. Moreover, the standard assumptions in a non-stationary series may not be valid, as the usual t-ratio and f-ratio will not follow their distribution. A stationary series has a constant mean, constant variance and constant autocovariances for each given lag. In this regard, it is imperative to carry out the stationarity test first, before modelling, and thus this step constitutes part of the data processing for this research. To test for stationarity, many approaches are advocated, from those that test if a series has a unit root, such as the Augmented Dickey Fuller test and the Phillips–Perron (1988) test, to ones with a hypothesis of stationarity developed by Kwiatkowski, Phillips, Schmidt and Shin (1992).

The remainder of this chapter is structured as follows: Section 2.1 presents the unit root tests that will be used in this thesis; Section 2.2 the Granger causality tests; Section 2.3 cointegration tests; and Section 2.4 impulse response and variance decomposition. Structural breaks are considered in Section 2.5; while nonparametric kernel regression is looked at in Section 2.6; and nonparametric cointegration test of Bierens explored in Section 2.7.

2.1 Unit root tests

As noted above, non–stationary series yield "spurious regression" or "nonsense regression" where two series have no relationship but when regressed on each other the standard statistics, i.e. R^2 and t-statistic, will suggest that there is a linear relationship (Cuthbertson, 1996). Thus the standard statistics in this case are misleading, and this might be caused by the fact that the coefficients of the regression do not follow the acceptable standard distributions. One way of determining if a series is stationary or not is to observe the line graph of the series, and if the graph revolves around the mean one may conclude that the series is stationary. Koop (2000), however, notes that deterministic trends can yield time series plots that closely resemble those from non–stationary models having a stochastic trend. Thus, "looking" at time series plots alone is not enough to tell whether a series has a unit root; hence unit root tests have to be conducted to ascertain stationarity. According to Brooks (2002), if a non–stationary time series y_t must be differenced d times before it can become stationary, then the series is said to be integrated of order d. In an autoregressive model (AR) of the form:

$$y_t = \alpha + \phi y_{t-i} + e_t \qquad 2.1$$

where α is the constant, ϕ is the coefficient of y a period back and e_t is the error term, Koop (2000) states that the following determines whether a series is stationary or has a unit root: If

$\phi = 1$, then y has a unit root, however if $|\phi| < 1$ then y is stationary. So, if y has a unit root, then the first difference of y will be stationary when y is an AR(1).

According to Maddala (2001), unit root testing in the 1980s was a topic which most econometricians devoted their energies to. Early pioneering work on unit root testing is attributed to Dickey and Fuller, whose basic objective was to examine the Null hypothesis that $\phi = 1$ in a white–noise process of the form (Brooks, 2002):

$$y_t = \phi y_{t-1} + u_t \qquad 2.2$$

where u_t is an error term. The one–sided alternative hypothesis is that $\phi < 1$. Brooks states that the Dickey–Fuller (DF) tests are also known as $\tau-\text{tests}\ \tau, \tau_\mu, \tau_\tau$ where the second and the third tests, τ_μ, τ_τ, are the same as the first, except that the second allows for a constant while the third allows for a constant and deterministic trend. The problem with this test is that it assumes that the error term follows a white–noise process and is thus not autocorrelated. However, Brooks (2002) notes that if there was autocorrelation in the variable y_t in Equation 2.2, then the error term u_t is also expected to be autocorrelated; thus the test will be oversized compared to the ordinary significant levels. To address this problem, the test is augmented by using lags of the dependent variable; however, the optimum number of lags to be used creates another problem which might compromise the robustness of the test results. Another test to be considered here is the Philips–Perron (PP) test, which also tests for unit root presence within a series. This test is similar to the Augmented Dickey–Fuller (ADF) test, but it incorporates an automatic correction to the DF procedure to allow for autocorrelated residuals (Brooks, 2002).

The main problem in using the ADF and PP unit root tests is that these tests have low power particularly for a small sample size and when the series is border stationary with a ϕ coefficient close to 1. According to Brooks (2002), under the classical hypothesis testing framework, the Null hypothesis (H_O)is never accepted, it is simply stated that it is either rejected or not rejected thus, a failure to reject the Null hypothesis could occur because of the following: first, the Null was correct; second, there is insufficient information in the sample to enable rejection. To address this problem Kwiatkowski, Phillips, Schmidt and Shin (1992) developed a stationarity test whose Null hypothesis is that the series is stationary. The following four outcomes for this test are noted by Brooks (2002) and for the conclusions to be robust, the results should fall under outcomes 1 or 2:

1. Reject H_O and Do not reject H_O
2. Do not Reject H_O and Reject H_O
3. Reject H_O and Reject H_O
4. Do not reject H_O and Do not reject H_O

In this thesis the aforementioned tests will be used. When testing for stationarity at levels, tests will be done for an equation that includes an intercept only and another with both a trend and a constant while for first difference series the above tests will be done without trend and intercept as well as with only an intercept.

2.2 Granger causality tests

According to Patterson (2000), the central idea in this test is that a variable is not Granger caused by another if its optimal predictor does not use information from that variable. If there are two vector autoregressive systems of the form:

$$Y_t = \delta + \sum_{i=1}^{k} \alpha_{1i} Y_{t-i} + \sum_{i=1}^{k} \alpha_{2i} X_{t-i} + \varepsilon_{1t} \qquad 2.3$$

$$X_t = \delta + \sum_{i=1}^{k} \beta_{1i} X_{t-i} + \sum_{i=1}^{k} \beta_{2i} Y_{t-i} + \varepsilon_{2t} \qquad 2.4$$

in which Y_t depends upon lags of itself and that of X_t and symmetrically X_t depends upon lags of itself and the lags of Y_t (Patterson, 2000). The hypothesis for the Granger causality test for Y_t is $H_0 : \alpha_{21} = \alpha_{22} = \cdots = \alpha_{2k} = 0$ and if this hypothesis is not rejected, then X_t Granger causes Y_t. Similarly, the rejection of the Null hypothesis $H_0 : \beta_{21} = \beta_{22} = \cdots = \beta_{2k} = 0$ indicates that Y_t does not Granger cause X_t. Patterson (2000) notes that the errors ε_{1t} and ε_{2t} may be contemporaneously correlated, so that a shock to one of the equations has a “ripple” effect on the other equation. According to Wooldridge (2006), the term “cause” in ‘Granger cause’ should be interpreted with caution, since it does not say anothing about contemporaneous causality between Y_t and X_t; thus it does not allow for the determination of whether X_t is an exogenous or a endogenous variable in Equation 2.3.

2.3 Cointegration tests

Cointegration is a modern empirical technique whose use has grown in recent years primarily to ascertain the degree to which variables are related in the long run. Granger first introduced the concept in 1981 in his paper that sought to analyse properties of time series data. According to Hendry (1995), cointegrated processes define a “long-run equilibrium trajectory” for the economy, departures from which induce “equilibrium corrections” which then shift the economy back towards its normal path. The introduction of cointegration was due to the realisation that most financial data is not stationary. Cuthbertson (1996) says regression models from non-stationary time series variables result in spurious regressions, and since cointegration deals with data with stochastic trends, it avoids this problem. If we consider a stochastic trend, that is, a random walk with drift:

$$Y_t = \delta_0 + Y_{t-1} + \varepsilon_t \qquad 2.5$$

$$X_t = \beta_0 + X_{t-1} + v_t \qquad 2.6$$

where Y_t and X_t are independent variables, ε_t and v_t are assumed to be serially and mutually uncorrelated errors, δ_0 and β_0 are constants and t is time. When the above two random walk processes are regressed we get:

$$Y_t = \alpha_0 + \alpha_1 X_t + \mu_t \qquad 2.7$$

where μ_t is the error term, α_0 is the constant, and α_1 is the coefficient for the independent variable. The expectation, according to Maddala and Kim (1998), is that R^2 will be zero. However, owing to spurious correlation, this may not be the case, as shown by Yule (1926) and then Granger and Newbold (1974). Cuthbertson (1996) says that R^2 and the t-statistic from the “spurious regressions” or “nonsense regression” are misleading because R^2 is often bimodal and the t-statistic for α_1 is not distributed as a student’s *t* distribution, and therefore cannot be used to test the hypothesis for α_0, α_1 and μ_t. Granger and Newbold (1974) also point out that the R^2 in spurious regressions is more than the Durbin–Watson statistic and this low statistic reflects the existence of serial correlation in the residuals.

For cointegration to exist two variables should be integrated to the same order, thus Y_t and X_t should both be integrated to the same order, say, 1 (differenced once to be stationary) or more.

Maddala and Kim (1998) say that Y_t and X_t are cointegrated if there exists a β such that $Y_t - \beta X_t$ is integrated to order zero I(0), and this is denoted by saying that Y_t and X_t are CI(1,1). Over time, Maddala and Kim (1998) note that if Y_t is I(d), thus integrated of order d, and X_t is I(d), then Y_t and X_t are CI(d,b) if $Y_t - \beta X_t$ is I(d-b) with b>0. If b=0, then $Y_t - \beta X_t$ is I(d). Thus Y_t and X_t drift away from each other over time and, according to Maddala and Kim (1998), any relationship between Y_t and X_t in this case would be spurious. Thomas (1997) adds to this discussion by saying that cointegration is the statistical equivalent of the existence of a long-run economic relationship between same order variables.

2.3.1 Estimation of cointegrated systems and error correction models

Unless otherwise stated, this section closely follows Maddala and Kim (1998), who suggest that methods of estimating cointegrated systems fall into two categories, single equation methods and system methods. Single equation methods, as the term suggests, are interested in estimating one cointegration vector, while system methods consider cases of more than one cointegration vector. Taking the above two variables Y_t and X_t, which are I(1), the following can be the cointegration relationship, where μ_t is a stationary series:

$$Y_t = \beta X_t + \mu_t \qquad 2.8$$

Maddala and Kim (1998) present a number of issues that are related to this simple two–variable model. First, the uniqueness of β that is, in a two variable case β in the cointegrating regression $Y_t - \beta X_t$ is unique. Second, the superconsistency of β ; hence Stock (1987), after Monte Carlo simulations and analysis of Ordinary Least Squares (OLS) and Nonlinear Least

Squares (NLS), concludes that OLS and NLS estimators of the parameters of a cointegrating vector are shown to converge in probability to their true values at a rate $T^{1-\delta}$ for any positive δ. Thus $\hat{\beta}$ of β converges to its true rate at a superconsistency rate T instead of the consistency rate $T^{0,5}$. This superconsistency property also holds in the case of several I(1) variables, where the OLS estimation of the cointegrating vector is considered.

Third, according to Banerjee *et al*. (1986), though $\hat{\beta}$ is superconsistent, there can be substantial small sample biases, and they suggest the estimation of the long-run parameter β by estimating a dynamic regression rather than $Y_t = \beta X_t + \mu_t$, which is a static regression. Fourth, the fact that Y_t and X_t are cointegrated implies that they are related by an error correction model (ECM), which measures short–run dynamics, while the cointegration relationship gives the long–run relationship. Banerjee *et al*. (1986) say that the Engle–Granger 2–step procedure, which will be looked at later, involves estimation of β by OLS using the above static regression, substituting this for β in the error correction model and then estimating the ECM by least squares. The superconsistency of $\hat{\beta}$ assures that the two-step estimators of the parameters of the ECM have the same asymptotic distribution as the ones that one would get if β is known. Fifth, normalisation is the other issue for consideration, and the abovementioned static equation is normalised in respect of Y_t. If it is instead normalised with respect to X_t it would appear as:

$$X_t = \alpha Y_t + v_t \qquad 2.9$$

and the least squares estimator $\hat{\alpha}$ of α will also be superconsistent. Since $\alpha = 1/\beta$, the superconsistent estimator of β can be derived from $1/\hat{\alpha}$, and if R^2 from the equation is very close to 1, then $\hat{\beta} = 1/\hat{\alpha}$, which Hendry (1986) argues is the case with most economic relationships but not all. Ng and Perron (1997) show that the least squares estimator can have very poor finite sample properties when normalised in one direction, but can be well behaved when normalised in the other, and this occurs when one of the variables is a weak random walk or is nearly stationary. Ng and Perron (1997) suggest using the variable that is less integrated as the regressand, hence the need to rank the variables by the spectral density at frequency zero of the first differenced series.

2.3.2 The Engle–Granger 2–Step method

Engle and Granger (1987) developed a single equation technique, which is simplified by Brooks (2002, pg 393-394) as follows:

Step 1

The first step to the two-step method is to ensure that the variables are integrated of order one I(1) and this is done using stationarity or unit root tests. As noted above, if the variables are not of the same order, then it would not be possible to proceed with cointegration. If both are of the same order like Y_t and X_t in Equation 5.4 above, then estimate the cointegrating regression using OLS. Save the residuals of the cointegrating regression $\hat{\mu}_t$ and test these to ensure that they are I(0). If they are integrated of order zero, then proceed to the next step; if they are I(1), then estimate a model containing only first differences.

Step 2

Use the step 1 residuals as one variable in the error correction model of the form:

$$\Delta Y_t = \beta_1 \Delta X_t + \beta_2 (\hat{\mu}_{t-1}) + v_t \qquad 2.10$$

where, $\hat{\mu}_{t-1} = Y_{t-1} - \hat{\tau} X_{t-1}$. The linear combination of non-stationary variables that is stationary is known as the cointegrating vector; in this case it will be $[1, -\hat{\tau}]$. It is now valid to perform inferences in the second-stage regression concerning the parameters β_1 and β_2 provided there are no other forms of misspecification.

The Engle–Granger 2–step method, however, suffers from a number of problems, of which Brooks (2002, pg 394-395) identifies the following:

a) It suffers from lack of power in the unit root and cointegration tests just like most finite sample cases. This is a small sample problem, which should disappear asymptotically.

b) There would be a simultaneous equation bias if causality between y and x runs in both directions, while this single equation approach requires the researcher to normalise on one variable. The researcher is forced to treat y and x asymmetrically, even though there may have been no theoretical reason for doing so.

c) It is not possible to perform any hypothesis tests about the actual cointegrating relationship estimated at stage 1. This problem is addressed by the Engle and Yoo 3–step method, who add a third step to the above Engle–Granger 2–step method. The third step entails giving updated estimates of the cointegrating vector and its standard errors.

2.3.3 The Johansen procedure

This is a system estimation method based on the work of Johansen (1988), and later developed by Johansen and Juselius (1990), to apply maximum likelihood inference concerning cointegrating vectors in non-stationary vector autoregressive (VAR) models assuming Gaussian errors. Consider the following VAR with k lags:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots\ldots + A_k Y_{t-k} + U_t \qquad 2.11$$

where $t = 1,2,\ldots\ldots,T$ and Y_t is an n-vector of I(1) variables. According to Brooks (2002), in order to use the Johansen test, the VAR above needs to be turned into a vector error correction model (VECM) of the form:

$$\Delta Y_t = \Pi Y_{t-k} + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \ldots\ldots + \Gamma_{k-1} \Delta Y_{t-k+1} + U_t \qquad 2.12$$

where $\Pi = \left(\sum_{i=1}^{k} A_i\right) - 1$ and $\Gamma_i = \left(\sum_{j=1}^{i} A_j\right) - 1$

Since $\Delta Y_t, \ldots\ldots, \Delta Y_{t-k+1}$ are all I(0) but Y_{t-1} is I(1), in order that this equation be consistent, Π should not be of full rank and if this rank is *r* therefore:

$$\Pi = \alpha\beta' \qquad 2.13$$

where α is an $n \times r$ matrix and β' is an $r \times n$ matrix, and in this case then $\beta' Y_{t-1}$ are the *r* cointegrating variables, β' is the matrix of coefficients of the cointegrating vectors and α has the interpretation of the matrix of error correction terms. In this regard, Brooks (2002) notes that the Johansen test centres on an examination of the Π matrix, which can be interpreted as a long–run coefficient matrix. According to Maddala and Kim (1998), since cointegration is interested in α and β', eliminate $\Gamma_1, \ldots\ldots, \Gamma_{k-1}$. This is done by regressing ΔY_t on $\Delta Y_{t-1}, \ldots\ldots, \Delta Y_{t-k+1}$, getting the residuals from this regression and calling them R_{0t}, then regressing Y_{t-1} on these same variables and calling the residuals from it R_{1t}. The ensuing regression equation is reduced to the following multivariate regression problem:

$$R_{0t} = \alpha\beta' R_{1t} + u_t \qquad 2.14$$

Let $\begin{bmatrix} S_{00} & S_{01} \\ S_{10} & S_{11} \end{bmatrix}$ be the matrix of sums of squares and sums of products of R_{0t} and R_{1t}. Maddala and Kim (1998) point out that each of these matrices is of order $n \times n$. Johansen (1991), when presenting the likelihood methods for analysing cointegration in VAR models with Gaussian errors, also "…….shows that the asymptotic variance of $\beta' R_{1t}$ is $\beta' \Sigma_{11} \beta$, the asymptotic variance of R_{0t} is Σ_{00} and the asymptotic covariance matrix of $\beta' R_{1t}$ and R_{0t} is $\beta' \Sigma_{10}$ where Σ_{00}, Σ_{10}, and Σ_{11} are the population counterparts of S_{00}, S_{10}, and S_{11}." (Maddala and Kim 1998, pg 166)

Johansen (1991) says this function is easily minimised for fixed β to give:

$\hat{\alpha}(\beta) = S_{10}\beta(\beta' S_{11}\beta)^{-1}$ where α is an $r \times n$ matrix, 2.15

$\hat{\Phi}(\beta) = S_{00} - S_{10}\beta(\beta' S_{11}\beta)^{-1}\beta' S_{O1}$,

$L_{\max}^{-2/T}(\beta) = \left| S_{00} - S_{01}\beta(\beta' S_{11}\beta)^{-1}\beta' S_{10} \right|$ which is the conditional maximum of likelihood function. This is minimised by the choice $\hat{\beta} = (\hat{v}_1, \ldots\ldots, \hat{v}_r)$, where $\hat{V} = (\hat{v}_1, \ldots\ldots, \hat{v}_p)$ are eigenvectors of the equation:

$$\left| \lambda S_{11} - S_{10} S_{01} S_{00}^{-1} \right| = 0 \qquad 2.16$$

According to Johansen (1991) this is normed by $\hat{V}'S_{11}\hat{V} = I$ and ordered by $\hat{\lambda}_1 > \hat{\lambda}_2 > ..... > \hat{\lambda}_p > 0$ and the maximum likelihood function is found from:

$$L_{\max}^{-2/T}(r) = |S_{00}| \prod_{i=1}^{r} (1 - \lambda_i) \qquad 2.17$$

According to Maddala and Kim (1998) the number of cointegrating relationships in the system, *r*, is then chosen in the procedure by Lagrangle Multiplier (LM) tests to be described later, which make use of the fact that if there are *r* cointegrating vectors, then $n - r$ smallest eigenvalues of the above equation are zero, and the corresponding *r* eigenvectors are chosen as cointegrating vectors. Maddala and Kim (1998) say this way of imposition of $n - r$ restrictions in the system yields an asymptotically efficient and optimal estimator of the cointegrating vectors.

According to Brooks (2002), there are two test statistics for cointegration under the Johansen approach, which are formulated as:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} In(1 - \hat{\lambda}_i) \text{ and} \qquad 2.18$$

$$\lambda_{\max}(r, r+1) = -TIn(1 - \hat{\lambda}_{t+1}) \qquad 2.19$$

where *r* is the number of cointegrating vectors under the Null hypothesis and $\hat{\lambda}_i$ is the estimated value of the ith ordered eigenvalue from Π matrix above. Maddala and Kim (1998) say that the trace test tests the hypothesis that there are at most r cointegrating vectors, while the maximum eigenvalue test tests the hypothesis that there are r+1 cointegrating vectors versus the hypothesis that there are r cointegrating vectors. In this thesis both will be used, despite the fact that Johansen and Juselius (1990) submit that the latter could be better. For the trace test, Maddala and Kim (1998) submit that the asymptotic distribution of the above trace statistic is given by the trace of the stochastic matrix:

$$\int_0^1 (dW)W'\left(\int_0^1 WW'dr\right)^{-1}\int_0^1 W(dW)' \qquad 2.20$$

where W is an $(n-r)$ dimensional Brownian motion and in case there is a constant and/or a trend term in the VAR model, the matrix is changed to:

$$\int_0^1 (dW)\tilde{W}'\left(\int_0^1 \tilde{W}\tilde{W}'dr\right)^{-1}\int_0^1 \tilde{W}(dW)' \qquad 2.21$$

where $\tilde{W}$ is the demeaned or detrended Brownian motion. Critical values for the trace and the maximum eigenvalue tests are provided by Johansen and Juselius (1990), and the complete set was further developed by Osterwald–Lenum (1992). Brooks (2002) notes that if the statistic is greater than the critical value from the tables, reject the Null hypothesis that there are r cointegrating vectors should be rejected in favour of the alternative that there are $r+1$ (for λ_{trace}) or more than r (for $\lambda_{\max}$). This testing is conducted in a sequence and under the null, $r = 0,1,.....,n-1$, so that the hypotheses for max are:

$\mathrm{H}_0 : r = 0$ versus $\mathrm{H}_1 : 0 < r \le n$

$\mathrm{H}_0 : r = 1$ versus $\mathrm{H}_1 : 1 < r \le n$

$\mathrm{H}_0 : r = 2$ versus $\mathrm{H}_1 : 2 < r \le n$ …….until

$\mathrm{H}_0 : r = n-1$ versus $\mathrm{H}_1 : r = n$

If, after the first test, the Null hypothesis is not rejected, Brooks (2002) says it can be concluded that there are no cointegrating vectors, hence the end of the test. However, if

$\mathrm{H}_0 : r = 0$ is rejected, the null that there is one cointegrating vector would be tested, then two, and if it continues to be rejected then r is increased until the null is no longer rejected.

2.4 Impulse response and variance decomposition

The F-test results in a VAR will not reveal whether changes in the value of a variable have a positive or negative effect on the other variable in the system, or how long it will take for the effect of that variable to work through the system (Brooks, 2002). The impulse response and the variance decomposition examinations will thus assist in the provision of such information. Impulse response, Brooks (2002) argues, trace out the responsiveness of the dependent variables in a VAR to shocks to each other of the variables, thus for each variable and from each equation separately, a unit shock is applied to the error. The effects upon the VAR system over time are then noted. To achieve this, a VAR has to be expressed as a vector moving average (VARMA) model and for a system with k number of variables k^2 impulse responses can be generated.

According to Patterson (2000), given two random variables Y_t and X_t the variance of Y_t can be given by:

$$Var(Y_t) = E_X\{Var(Y_t|X_t)\} + Var_X(E\{Y_t|X_t\}) \qquad 2.22$$

Thus the variance of Y_t is the sum of the expected value of the conditional variance of Y_t given X_t plus the variance of the conditional expectation of Y_t given X_t. In other words "……..the left-hand side is the unconditional variance of Y_t (that is the variance of marginal distribution), while the right hand side involves the conditional variance $Var(Y_t|X_t)$ and another term; it emphasises that the unconditional variance and the conditional variance are not generally equal." (Patterson, 2000, p 72) Brooks (2002) states that variance decomposition gives the proportion of the movements in Y_t that are due to its own shocks compared to those that are induced by X_t.

2.5 Structural breaks

To identify a break in both the stock price and inflation series, a technique developed by Bai and Perron (1998, 2003 a, b) is used. The test considers the estimation of multiple structural changes in linear models and is considered an improvement to the classical test attributed to Chow (1960). According to Hansen (2001), the Chow testing procedure splits the sample into two sub-periods, then estimates the parameters of the model in each sub-period, after which the two sets of parameters are tested using standard F-statistics to determine statistical differences. The problem with this approach, though, is that the break point will have to be known before the division for the subsets can be made. In identifying the break point, Hansen (2001) considers two options, the first being an arbitrary choice of the break date. This approach might result in the choice of a break date which is not accurate. The second option is to use a known event or feature in the data to expose the break date; however even this method results in a break date which might be inaccurate. Owing to the accuracy problems of these tests, recent research has concentrated on the testing as well as the estimation of the time and size of break points (Hansen, 1992; Banerjee *et al*., 1992; Andrews, 1993; Bai, 1994, 1997a; Chong 1995; Bai and Perron, 1998, 2003a, b).

Hansen (2001) states that the least squares method is the appropriate approach to estimating parameters in a regression model including break points; hence it is the basis of the break date estimation technique developed by Bai (1994). Further development of the Bai (1994) approach entailed the test for multivariate breaks of unknown break dates, a product of Bai and Perron (1998, 2003a,b). McMillan (2007) summarises the method provided here and says that the break test involves regressing the variable of interest on a constant and testing for breaks within that constant, thus considering the model with m breaks:

$$x_t = \beta_j + \varepsilon_t \qquad ; \quad t = T_{j-1} + 1, \ldots\ldots, T_j \qquad 2.23$$

for $j = 1, \ldots\ldots, m+1,$ where x_t is the variable of interest and $\beta_j\,(j = 1, \ldots\ldots, m+1)$ is the mean level in the jth regime; accordingly, the m-partition represents the break point for the different regimes and therefore is treated as unknown. Each partition is estimated by OLS with the estimate of $\beta_j\,(j = 1, \ldots\ldots, m+1)$ generated by the minimisation of the sum of square residuals. The procedure, McMillan (2007) notes, aims to identify the number of break points m, with the testing procedure first assuming there is no break within the data against an alternative that there are up to b breaks in the data.

2.6 Nonparametric kernel regression

Nonparametric kernel regression provides an alternative approach to the parametric methods (Speight, 2002), and is based on the estimation of a probability density function initially presented by Rosenblatt (1956). With this technique, which is a flexible functional form of a regression (Hardle, 1990), the conditional mean is drawn from a dense family of continuously differentiable functional forms (Speight, 2002). Consider an equation of the form:

$$y_t = f(x_{t-i}) + \varepsilon_t \qquad 2.24$$

where y_t is the dependent variable, x_t is a vector of regressors, $f(x_{t-i})$ denotes the unspecified function of the exogenous variables with f denoting the conditional expectations of y_t at given values of x_t, and ε_t is the disturbance or the error term. If $f(x)$ is greater than zero and the joint density $f(y,x)$ exists, then equation 2.24 can be written as:

$$f(x) = \int y[f(y,x)/f'(x)]dy \qquad 2.25$$

where $f'(x)$ represents the density of x marginal to the joint density. The true function of x can thus be determined if the data–generating process is known, for example in the case of a bivariate normal density where $p = 1$. Another case is when the expectation of y given x thus $E(y|x)$ is assumed, which is the case with a linear form taken by $f(x)$. So an alternative to this parametric approach is to estimate the joint and marginal density in Equation 2.25 directly (Speight, 2002). However, the difficulty in estimating the function $f(x)$, according to Duclos and Araar (2006), is that typically there is no observed response of y in a sample at that particular value of x and even if there is a response, there are rarely other observations with exactly the same value of x that will allow computational reliability of the expected response. The commonly used approach to this problem is the use of the kernel estimation, a density estimation technique which uses weighted averages and requires no functional form specification, as in Equation 2.26 below:

$$\hat{y}_t = \sum_{j=1}^{T} w_{jt} x_{t-1} \, ; \sum_{j=1}^{T} w_{jt} = 1 \qquad 2.26$$

where the weights accorded depend upon the proximity of the points y_t to given x_{t-1} values. Although a variety of weighting schemes are available, the scheme chosen in this thesis is one of the more popular methods, namely the Nadaraya–Waston estimator (Pagan and Schwert, 1990; McMillan, 2001). The Nadaraya–Waston estimator is given by Equation 2.27:

$$f(x) = \sum_{i=1}^{n} y_i k(w_i) / \sum_{i=1}^{n} k(w_i) \, ; \, w_{ji} = (x_{ji} - x_i)/h_j \;\; n : h_j \to 0 \text{ as } n \to \infty \qquad 2.27$$

where h_j defines the scalar bandwidth or smoothing parameter which surrounds x_j and determines the degree of smoothness imposed upon the estimation, and depends on the sample size n. The kernel weighting function is given by $k(.)$ and, according to McMillan (2001b), the kernel is a probability density function such that $k(.) \geq 0$ and $\int k(y)dy = 1$, while the optimum kernel function and the bandwidth selections minimise the integrated mean square error (IMSE). There are various ways of choosing the kernel for implementing the nonparametric estimator, and Speight (2002) notes that the popular choice is the Epanechnikov kernel for $k(.)$, a product of Epanechnikov (1969), which is an optimum kernel from a calculus of variation solutions to minimise the integrated IMSE estimator. Equation 2.28 below shows the basis for the Epanechnikov kernel:

$$K(y_i) = \left[\frac{3}{4\sqrt{5}}\right]\left[1 - \frac{1}{5} y_i^2\right]; \text{if } y_i^2 < 5.0 \, ; \text{ otherwise, } K(y_i) = 0 \qquad 2.28$$

The general asymptotically unbiased and mean squares consistency of the kernel was established by Rosenblatt (1969), then Prakasa Rao (1983), for the case of independent observations, and for the dependent observations it was introduced by Robinson (1983). McMillan (2001) notes that more specifically, the estimator is consistent under the conditions in Equation 2.29 regarding $k(y)$ and h_j, where all integrals are defined over the range $\{-\infty, \infty\}$:

$$\int K(y)dy = 1; \int yK(y)dy = 0; \int y^2 K(y)dy < \infty; \quad \lim_{n\to\infty} h \to 0 \ \ \lim_{n\to\infty} nh_j \to \infty \qquad 2.29$$

That is, the kernel function $K(y)$ is a twice differentiable 'Borel-measurable' bounded real-valued function symmetric about the origin, the bandwidth vector h approaches zero as the sample size approaches infinity, and the product of the bandwidth h_j and the sample size approaches infinity as n approaches infinity (Speight, 2002). The bandwidth h_j above, which is the optimum bandwidth that minimises the IMSE of $f(x)$ for a variable j in x_t, is given in Equation 2.30 (Ullah, 1988; Speight, 2002):

$$h_j^{opt} = c_j \sigma_j n^{-(p+4)^{-1}} \qquad 2.30$$

where σ_j is the standard deviation of the $j-\text{th}$ regressor such that $j = 1, \ldots\ldots, p$ with p being the number of regressors and c_j referred to as a constant scaling factor that depends on the kernel function $K(.)$ and the underlying distribution of the regressors. According to McMillan (2001b), nonparametric studies have imposed a value for c in accordance with that suggested by Silverman (1986) to approximate the optimal choice of bandwidth, but the value of c is strictly data dependent, and hence the need to use an automatic bandwidth selection procedure which has been seen to minimise the integrated mean square error. Equation 2.31 below is the leave-one-out cross-validation procedure which is a recommended approach for this exercise to determine the appropriate (C_j, h_j):

$$CV(h) = \sum_{i=1}^{n}[y_i - \hat{f}(x_{-i}, h(c))]^2 \qquad 2.31$$

where $\hat{f}(x_{-i}, h(c))$ is the estimate of the conditional mean after leaving out the $t-\text{th}$ observation, and $h(c)$ is the vector of bandwidth calculated according to Equation 2.30 for various C_j (Speight, 2002). Stone (1974, 1984) shows that, asymptotically, the vector of scaling estimated factors c and the bandwidth that minimises the leave-one-out CV in Equation 2.31 also minimises the IMSE.

2.7 Bierens nonparametric cointegration test

The Bierens nonparametric cointegration test is based on the solutions to a generalised eigenvalue problem that is encountered by the Johansen method. Thus it is formulated on the basis of two random matrices that are constructed without reference to the data generating process (Davradakis, 2005). In particular, the method considers the following general framework:

$$z_t = \pi_0 + \pi_1 t + y_t \qquad 2.32$$

where $\pi_0 (q \times 1)$ is the optimal mean term, $\pi_1 (q \times 1)$ is the trend term and y_t is the zero-mean unobservable process such that the change in y_t is ergodic and stationary. Apart from assuming that z_t, generated from Equation 2.32, is an unobservable *q*-variate process for $t = 1,2,....,n$ no further specification of the data–generating process is placed by this method in respect of z_t, thus making it completely nonparametric (Maghyereh, 2006; Chang, *et al.*

2008). The technique is based on the generalised eigenvalues of matrices A_m and $(B_m + n^{-2}A_m^{-1})$, where A_m and B_m are defined as:

$$\hat{A}_m = \frac{8\pi^2}{2}\sum_{k=1}^{m} k^2 \left(\frac{1}{n}\sum_{t=1}^{n}\cos\left(\frac{2k\pi(t-0.5)}{n}\right)z_t\right) \times \left(\frac{1}{n}\sum_{t=1}^{n}\cos\left(\frac{2k\pi(t-0.5)}{n}\right)z_t\right)' \qquad 2.33$$

$$\hat{B}_m = 2n\sum_{k=1}^{m} \left(\frac{1}{n}\sum_{t=1}^{n}\cos\left(\frac{2k\pi(t-0.5)}{n}\right)\Delta z_t\right) \times \left(\frac{1}{n}\sum_{t=1}^{n}\cos\left(\frac{2k\pi(t-0.5)}{n}\right)\Delta z_t\right)' \qquad 2.34$$

which are computed as the sum of the outer products of weighted means of z_t and changes in z_t, where n is the sample size. To ensure invariance of the test statistics to the drift terms, the weighted functions of $\cos(2k\pi(t-0.5)/n)$ are suggested. Similar to the properties of the Johansen's likelihood ratio test, the ordered generalised eigenvalues $\hat{\lambda}_{1,m} \geq ..... \geq \hat{\lambda}_{n,m}$ that are obtained from this nonparametric test are the solution to the problem $\det[P_n - \lambda Q_n] = 0$. In order for this to happen, P_n should be defined as $P_n = \hat{A}_m$ and $Q_n = \hat{B}_m + n^{-2}A_m^{-1}$. Thus the method can be used to test for the cointegration of rank r. To estimate r, Bierens (1997, 2004) suggested two statistics. The first statistic is the $\lambda_{\min}$ test statistic $\hat{\lambda}_{q-r_0,m}$ to test for the Null hypothesis $r = r_0$ against the alternative $r = r_0 + 1$. The corresponding asymptotic null distribution is non-standard; thus Bierens tabulates critical values for the distribution after Monte Carlo simulations. Parameter *m* is also tabulated for different significance levels and for various values of r_0 and *q* in such a way that the lower end of the power of the test is maximised. The second statistic is the $g_m(r_0)$, which is computed from Bierens' generalised eigenvalues as follows:

$$\hat{g}_m(r_0) = \begin{cases} \left(\prod_{k=1}^{q} \hat{\lambda}_{k,m} \right)^{-1} \text{if } r_0 = 0 \\ \left(\prod_{k=1}^{q-r_0} \hat{\lambda}_{k,m} \right)^{-1} \left(n^{2r_0} \prod_{k=q-r_0+1}^{q} \hat{\lambda}_{k,m} \right)^{-1} \text{if } r_0 = 1,\dots, q-1 \\ n^{2q} \prod_{\mathrm{k}=1}^{\mathrm{q}} \hat{\lambda}_{k,m} \text{ if } r_0 = q \end{cases} \qquad 2.35$$

When $r_0 = q$ the optimal value of m is given by $m = q$, while when $r_0 < q$ then the optimal value of m is given by tabulated values for different significance levels and different combinations of r, q. Thus $g_m(r_0)$ converges in probability to infinity if the true number of cointegration vectors is unequal to r_0. A consistent estimate of r is therefore derived from $\hat{r}_m = \arg\min_{r_0 \leq q} [\hat{g}_m(r_0)]$.

Having determined the dimension of the cointegration space, linear restrictions on the cointegrating vectors can be tested. Bierens suggests the trace and the lambda-max statistics based on the following eigenvalue problem:

$$\det\left[H'\hat{A}_m H - \lambda H'(\hat{A}_m + n^{-2}\hat{A}_m^{-1})^{-1} H\right] = 0 \qquad 2.36$$

The test statistic engaged is $n^2 \lambda_{\max}(H)$, where the null hypothesis can be rejected if $n^2 \lambda_{\max}(H)$ is greater that the critical values as provided by Bierens (1997).

CHAPTER THREE

EMPIRICAL WORK REVIEW AND THE CONTEXT

3.0 Introduction

The relationship between inflation and stock returns was first defined in the context of the Fisher effect, also known in some literature as the Fisher hypothesis. The Fisher effect is a product of the economic theory by Fisher (1930), who sought to explain the relationship between asset returns and inflation. For most of the period from the 1930s to the 1970s this theory was the logical explanation for the stock–inflation relationship, as it solidified the notion that the asset's underlying value is maintained in the face of inflation. However, Sharpe (2002) notes that during the 1970s investors found this Fisher theory to falter in the short and intermediate term, as stock returns were negatively related to inflation. The late 1970s thus heralded a wave of research in this area, with Nelson (1976), Jaffee and Mandelker (1976), Bodie (1976), Fama and Schwert (1977) and Modigliani and Cohn (1979) all producing empirical evidence to show the negative relationship between stocks and inflation (herein after also referred to as 'the variables'). Many reasons for this negative relation were provided, with Feldstein (1980) arguing that taxation–inflation relations played a pivotal role in influencing the relationship contrary to Fisher's theory.

The most significant reason put forward in the 1980s and 1990s for the new empirical evidence was the independent effect of real economic activity to both stocks and inflation. Thus Fama (1981) argued that the direct relationship between these two variables was spurious and was explained by the inferred (Proxy) relationship between the variables and economic activity. This argument by Fama found many supporters from the 1980s through to the late 1990s, notably Geske and Roll (1983), Gultekin (1983), Vanderhoff and Vanderhoff (1986), Chang and Pinegar (1987), Kaul (1987, 1990), Lee (1992), and Lee and Ni (1996). Ely and Robinson (1997), Boudoukh and Richardson (1993), and Boucher (2006), however, criticised the Proxy hypothesis and failed to find justification for the Fama–generated explanation of the stock–inflation relationship.

In addition to the arguments by Fama (1981) and Feldestein (1980) presented herein, Modigliani and Cohn (1979) attributed the negative relationship between stocks and inflation to inflation illusion, which states that the negative relationship between inflation and stocks is a result of the use of nominal interest rates by irrational investors to discount real cash flows. The inflation illusion hypothesis, also supported by Summers (1983), Ritter and Warr (2002), Asness (2000, 2003), Campbell and Vuolteenaho (2004), Feinman (2005), and Estrada (2009), has been topical lately owing to its association with the ‘Fed Model’ of stock valuation. However, the ‘Fed Model’, which supports the inflation illusion hypothesis, has also been widely discredited recently. Boucher (2006) advocates the rejection of both the Fisher and Fama hypotheses mentioned above in favour of what he terms ‘subjective inflation risk premium’, whose view is in line with the Modigliani and Cohn hypothesis. Interestingly, though, there are a number of researchers whose papers simply criticise or disprove the aforesaid hypotheses without giving an alternative, or any reason why the relationship between stocks and inflation is either positive or negative. The value added by these empirical works is found in the use of different techniques and the use of data sets to review the relations in different economic regimes and settings.

The above overview and the review in this chapter will demonstrate that there is no conclusive evidence to date to show the real nature of the relationship between stocks and inflation. Thus supporters of the Fisher effect, Proxy and Inflation illusion hypotheses provide different empirical evidence to substantiate their schools of thought. In this chapter, therefore, these hypotheses and other competing theories will be explored with a view to lay bare the unanswered research questions. The literature review contained herein covers the period from the 1930s, when the Fisher hypothesis was put forward, to the beginning of 2009, when the writing up of this research work started. Mindful of the above-mentioned developments in the literature concerning the relations between stocks and inflation, this chapter will explore the hypotheses that sought to explain the underlying reasoning for the relationship, as well as the various arguments, methodologies, and geographical and market differences presented in the current literature.

After the literature review, an overview of the stock market will be explored as part of contextualising the research topic. Also related to setting the scene for this research is the brief history of African stock markets which are considered at the end of this chapter. The section on African stock markets will show that the markets are small apart from the South African stock market, which is ranked in the top twenty of all world stock markets in terms of size (capitalisation) and sophistication. The markets, however, are not very liquid and are dominated by foreign investor restrictions which results in constrained growth. Restrictions have been reduced, however, especially in the 1990s, when most countries experienced economic reforms. Smith *et al*. (2002) note that there is no programme of financial sector reform considered complete in Africa without the establishment of a new stock market or the rehabilitation of an existing one. Another development in the African stock exchanges, according to Irving (2005), is the introduction of new financial instruments such as mutual funds and other collective investment vehicles with a view to supporting further capital market development.

This chapter is organised as follows: Section 3.1 will look at the Fisher hypothesis, after which Section 3.2 investigates the Proxy hypothesis. The money illusion hypothesis is the third main hypothesis to be explored and it is contained in Section 3.3, while other competing theories, including the tax argument by Feldstein, are examined in Section 3.4. A stock market overview will be given in Section 3.5, before African stock markets are considered in Section 3.6. Section 3.7 presents the conclusions, which are based on the information contained in the rest of the chapter.

3.1 The Fisher hypothesis

The Fisher (1930) hypothesis, also known as the Fisher effect, (hereafter used interchangeably) states that real interest rates depend on nominal rates and inflation such that nominal rates less inflation result in real interest rates. According to Fama and Schwert (1977), this association holds in an efficient market, and can be effectively applied to all assets, including stocks, such that expected nominal return on stocks is the sum of expected real return and expected inflation. In this regard, a rise in expected inflation *ceteris paribus* would result in a rise in nominal returns in an efficient market where prices reflect current and future levels of inflation; hence the notion that stock returns and inflation move in the same direction. Nelson (1976), Fama and Schwert (1977), and Choudhry (2001) provide a summary analysis of the Fisher hypothesis through an application of this approach on the stock market. The analysis starts by looking at *ex ante* real stock returns which are the forecast level returns and are the difference between the expected nominal return on stocks and expected inflation given current information. Equation 3.1 presents this as follows:

$$r_t = E(R_t | l_{t-1}) - E(\pi_t | l_{t-1}) \quad 3.1$$

Where r_t is the *ex ante* real return on stocks, R_t is the nominal rate of return, π_t is inflation, E is the mathematical expectations operator and l_{t-1} is the information available, a lag before t. Equation 3.1 is one way of determining *ex ante* real return on stock; another way of expressing these returns is in terms of average return and the variable part of the returns thus:

$$r_t = r + \bar{r}_t \quad 3.2$$

where r is the average return and $\bar{r}_t$ is the variable part from the average return to the real return. If Equation 3.1 and 3.2 are then brought together, the resulting expression or equation would be:

$$r_t = E(R_t | l_{t-1}) - E(\pi_t | l_{t-1}) = r + \bar{r}_t \quad 3.3$$

thus, $E(R_t | l_{t-1}) - E(\pi_t | l_{t-1}) = r + \bar{r}_t$ 3.4

Taking $E(\pi_t | l_{t-1})$ to the other side of the equation, the simplified result will be Equation 3.5:

$$E(R_t | l_{t-1}) = E(\pi_t | l_{t-1}) + r + \bar{r}_t \quad 3.5$$

On the other hand, actual real rate of return can also be expressed in terms of expected values and prediction errors as follows:

$$R_t = E(R_t | l_{t-1}) + \mu_t \qquad 3.6$$

where μ_t is the prediction error for the real rate of return and is uncorrelated with the predicted value of return. If $E(R_t | l_{t-1})$ is made the subject of the formula, Equation 3.6 can be rewritten as:

$$E(R_t | l_{t-1}) = R_t - \mu_t \qquad 3.7$$

Similarly and using the concept contained in Equation 3.6, actual inflation rate can be expressed in terms of expected values and prediction errors as follows:

$$\pi_t = E(\pi_t | l_{t-1}) + \varepsilon_t \qquad 3.8$$

where ε_t is the prediction error for the inflation rate and is uncorrelated with the predicted value. If ε_t is moved to the left–hand side of Equation 3.8, the expression can be rewritten and rearranged as:

$$E(\pi_t | l_{t-1}) = \pi_t - \varepsilon_t \qquad 3.9$$

Bringing Equations 3.5 and 3.7 together using the common variable $E(R_t | l_{t-1})$, the following simplification will result in Equation 3.12:

$$E(R_t | l_{t-1}) = R_t - \mu_t = E(\pi_t | l_{t-1}) + r + \bar{r}_t \qquad 3.10$$

thus $R_t = E(\pi_t | l_{t-1}) + r + \bar{r}_t + \mu_t$ 3.11

and, $R_t = r + \beta E(\pi_t | l_{t-1}) + \eta_t$ 3.12

where $\eta_t = \bar{r}_t + \mu_t$ and according to the Fisher effect the coefficient β is unity. This is the Fisher effect equation which Fama and Schwert (1977) went on to prove was not supported by empirical data. Their findings were that expected inflation and real return do not move one on one, nor do unexpected inflation and stock returns. If Equation 3.12 is further broken down by bringing in Equation 3.9 to remove the expectation component from the inflation expression, the result will be the following equation:

$$R_t = r + \beta\pi_t + \upsilon_t, \qquad \text{where } \upsilon_t = \eta_t - \beta\varepsilon_t \qquad 3.13$$

The above expression with β as unity suggests that inflation and stock returns have a positive relationship; thus stocks maintain their value in the face of a rise in the inflation rate. Nelson (1976) notes that the properties of the compound disturbances that make up υ_t will determine the properties of the least squares estimator of r and β, while there is a positive relationship between the inflation rate and its prediction errors (ε). In addition, Choudhry (2001) points out that the relationship between inflation rate and the stock market prediction errors μ will depend on the correlation between μ_t and ε_t, and argues that the two will be correlated if stock prices react systematically to new information about inflation.

The assumption that β is unity and positive is based on the classical theory which Lintner (1974) attributes to both Fisher (1930) and Williams (1938). In the classical theory there is presupposition that real returns to stock prices will be invariant to the inflation rate, since the returns depend fundamentally upon production functions and input and output relations as well as factors which are invariant to the general price level (Lintner, 1974). The implication of this relationship, therefore, is that the present value of the flows in real returns and real capitalisation is unaffected by general price movements either expected or current. Lintner (1974) thus notes that the invariance of real values means current money values will vary in direct proportion to inflation, making nominal capital gains on unlevered equity equal to the rate of inflation; thus β in Equation 3.12 is assumed to be unity and positive.

Fraser (1993) supports this belief in economic theory by looking at the relationship between income, inflation, turnover, costs and profits. He says rising real incomes mean that firms face rising demand for goods and services, enabling them to recover increased costs by raising their prices. If the demand for goods and services do increase, this in turn results in an increase in turnover, which would eventually translate to an increase in profits for the firm. Since share price is directly affected by movements in achieved profit, then the turnover increase would result in share movement and, if this increase is more than what was achieved in the previous period, then a positive relationship between inflation and share price would be achieved. Fraser argues that in the 1950s and early 1960s, inflation seemed to be caused predominantly by 'demand–pull' pressures, whereby rising demand for goods and services enabled firms to raise prices and make higher profits. An initial reaction to this analysis is that it assumes that cost of providing services and producing goods was static. However, Fraser acknowledges the effect of costs by pointing out that "…costs rose as well, particularly wages, but wage rises tended to follow the price rises and, in times of rising demand, cost increases could be recovered by further price increases and increased efficiency of production." (Fraser, 1993, p. 94).

The theoretic reasoning offered above will not adequately explain the relationship in the face of cost–push inflation, but will be supported by the monetarist view of the causes of inflation.

Inflation driven by cost–push factors, especially those which are not wage related, may induce a reduction in profit margin to ensure company goods and services remain competitive and affordable. Such decrease in profits will eventually bring down company share prices; thus a negative relationship between inflation and stocks will be achieved in this case. Since the competitive nature of industry in the production and provision of services has evolved from monopolistic tendencies of the past to supplier diversity, the notion of keeping prices competitive and affordable is modern; thus Fraser's assessment can be considered appropriate for the period and conditions at play then.

The Fisher Effect, which is rooted in economic theory, reflects the classical economist's concentration on long–run comparative static equilibrium denominated in real terms of exchange, independent of current levels of money prices which depend on actions of monetary authorities by way of the classical Quantitative Theory of Money (Lintner, 1974). The long–run justification of the Fisher effect is empirically proved by Boudoukh and Richardson (1993), who found the relationship between stocks and inflation to be positive using UK and USA data from 1802 to 1990. Their study also confirmed that while the Fisher hypothesis is based on *ex ante* stock returns, *ex post* returns can also be interpreted in the same way. The UK empirical evidence on the relationship between stocks and inflation, as noted in Gultekin's (1983) research on different international stock markets, has predominantly been positive. Thus, the interesting component of the research by Boudoukh and Richardson (1993) is the empirical evidence from the USA, which was found to be negative by Fama (1981) and the rest of the Proxy hypothesis empirical researchers.

Ely and Robinson (1997) carried out research on sixteen industrialised countries, and their results indicated that stocks do maintain value relative to movements in inflation and, like Boudoukh and Richardson (1993), they argued that the evidence of a negative relationship is based on the use of models that do not capture long–run relationships. Their conclusions also found that the relationship does not depend on the source of the inflation, whether it comes from real or monetary sources. These findings are contrary to empirical work done prior to their research, which suggested that the relationship might depend on the source of the inflation. Using the vector correction models to account for long–term relationships, the relationship is confirmed as positive. This conclusion raises the question of whether the number of years considered in the analysis of this relationship is important.

Anari and Kolari (2001) used stock prices and inflation data in six industrialised countries, pointing out that the time path of the response of stock prices to a shock in goods exhibits an initial negative response which turns positive over long horizons. In addition, their research reveals that stocks have a long memory with respect to inflation shocks; thus they are a good inflation hedge over a long holding period. Lintner (1974) dismissed this notion of the length of data by pointing out that statistical analysis of data covering the first three quarters of the twentieth century uniformly shows that both nominal and real rates of return on stocks had been negatively and very significantly related to the inflation rate. The challenge with the analysis by Lintner is that it did not use techniques which capture long-run dynamics such as cointegration.

Apart from the influences of expected and current values of inflation, Choudhry (2001), who used stochastic structural tests, found that past inflation levels have a bearing on current stock price changes. This is a departure from the above economic theory and empirical work whose interests focused primarily on expected and current inflation level; thus the relationship and indeed the significance of inflation to stock market prices is cemented. Choudhry (2001) made these findings when he looked at the relationship between inflation and stock returns in four high–inflation Latin and Central American countries and concluded that there is a positive relationship between the two variables. His conclusion is in unison with Ely and Robinson's (1997) finding that inflation moves in the same direction as stock market prices, but more important for investors is the fact that stocks are a good hedge against inflation, and hence a retention of value. Henry (2002), who worked on twenty one predominantly emerging markets that experienced disinflation, states that the stock market appreciates by an average of 24% in real dollar terms when countries attempt to stabilise high annual inflation rates of more than 40%. Choudhry's conclusions, (2001) though, bring out the issue of inflation rate announcement dates. Thus the one-month lag relationship could be an indication that using month–end results to ascertain the relationship could be questioned.

To counter the notion that the positive relationship between inflation and stocks is sector based, given that Lintner (1974) and Fraser (1993) use predominantly the production sector to infer on the relationship, Luintel and Paudyal (2006) looked at the relationship from the cross sector angle. They tested whether UK common stocks hedge against inflation using a framework of the tax–augmented Fisher hypothesis. The cointegration analysis was used on seven industry groups and monthly data covering forty–eight 48 years, and the results showed that point estimates of the goods elasticity were significant above unity in five of the sectors. The exceptions in this case were the mineral extraction industry, which showed below unity price elasticity, and investment trusts, which showed unity elasticity. This inflation hedge paradigm is supported by Anari and Kolari (2001) who showed that long-run Fisher elasticity of stock prices with respect to inflation exceed unity and range from 1.04 to 1.65 in the following countries: UK, USA, Canada and Japan. Luintel and Paudyal (2006) noted that their results were plausible because nominal returns from stock investment must exceed inflation rate to fully insulate tax–paying investors, failure to which real wealth losses will be realised.

3.2 The Proxy hypothesis

The view that inflation and stocks are positively related as defined by the Fisher Hypothesis was questioned by Tobin (1969), Branch (1974) and Lintner (1974) but, more importantly, Nelson (1976), Jaffee and Mandelker (1976) and Bodie (1976) empirically ignited the contrary discussion. As noted earlier, economic theory before the 1970s held the position that there was a positive relationship between inflation and stock market prices, and this position drew its strength from the rationale that stocks ought to at least maintain their value during inflationary periods. However, contrary to the then held belief among economists on this stock value preservation rationale Bodie (1976), who looked at USA data and empirical work between 1953 and 1972, found that the real return on equity was negatively related to both anticipated and unanticipated inflation, in the short run. This result by Bodie was also confirmed by Fama and Schwert (1977), whose study considered both expected and unexpected components of inflation by looking at the variables' relationship in the USA between 1953 and 1971. Their empirical evidence demonstrated that common stocks were rather perverse as a hedge against inflation.

The justification of this empirical evidence was attributed to the Proxy effect by Fama (1981), who acknowledged that the negative relationship is puzzling given the accepted wisdom that common stock, representing ownership of the income generated real assets, should be a hedge against inflation. In accordance with the Proxy effect, the negative inflation and stock return relations are proxying for the positive relationship between stock returns and real variables which Fama (1981) argued are more fundamental determinants of equity values. The negative relations are induced by the negative relationship between the real economy and inflation, owing to both the money demand theory and the quantity theory of money (Fama, 1981). In his paper, which used monthly, quarterly and annual data from the USA between 1953 and 1977, Fama concluded that there was evidence that real stock returns positively related to measures of real activity like capital expenditure, average real return on capital and output, which reflected the variations in the quantity of capital investment with expected return in excess of costs of capital. Furthermore, he noted that the anomalous stock return and inflation relations are strongly related to measures of future real activity, and this is consistent with a rational expectations view in which markets for goods and securities set current prices on the basis of forecasts of relevant real variables. Ram and Spencer (1983) note that the Proxy hypothesis is a three–step procedure. First there is the need to estimate two sets of the inflation regression to show the negative inflation and real activity relations. One of the regressions is derived from the money demand equation and the other is based on the rational expectations theory in the same form as the Fisher-type equation. The objective of the second step is to show the positive relationship between stock returns and real activity; thus it estimates the regressions on capital expenditure functions and real stock returns. For the third step, the intention is to demonstrate that inflation is not negatively related with stock returns, and this is achieved by holding real activity constant in a stock return regression, with inflation and real activity as variables. The result is a demonstration of the inference in the expected inflation and stocks returns relations. This has led to a new school of thought about the interaction of these variables which is now commonly known as the Proxy hypothesis.

In an economy with a long–run vertical supply curve, demand shocks have little or no impact on the future of output growth, while the inverse is also true for supply shocks (Gallagher and Taylor, 2002). Given this economic reality, Gallagher and Taylor argue that only inflation which is induced by supply shocks should act as a proxy for expected future movements in real activity. This observation thus calls for the decomposition of the inflation data to reflect its drivers. Thus, inflation is broken down to reflect the drivers generated by supply shocks or those from demand shocks. Using multivariate innovation decomposition and quarterly data between 1957 and 1997, Gallagher and Taylor confirmed the Proxy hypothesis, but based on the evidence that only the component due to supply shocks is negative and significantly correlated with stock returns. The evidence also showed that stock returns were insignificantly correlated with the inflation rate which is purely derived from demand innovations.

Geske and Roll (1983), who subscribe to the Proxy hypothesis, strengthen the Proxy hypothesis by showing that the spurious negative relationship between stocks and inflation is driven by a chain of macroeconomic events which result in a higher rate of monetary expansion. Geske and Roll state that this chain starts with a random negative real shock which affects stock returns. This in turn this signals higher unemployment and low corporate earnings. The low corporate earnings and unemployment induce a fall in personal and corporate tax revenues and this happens without an adjustment in the government expenditure, hence an increase in treasury deficit. To cover this deficit, an increase in the borrowings by treasury becomes imminent, as well as an expansion in money supply, which ultimately induces a rise in the inflation rate. The analysis implies that a decrease in economic activity will result in expected growth in money supply and thus large increases in inflation (Stulz, 1986). According to Chang and Pinegar (1987), Fama (1981) and Geske and Roll (1983), models suggest that the stock and inflation relation varies systematically with security risk, and they support this notion through the analysis of American data from 1952 to 1982. James, Koreisha and Partch (1985) find support for the Geske and Roll money supply explanation when they examined the causality links between stocks, real activity, inflation and money supply using a vector autoregressive-moving average (VARMA) model. They found evidence that stocks signal both changes in real activity and changes in the monetary base, which suggests a link between money supply and real activity (Lee, 1992). However, Lee (1992) noted that, as observed by Mehra (1978) and Sims (1980), the causality relations used by Geske and Roll (1983) are based on a bivariate causality test and may not be robust when other variables are introduced into the vector autoregressive (VAR) system. Thus James, Koreisha and Partch's (1985) VARMA model might be more appropriate.

Kaul (1987) also argued that Geske and Roll (1983) did not analyse the money supply process completely because a procyclical monetary policy is either positively related to or has no relation with inflation. Thus, the explanations contained in Geske and Roll (1983) would be relevant when the government embarks on a reactive monetary policy which either addresses unemployment, foreign currency shortages or a deficit in the treasury; hence a shortcoming of the Geske and Roll explanations of the proxy relation between inflation and stocks. To give a more robust explanation to the Proxy hypothesis relationship, Kaul (1987) argued that it depends on the equilibrium process in the monetary sector, thus placing the importance of demand and supply factors of money in the relationship. While this seems to suggest that Kaul's conclusions reflect a negative relationship between stocks and inflation, the inference is that it could either be positive or negative depending on money demand and the cyclical nature of the monetary policy. In this regard, Kaul hypothesised that if money demand effects were coupled with monetary responses that are procyclical, stock return and inflation relations would be either insignificant or positive. In this empirical analysis, growth of money was related to government deficit, unemployment rate and lags of money growth, with deficit said to induce countercyclical monetary policy hence a negative relationship. Kaul (1990) reinforced this reasoning to the Proxy hypothesis by concluding that countercyclical monetary policy induces stronger negative relationships than procyclical and neutral monetary regimes. Ely and Robinson (1992), however, found no evidence to support these various policy regimes to explain the relationship between stocks and inflation.

Apart from Kaul's research, most of the Proxy hypothesis findings contained above are based on USA evidence. Thus Spyrou (2001) investigated the relationship in an emerging market using the regression models as well as cointegration techniques to arrive at his conclusions. His findings, based on data from the emerging market of Greece between 1990 and 2000, were that the stock–inflation relations in the first half of the decade were a strong negative relationship, and in the second half statistically insignificant figures were noted. The reason for this difference is attributed to the role of monetary fluctuations (rather than real activity) influencing inflation levels. In order to examine the relationship between stock prices and inflation, Spyrou's study tested for cointegration among the variables using the Johansen technique, and tests showed that the first difference was stationary and thus the series were candidates for cointegration. Spyrou (2001) noted that the results of this study were consistent with conclusions made by Marshal (1992) which showed that the negative relationship between stock and inflation is influenced by monetary fluctuations. While this research confirms the earlier submission about the influences of monetary policy on the relationship between the variables, conclusions from one country represent a bias and cannot be used with confidence to infer the relationship in all emerging markets, nor, indeed, in the world generally.

Guitekin (1983) investigated twenty–six countries over thirty–two years from January 1947, using data from International Financial Statistic (IFS) and Capital International Perspective (CIP). He employed regression models estimated by using contemporaneous rates as proxies for expected inflation, autoregressive integrated moving average (ARIMA) models to derive expected inflation and short-term interest rates as predictors of inflation. Cross–sectional data was also considered to appreciate the relationship between inflation and stock market returns.

Using time series regressions, Guitekin (1983) concluded that there was no reliable positive relation between nominal stock returns and inflation rates for the period between 1947 and 1979, with evidence showing a negative relationship between stocks and inflation in most countries except for the United Kingdom. While he found the regression coefficients to be negative, the stock returns–inflation relation was discovered not to be stable over time and was different between countries, with results from the UK continuously positive and different from the rest. Graham (1996) also found the relationship between stocks and inflation to be unstable throughout the post–World War II era, in the sense that it was negative before 1976 and after 1982, but positive in between these years. "Real stock return-inflation relation should be negative only when variation in money demanded is not accommodated by offsetting variation in nominal money growth i.e. procyclical monetary policy," (Graham, 1996 p. 29). This finding raises questions about the effect of economic or monetary regimes on the relationship, and adds the dimension that the stock–inflation relations could be cyclical and induced the changes in monetary policy.

Partial confirmation of and modification to the Proxy hypothesis are documented by Ram and Spencer (1983), Hasbrouck (1984), Stulz (1986), Lee (1992) and Lee and Ni (1986). Ram and Spencer (1983) question the rationale of the view that inflation and real activity are negatively related in the Proxy hypothesis, given the Phillips curve, which hypothesises positive relations. In this context, Ram and Spencer show that inflation and stock relations instead proxy a reverse of Fama's hypothesis and explanation of the inferred relations. They suggest that the negative relationship is a result of the relations in the Phillips curve and the negative relations between stocks and output which is in line with the Mundell–Tobin effect. However, Lee

(1992) states that the measure of real activity adopted by Ram and Spencer (1983) is current output, whereas Fama's theory is based on future output. In addition to the above limitation to Ram and Spencer explanation of the Proxy Hypothesis, output is not the only measure of economic activity, as demonstrated above by Geske and Roll (1983), who propose that government deficit plays a role in the chain (Lee, 1992).

Research findings from the Proxy hypothesis and, indeed, most confirmations thereof, use *ex post* data for their evidence, in particular proxy variables to infer expected inflation levels. However, Hasbrouck (1984) noted that the strength of such findings were in part due to the proxy used, and thus propose the use of Livingstone Surveys as the measure for expected inflation. Gultekin (1983a) also used Livingstone Surveys and found a negative relationship between expected inflation and actual stock returns, though these findings were insignificant. Hasbrouck (1984) found a slight negative relationship between expected economic activity and expected inflation in quantity theory estimation; however, there is no significant simple bivariate relationship. For the stock–economic activity relations, a positive sign in the coefficient of the dependable variable is noted. The conclusion from this evidence, therefore, is that Fama's Hypothesis is less strong when survey data is used to determine expected variables of this stock–inflation puzzle. Having noted these findings, it is important to mention that the use of data from the Livingstone Survey, however, has been criticised by Lakonishok (1980) and this questions the robustness of these results.

Stulz (1986) provides an equilibrium model in which expected real returns that are endogenously determined on market portfolio of risky assets are negatively related to expected inflation and money growth. The evidence is in support of the Fama hypothesis as well as the findings presented by Geske and Roll's (1983) view of the negative relationship between stock returns and inflation. Stulz provides a theoretic framework explaining these relations by noting that an increase in expected inflation, irrespective of its origin, results in the fall of real wealth of households because of the increased opportunity cost of real balances and the decrease in households' holdings in real balances. To keep the stock capital invested in production, which Stulz equates to households' desired holdings of nominal assets, the default-free nominal interest rate and cash must fall by the same margin as the desire by households to hold real balances, and this can be achieved though a decrease in real rate of interest. The fall in interest rates thus makes the investment in nominal assets less attractive to invest in compared to investment in production (Stulz, 1986). The result, according to Stulz, is that the decrease in real wealth caused by a rise in expected inflation results in households choosing a portfolio of investments in production with a lower mean and a variance of return. The model thus predicts a negative correlation between expected inflation and *ex ante* real stock returns, but Marshall (1992) stated that the model does not provide evidence as to whether the predicted negative correlation is large enough to match the data. Moreover, it fails to reconcile the negative relationship between stock returns and inflation with the positive correlation between returns and money growth.

The final weak support for the Proxy hypothesis provided herein is by Lee (1992) and Lee and Ni (1996). Lee (1992) used multivariate VAR on post–war USA data between June 1947 and December 1987 to determine the causal relations among stock returns, interest rates, real activity and inflation. The findings show that stock returns help explain significant movements in real activity which respond positively to stock return shocks, but with interest rates in the VAR, stock returns explain little variations in inflation rate, contrary to findings by James, Koreisha and Partch (1985) which are compatible with the original Proxy hypothesis (Lee, 1992). Furthermore, Lee finds no support for the inflation–economic activity hypothesis, given that inflation explained little variations in real activity movements which, however, responded negatively to inflation shocks. These results question the reliability of the negative inflation–stock relations findings,, given the weak evidence of the causal interactions. In a subsequent paper with Ni, Lee further examined the Fama hypothesis and noted that persistent inflation has a stronger effect on future output than temporary inflation. The decomposition of inflation into persistent and temporary elements, using a filter model, was based on the intuition that future economic activity can be more sensitive to persistent movements on inflation than to temporary ones, as an increase in persistent inflation predicts slower future real activity and a consequent fall in stock returns (Lee and Ni, 1996). Moreover, Lee and Ni (1996) state that an increase in temporary inflation induces investors to shift portfolios from stocks to interest–bearing liquid assets because a rise in temporary inflation decreases the relative attractiveness of stocks even though market present value of future cash flows is unchanged. The findings of this research show that both persistent and temporary inflation are negatively correlated with stock returns, though with different patterns. However, the inclusion of output does not suggest the presence of a proxy relation, especially when temporary inflation is considered. These results further bring into question the reliability of the Fama hypothesis which is based on the significance of the relationship between inflation and future output.

3.3 Inflation illusion hypothesis

Another empirical hypothesis that was developed after the discovery of the negative relations between inflation and stock returns in the 1970s is the Inflation Illusion hypothesis developed by Modigliani and Cohn (1979). According to Basu *et al*. (2005), the inflation illusion hypothesis is a version of the money illusion coined by Fisher (1928), which was defined as a bias in the assessment of real value of transactions, induced by nominal representation (Shafir *et al*., 1997), but mostly used to explain slow adjustments of nominal prices and wages to money supply shock. The Inflation Illusion hypothesis states that investors fail to understand the effect of inflation on nominal dividend growth rates (Campbell and Vuolteenaho, 2004; Chordia and Shivakumar, 2005; Basu *et al*., 2005; Cohen *at el*., 2005) and hence extrapolate historical nominal growth rates during inflation. Cohen *et al*. (2005) attribute this behaviour of investors to the difficulty in estimating long–term future growth rates of cash flows, and Akerlof (2002) states that the cost of incorporating inflation in forecasting earnings are too high relative to the benefits of improving the accuracy of the forecast. If accuracy of the forecast is to be compromised, then growth of dividend is usually related to the relationship between inflation and the growth of output measured through time-averaged growth rate of real per capita output and supporting the negative relationship between the two variables (Levine and Renelt, 1992; De Gregorio, 1993; Fischer, 1993; Barro, 1995; and Crosby and Otto, 2000). Crosby and Otto (2000), however, note that the existence of a negative long–run relationship between output growth and inflation does not necessarily imply that persistent inflation lowers the capital stock.

The above explanation of the Inflation Illusion hypothesis can easily be taken in the context of the Proxy hypothesis, which looks at the relationship between economic activity and inflation. The difference is, however, that with the inflation illusion the relationship is not inferred but is a result of the effect of inflation on the components of the Gordon's growth model. Ritter and Warr (2002) outline four areas which drive the inflation illusion hypothesis, namely: the debt capital gains error, the capital rate error, disintermediation and the valuation errors in the literature. The following paragraphs that explain these four areas are based on the work by Modigliani and Cohn (1979), Ritter and Warr (2002), Asness (2000, 2003) and Campbell and Vuolteenaho (2004), and are a function of the dividend growth model which is classically known as the Gordon Growth Model (Williams, 1938; Gordon 1962). Thus:

$$P_0 = \frac{D_0(1+g)}{Rf + Rp - g} = \frac{D_1}{Rf + Rp - g} \qquad 3.14$$

Where:

P_0 is the intrinsic stock value

D_0 is recently paid dividend

D_1 is dividend to be received at the end of the first year

$Rf + Rp$ is the risk–adjusted interest rate, with Rf as the risk–free rate and Rp as the risk premium

g is the dividend growth rate.

Given the above model, an increase in inflation is expected to influence the movement of interest rates (Rf). Thus the denominator will increase, thereby reducing the price (P_0) of the stock, and this is considered the capital rate error. Inflation, however, also affects growth of dividends (g), which Ritter and Warr (2002) note will increase as inflation increases, and thus will have the effect of reducing the denominator of the above equation, leading to an increase in the price of stocks.

The effect of inflation on both the rate of return and the growth of dividends is considered by Modigliani and Cohn (1979) to have a neutralising effect on the price of stocks. The misvaluation therefore happens because investors do not consider the effect of growth and only use the increases in bond yields as if they were the rates of return. Thus Cohen *et al*. (2005) note that if an optimising investor suffers from money illusion, higher nominal interest rates resulting from inflation are used by stock market participants to discount unchanged expectations of future nominal dividends. Ritter and Warr (2002) point out that the failure to incorporate nominal earnings growth will result in the undervaluation of stock market prices when inflation increases. According to Bodie *et al*. (2005), in terms of this simple constant-growth-rate model, an increase in inflation is associated with a decrease in dividend (D_1), an increase in the risk–adjusted interest rate $(Rf + Rp)$, a decrease in dividend growth (g), or some combination of all three. The argument associated with the risk–adjusted interest rate $(Rf + Rp)$ is that a rise in the rate of inflation increases uncertainty about the economy, and this tends to induce a rise in the risk premium (Rp) due to both systematic and unsystematic risk, and hence an increase in the level of the required rate of return on stocks. Since movements in $(Rf + Rp)$ will increase the denominator of Equation 3.14, the result is a decrease in stock market prices. Hence the perception that the higher the rate of inflation, the riskier the stocks returns become. Bodie *et al*. (2005) also argue that another school of thought believes that economic ‘shocks’ such as oil price hikes can cause a simultaneous increase in the inflation rate and decline of expected real earnings (and dividends). Fama (1981) says that this would result in a negative correlation between inflation and real stock returns.

If corrected for dividend growth, the above submission suggests that dividend earnings within a market will move homogeneously with changes in the inflation rate. Basu *et al*. (2005), whose study examined whether financial analysts’ earnings expectations fully incorporate information about expected inflation, realise that the sensitivity of individual firms will likely vary through time. Their study is motivated by two market realities. First, the analysts’ expectations offer inflation illusion evidence beyond stock returns testing because they can be viewed as proxies for unobservable investor expectation. Second, the competition in selling forecasts to the market among financial analysts’ who are sophisticated financial information users, means investigating the full use of such information in their forecasts offers proof of the rationality of these agents. Following the work of Chordia and Shivakumar (2005) in analysing portfolios formed by sorting stocks on a proxy for earning growth labelled standard unexpected earning (SUE), Basu *et al*. (2005) conclude that SUE–based hedge portfolios have significantly positive earnings exposure to concurrent inflation. They also show that common proxies for expected inflation, such as lagged inflation, and forecasts from the Michigan Survey of customers predict the expected earnings growth of SUE–based hedge portfolios. Despite such findings, analysts were found not to fully use this predictive information on the expected inflation when forecasting future earnings (Basu *et al*., 2005). The implication of this is that the accuracy of future earnings forecasts is compromised, thus affecting the interaction within the Gordon Growth Model and increasing the inflation illusion syndrome.

Another cross-sectional approach is offered by Cohen *et al*. (2005), who consider the dividend–price ratio in ascertaining the rational and irrational investor behaviours in a stock market. The dividend–price ratio is stated below as Equation 3.15:

$$\frac{D_{t+1}}{P_t} = R - G \qquad 3.15$$

Where, D_{t+1} is future dividend, P_t is current price, R is long-term discount rate and G is long-term dividend growth rate. The pricing miscalculation in this case is a result of investors using mixing nominal rates and real rates for the discount rate and the growth rate, which is not consistent with the model. In this case, Cohen *et al*. (2005) consider excess discount rate and growth rates by subtracting riskless interest rate from both the discount rate (i.e. $R^e \equiv R - Rf$ and growth rates $G^e \equiv G - Rf$). In their support of the Modiglian and Cohn (1979) hypothesis they follow the work of Campbell and Vuolteenaho (2004) to distinguish between subjective expectations of irrational investors (herein after superscripted SUB) and objective expectation of irrational investors (herein after superscripted OBJ). Thus:

$$\frac{D}{P} = R^{e,obj} - G^{e,obj} = R^{e,sub} - G^{e,sub} = -G^{e,obj} + R^{e,sub} + (G^{e,obj} - G^{e,sub}) \qquad 3.16$$

The implication of Equation 3.16, according to Cohen *et al*. (2005), is that dividend yield has three components: first, the negative of objective expected excess divided growth; second, the subjective risk premium expected by irrational investors; and third, the mispricing term which is induced by the divergence between the rational and irrational growth forecast. Thus the dividend growth rate mispricing error specified in terms of excess yields is $G^{e,obj} - G^{e,sub}$, with $\varepsilon < 0$ indicating overpricing. The results of the empirical work by Cohen *et al*. (2005) show that money illusion will have a constant additive effect on all future stock returns regardless of the exposure to systematic risk. This noted constant effect is not consistent with the impact of investor risk attitudes on future stocks, which Cohen *et al*. (2005) note is proportional to the stock's risk, as risky stocks' future returns will be affected much more than safe stock's future returns.

Another error that is induced by the investors' inflation illusion is that of debt capital gains, which Ritter and Warr (2002) argue is less obvious to investors and they consider that inflation has two effects on nominal debt instruments. The first of these effects is that unexpected increase in inflation results in the movement of funds by investors from bonds to stock of levered firms. The second effect of inflation on nominal debt instruments is that an expected inflation rise will induce a transfer of funds from bond markets to stock markets as inflation erodes the real value of bondholders' assets. Ritter and Warr (2002) note that debt is decreased in real value by inflation, but bondholders are compensated by inflation premium in the nominal interest rate they charge the firm. Thus, an increase in nominal borrowing cost will result in a net decrease in the net income for the firm, while a decrease in net income is offset by real decrease (Ritter and Warr, 2002) in real value of nominal liabilities. This Ritter and Warr (2002) illustrate in the following relationships, assuming a zero real growth in the firm and that all earnings are paid out as dividends:

$$EPS = (1-T)[X - RDt] = (1-T)[X - rD - pDt] \qquad 3.17$$

Where EPS is the expected earnings per share, T is the corporate income tax, X is the operating income per share, Dt is the debt per share, p is the inflation rate and, assuming debt is replaceable on demand, then when inflation changes R, which is the new real interest rate, will be represented by $R = r + p$ (thus old interest rate plus inflation). The difference between the first and the second sections of the expected earnings per share (EPS) calculation is that the last part (second) has an inflation component that affects it such that an increase in the firm's debt will increase $(1-T)pDt$, hence the more the firm's EPS will be reduced by inflation. Ritter and Warr (2002) further submit that if inflation is neutral, the basic earning power of the firm remains unchanged in real terms and the level of operating income will increase with inflation $X_1 = X_0(1+p)$. Therefore, the value of the firm's assets must increase at the rate of inflation to support this increase in nominal profitability, illustrated as follows:

$$FV_0 = V_0 + De_0 \qquad 3.18$$

$$FV_1 = FV_0(1+p) - pDe_0 = V_0(1+p) + De_0 \qquad 3.19$$

where FV_0 is the firm's value at time $t=0$ and FV_1 is the firm's value at $t=1$; De_0 is the debt of the firm at $t=0$ and De_1 is debt of the firm at $t=1$; V_0 is the value of equity and p is the inflation rate. The first equation represents the value of the firm, which is total equity and debt. At $t=1$ (Ritter and Warr, 2002), prior to any debt issue but after nominal interest and dividend have been paid, the value of the firm would have grown by the inflation rate less the inflationary component of the nominal interest expense pDe_0, and this is represented by the second equation. Thus, to maintain the same debt–equity ratio the firm must issue incremental debt.

The final, and possibly most controversial proposition inferred by the Inflation Illusion hypothesis and in the above submissions, relates the yield on stocks to the yield on nominal bonds (Campbell and Vuolteenaho, 2004). This relationship is now famously known as the

'Fed Model' of stock pricing and Estrada (2009) notes that the negative relations between stock market price–earnings ratio and government bonds yields seems to have become conventional wisdom among practitioners. The implication of this relationship is that when the Treasury bond yields increase, stock market yields will also have to rise in order to remain competitive in a tight investment market. Campbell and Vuolteenaho (2004) state that practitioners argue that bond yields plus risk premium equate to nominal yield on stocks, and that actual stock yield tends to revert to this normal yield. This relationship does not, however, incorporate the effect of dividend growth rate, which in this case is implied not to exist thus promoting the Inflation Illusion hypothesis. The inferred suggestions are that when stock yields better bond yields they become attractive, as they are considered underpriced. Given these indications, the 'Fed Model' is considered an empirical success in describing stock pricing when evaluated using bond yield movement (Asness, 2000, 2003). However, as a behavioural description of stock, there is serious difficulty with its rational explanation of stock pricing (Ritter and Warr, 2002; Campbell and Vuolteenaho, 2004; Estrada, 2009). Astrada (2009) finds the 'Fed Model' to be flawed from a theoretical standpoint, and this is demonstrated using data from twenty countries, where he found it to be a failure as a normative and a positive model of equity pricing. The model, according to Asness (2003), erroneously compares real magnitude of earnings–price ratio to nominal government bond yields.

3.4 Competing theories

Using likely values of the tax and financial variables, Feldstein (1980) attributed the negative relationship between stock returns and inflation to the higher effective rate of tax on corporate income caused by historic-cost depreciation and the tax on the artificial capital gains caused by inflation, which reduce the real net yield that investors receive per unit capital. The implication is that higher inflation results in lower real dividends because the US tax system results in lower after-tax real earnings as the inflation rate rises. Thus taxation is related to depreciation, and capital gains is affected by inflation, which in turn affects real asset valuation (Jung *et al*., 2007). Lee and Ni (1996) note that this tax burden theory is attractive for periods of high and persistent inflation, since it implies that inflation increases the tax rate, thereby depressing output. Fama (1981) argues that taxes could not be responsible for the fall in real share values in the 1960s, when inflation increased in the USA, because the ratio of taxes to gross income does not support this notion. It is also not surprising that within a year of its submission the Feldstein tax burden model of share valuation drew serious criticism particularly from Friend and Hasbrouck (1982), who showed that the implied impact of inflation upon equity share in the Feldstein model is dependent on values assumed for critical parameters, notably the effective capital gains tax rate. They provided proof that the capital gains figures used by Feldstein are solely long–term values, that short–term capital gains are omitted and that the contribution of 0.15 to the present value of capital gains tax rate that will be paid in the future upon sale of the stock seems greatly exaggerated and may be closer to 0.05 instead. The tax burden model as an explanation of inflation and stock returns relations is much localised and at best explained the specific period which Feldstein sought to review. The fact that the tax laws are not homogeneous casts doubt on the credibility of the model as a platform or basis to explain the negative relationship within the international context. Given these challenges to the model, it is not surprising that it has not been a popular force in explaining the negative relationship between stock returns and inflation.

Another model that sought to explain stock–inflation relations is provided by Friedman (1977) when looking at the relationship between inflation and unemployment where he argues that inflation uncertainty is positively related to the level of inflation with uncertainty depressing future output because it discourages investment (Ball, 1992; Lee and Ni, 1996). The implication from this model, which is also supported by Malkiel (1979) and Friend (1981), is that, since inflation and inflation uncertainty are positively related, a rise in the inflation rate results in depressed prospects for output and thus a reduced dividend growth forecast which affects the denominator of the Gordon Growth Model. A closely related account of this model is provided by Mascaro and Meltzer (1993) who also find a positive relationship between inflation and inflation uncertainty and that a rise in uncertainty increases the demand for money, which in turn results in a decrease in demand for stocks, hence the negative relationship. While these relationships are noble in their inference of the stock–inflation relations, the model cannot be relied upon in stable inflationary environments. Moreover, in deflationary environments the expectation is that the inflation uncertainty will be reduced, but this depends on the level of the inflation rate and the degree of fall. If the fall in the rate is huge, all other factors remaining constant, the inflation expectations may not be clear, and instead of reduced inflation uncertainty such a fall might attract increased inflation uncertainty. In the context, this model may best define inflation–stock relations in high and volatile inflation environments rather than in areas of stable and low inflation. The introduction of inflation targeting has not helped either because inflation is now at the core of monetary policy decision making. Thus inflation uncertainty is a concern in the short term rather than the long–term where government policy is expected to provide direction.

3.5 The stock market

In this section we look at the stock market, which is sometimes referred to as the equities market. The first part explores stock ownership and the stock market in general. The second part examines the types of stock index that exist, as well as the forms of trading within the market. Companies issue shares which define the main part of their ownership structure, and these shares, also known as stocks, are either offered to the public when the company is listed or to individuals for privately owned entities. Reilly and Brown (2003) add to this definition by saying that equities are an ownership of a firm, with full participation in its success or failure. Companies issue shares to raise money to buy fixed assets or to enter into a business venture rather than use it for recurrent expenditure. A share, according to Hoesli and MacGregor (2000) is a paper asset which, as the name suggests, carries with it a share in the capital and income of the company and a share in the management of the company through voting rights proportional to the number of shares held. Ross *et al*. (2005), on the other hand, note that the term “common stock” has no precise meaning, and is usually applied to stocks that have no special preference in either dividend or bankruptcy, and where the stockholders receive certificates with a stated value of each share called “par value”, which is normally lower than the market value of the stock. Common stocks of a listed company can be bought or sold freely on the stock exchange and the income for ownership is paid in the form of a dividend. Since a dividend is not guaranteed in either real or nominal terms, Hoesli and MacGregor (2000) point out that it depends primarily on the profitability of the company and on the policy of its directors. As owners of the firm, stockholders indirectly make the dividend policy and other operational decisions through directors whom they choose at their annual general meetings (AGM), using their voting rights. While directors work in the interest of shareholders, between these meetings sometimes they make decisions that are not in the shareholders' interest, thus creating an agency problem. To counter this challenge, stockholders limit the decisions which the directors can make on their behalf to ensure some level of control.

According to Bodie *et al*. (2005), the most important characteristics of common stock as an investment vehicle is its residual claim and limited liability features. Residual claim means that stockholders are the last in line of all those who have a claim on the assets and income of the corporation. During the liquidation of the firm's assets, the shareholders have a claim to what is left after all other claimants, such as the tax authorities, employees, suppliers, bondholders and other creditors, have been paid. The limited liability feature indicates that the most shareholders can lose in the event of failure of the corporation is their original investment. Unlike owners of unincorporated businesses, whose creditors can lay claim to the personal assets of the owner, corporate shareholders may at worst have worthless stocks. Preference shares are another form of firm ownership similar to common stocks, but they are paid before profit and their rate of return is a fixed percentage of their nominal values. If the company makes no profit, no dividend will be paid, but Stanlake (1988) says there is a class of cumulative preference shares whose holders will receive payment of any arrears of dividends when the company has a profitable year. In the event of the company being liquidated, however, preference shareholders will be considered before the common stockholders, as they are considered creditors of the firm.

There are many reasons why a stock price could change, varying from company news to the economic or political situation within which the company operates. The factors are commonly subdivided into macro factors which are national factors affecting either a sector or the whole index of stocks, and micro factors which consider company level issues. It is important to note that the factors presented here are not exhaustive, and merely highlight the main issues within this subject area. In line with the above submission, macro factors that affect stock prices are broader and would include world stock price determinants. In the majority of cases macro factors affect either the revenue potential of the firm or its costs, thus contributing to either a decrease or increase in profit from which dividends used in the calculation of stock prices are derived. Fraser (1993) states that the increase in internationalisation of trade and finance has meant that firms are now affected by changing conditions in the world economy. Globalisation has meant that goods produced can now be sold in other countries and markets, especially with more countries removing or reducing trade restrictions, thus increasing the market of a company. Selling goods and services outside borders, however, has its own challenges for instance the firm will have to receive its revenue in foreign currency, hence its vulnerability to currency changes. Similarly, firms can also buy their raw materials beyond their borders, whether owing to unavailability of local materials or the availability of cheaper materials outside its borders. Such firms also suffer from changes in the exchange rate. A strengthening of the country's currency results in revenues from outside the currency regime being lower when converted, leading to a fall in the company revenues, while a company that imports materials will envisage a fall in the cost of production, hence a rise in expected profits. Internationalisation of markets and a reduction of trade restrictions also mean that companies are exposed to unlimited competition from throughout the world, and this reduces revenue expectations. Currency fluctuations also determine the level of competition from outside the currency regime, with a fall in the value of currency discouraging external firms, since they will get less revenue by participating in the market. Moreover, a fall will make it expensive for locals to buy outside the border, thereby boosting local sales of goods.

Apart from government foreign currency policies, other policies concerning interest rates, taxation, inflation, public spending, foreign policies and the general influence on economic activity, affect company productivity and profitability. Interest rates affect shares twofold. First they are an expense against revenue, as interest on loans track interest rates. Second, the rate of return which is used to calculate the price of shares is sensitive to movements in interest rates. The latter submission on the effect of interest rate on stocks is based on the rationale that interest rates present an opportunity cost of money at no risk, and those willing to invest in stocks where the risk is higher would naturally expect a higher return than that achieved by a risk–free asset. In this regard policy shift and economic changes within a region or country will affect either the revenue of the firm or the cost of production hence its profitability and subsequently share prices. Economic changes within a country also affect the demand for goods and services in as much as the availability and lack of disposable incomes is concerned, and hence profitability. The more disposable income people have, the higher the likelihood of them purchasing goods and services, thus providing a potential for revenue increase and dividend availability resulting in a price rise. Labour conditions, which are also a macro factor, could induce a rise in input costs and expenses of a firm, thereby negatively affecting its profitability. Despite the economic factors which affect stock markets, Bodie *et al*. (2005) note that the stock market is a leading economic indicator which tends to fall before the recession and rise before recovery.

The above factors may affect the whole economy; however, some industries would be more sensitive to each economic factor, depending on its thrust. Fraser (1993) points out that some industries are vulnerable to cuts in public expenditure, others to foreign competition, and anti-product campaigns (e.g. tobacco). As a result of these industry reaction differences and challenges, which could either be a benefit or disadvantage to the firms operating within the sector, share prices as indicated by a sector-index may rise or fall. An example is the ongoing campaign against tobacco which has the potential to limit revenue streams for industries that rely on tobacco products and services, thereby depressing interest in such companies. In addition to the above issues that could affect individual industries, some industries are affected by cyclical demand either owing to seasonality or climate changes. For instance, ice cream is more in demand in summer than in winter, and if this is the firm's sole product, prices tend to be unstable and have a seasonal trend. The stage of the industry in its life cycle also tends to affect the volatility of prices. Industries that are at their growth stage have a higher risk, which also affects the rate of return since the future prospects of the industry are an important factor in investor behaviour and hence stock prices. As noted earlier, the aforementioned macro factors are not exhaustive, but they do show the range of issues that could induce changes in stock prices besides inflation, thus setting the scene for this research given that the inflation rate is also one of the macro factors affecting share markets.

According to Fraser (1993), there are many variables that influence the profitability and risk of individual firms at a micro level. Of particular importance is the firm's financial structure, quality of management, labour relations and diversity of products and markets. A change in the senior management of a company may be met with mixed views from the market, and these views will be based on the prospects for growth and revenue generation due to such a change. The departure of a manager who is considered by the market as a driving force in the firm's prospects for growth may lead to a fall in the company's share price. Similarly, the resignation of a top manager and the news of a prospective powerful top individual moving in would increase the share price of the stock as investors anticipate revenue growth under the new management. This therefore illustrates the importance of information supplied by a firm to the market, which may, result in market perceptions that could lead to either the fall or rise in a stock price. Market perceptions are therefore important, and the way the information is presented to the market will drive these perceptions to a degree. Below, the share price movements are explored to show the diversity of issue and information that affect movement of stocks at the micro level, based on an article by Haddaway (2005);

- Tate & Lyle the sugar group, rebounded from Thursday's falls, when the World Trade Organisation made an adverse ruling to an appeal by the European Union on sugar exports. Analysts forecast lower sugar prices, although traders pointed out that sugar manufacture was a relatively small part of Tate's business. Tate was up 3.2 per cent at 468p.
- Hanson fell 1.4 per cent to 472p on news that a US senate committee had postponed action on a $140bn fund to compensate asbestos victims.

- Shire Pharmaceuticals traded 0.9 per cent lower ahead of its first-quarter results announcement today. The pharmaceuticals sector has fared well this week with strong numbers from several large drugs companies.
- Marconi continued to slide as analysts rushed to update their forecasts in the wake of the shock news that it had not been selected as a preferred supplier for BT's £10bn telecommunications contract. UBS slashed its price target on the company to 230p from 726p and cut its rating to 'reduce' from 'buy'. Shares in the telecom equipment group lost another 12.8 per cent to 260p.
- LogicaCMG added 3.2 per cent to 160¾p as Deutsche Bank upgraded the IT services group to 'buy' from 'hold', saying the weakness in technology stocks on the back of Marconi's contract loss had created a rare attractive entry point.

Mergers are also another micro factor that could drive changes in stock prices owing to their effects on growth prospects, cost reduction, or revenue increases, which induce price movements. According to Stanton (2002), on 16th May 2002 Easyjet made an announcement that it had sealed the takeover of another airline, GO. Given this piece of news, the Easyjet shares rose by 3% within a day owing to the market reception of the news and the feeling that the merger would generate more revenue for the new entity. It is important, though, to note that the market will only react to news on the day of the announcement if it has not yet factored it in, prior to that date. Ross *et al*. (2005) emphasise this by pointing out that news announcements are the sum of excepted and surprise news; therefore the effect of news on stocks depends on the surprise part of the announcement and not the part that the market has expected, which it would have discounted already. These issues highlight the diversity of the information and actions that could trigger market reaction and, though not exhaustive, the important issues are, how news or a company's plans would increase its risk, thereby affecting its rate of return; how they will affect revenue, growth or costs that determine dividends used to calculate the stock market price.

3.6 The African stock markets

The JSE Security Exchange, which is the main South African stock exchange, is the largest stock exchange in Africa in terms of size, volume and number of listings. Jefferis and Smith (2005) identify four Sub-Saharan Africa stock market categories, the first being South Africa which dominates other African stock markets that are considered to be extremely small by world standards. The second category is the medium–sized markets of Nigeria, Kenya and Zimbabwe which were established in the early to mid–twentieth century. Botswana, Ghana and Mauritius are in the third category of small new markets that have shown rapid growth. The final category is the very small, relatively new markets which are considered by Jefferis and Smith (2005) to be at the embryonic stage and yet to take off. These include Swaziland, Zambia, Malawi, Tanzania and Uganda. Smith *et al*. (2002) note that apart from South Africa, at the end of 1997 all other African stock markets accounted for 0.2% of the world stock market capitalisation and 2.2% of the emerging stock markets.

At the same time the South African stock market accounted for about 80% of all African stock market capitalisations. Jefferis and Smith (2005) state that the JSE security market is the eighteenth largest in the world and the fifth largest emerging market after China, Taiwan, South Korea and India. Table 3.1 below shows different properties of the African stock markets to illustrate the size of the stock markets under review, and that clearly South Africa has the highest capitalisation by far.

Country	Capitalisation[1]	Turnover[2]	Liquidity	Number of Stocks
Botswana	2,131	87	4.4	19
Ghana	1,426	46	4.1	28
Kenya	4,178	209	7.4	51
Mauritius	1,955	99	6.2	40
Nigeria	9,494	78	11.0	200
South Africa	267,745	102,808	44.8	426
Zimbabwe	4,975	1,345	26.1	81

Table 3.1: African Stock Markets as at the end of 2003[3]

Another striking feature of the markets is their liquidity, which is low for all the countries, with South Africa, Zimbabwe and Nigeria the only countries with double digit percentages. This lack of liquidity is considered by Smith *et al*. (2002) to stem from both the supply and the demand sides of the market. From the supply side the challenge is that many shares are held by parent, often foreign–based, controlling interests that make available a small proportion of shares for public trading. On the demand side, the investors know that the cost of trading in and out of the African stock markets is high, and it is not easy to re-establish a position once sold, hence the tendency to hold on to the shares when bought.

[1] Capitalisation is in millions and in US dollar terms
[2] Turnover is also in millions as well as US dollar terms
[3] The source of the data is Standards and Poors (2004)

According to Jefferis and Smith (2005), African stock market turnover increased at an average of 22% between 1994 and 2003, while during the same period emerging stock markets increased by only 9%. Smith *et al*. (2002) note that many factors have contributed to this expansion and growth, one of which has been the economic reform programmes undertaken by most African countries during the last two decades. Most African countries underwent economic reforms in the 1990s, including privatisation of formerly state–owned enterprises; thus more shares were floated on the stock exchanges. In addition to the privatisation strategy, the reforms also sought to strengthen the independence and working environment in which the stock markets operated, through financial sector reform. The greater role of market forces in price determination and allocation of real and financial resources is noted by Jefferis and Smith (2005) as a factor that contributed to the expansion and growth of African stock markets as well as improved standards of market governance.

Relaxing exchange rate controls and reducing foreign investor barriers to entry increased participation of foreign portfolio investors who were attracted to the African stocks mainly owing to their low correlation with major markets thus providing an alternative diversification option. In their 1993 report, Morgan Stanley (1993) noted five main problems facing foreign investors interested in African stock markets (Smith *et al*., 2002). First, the countries lacked a freely convertible currency and the margin between the official and the market exchange rates (reflected in the parallel market) was as high as 30%. Second, at that time, apart from South Africa and Zimbabwe, there were no investment reports. Another problem was the four to five months' lag on earnings reporting and the difficulty in obtaining timely news on listed firms. The fact that it was not an explicit requirement for listed firms to publish their audited accounts presented a challenge because many companies did not publish their income statements or balance sheets regularly. The final problem noted in the Morgan Stanley report related to the reality that there were few banks that met minimum capitalisation requirements for custodial banks outlined by the authorities, and this meant that there were delays in seeking suitable custody and settlement arrangements.

Most stocks are traded on the stock exchange. However, with the developments in the technology sector, some stocks can now exchange ownership through Internet transactions, and Ross *et al*. (2005), define the two types of market as an auction market and a dealer market. The former relates to an exchange market where trading takes place on a single site on the exchange floor and transaction prices are communicated immediately to the public. Most Sub-Saharan Africa stock exchanges operate an auction system, but in May 2002 the JSE Security Exchange started trading on the JSE Stock Exchange Electronic Trading Service (JSESETS) which is hosted in London and is a version of the London Stock Exchange (LSE) SETS technology tailored for the needs of the JSE (Irving, 2005). According to Irving (2005), JSESETS replaced the Johannesburg Equities Trading (JET) system under an agreement with LSE that promotes cross–border trading in most liquid securities between South Africa and the United Kingdom. Another Sub-Saharan Africa country which has been using sophisticated technology since 2001 is the Stock Exchange of Mauritius (SEM), whose trading, clearing and settlement are automated. Irving (2005) claims other African countries want to operate the SEM automated trading system (SEMATS), which is closely linked with the central depository system (CDS). Each of the stock markets that this research is looking at are reviewed below to provide further understanding of the markets.

3.6.1 Botswana Stock Exchange

The Botswana Stock Exchange (BSE) was formally established in 1995, but before then it had been operating as an informal share market since 1989. In 1989 it started with five listings growing to twelve in 1997 and eighteen in 2004. The stock exchange, whose listing is concentrated on the financial and services sectors, also caters for fixed income securities, particularly government bonds of two, five and twelve years, which are available to foreign investors. Trading is ‘open cry’ and settlement is on a manual T+5 basis, which means the settlement is five days after trading occurs. According to Irving (2005) capitalisation was US$2.55 billion with a turnover ratio of 0.2%. Foreign investors are allowed to participate in trading, but individual investors are limited to 10% ownership of a listed company with a 55% aggregate for all foreign investors. To list on the Botswana stock exchange a firm has to pass the profit test, which entails having achieved satisfactory profit over three years and at least 1 million Pula (equivalent to US$165.810 as at end of December 2006) before tax in its last reported and audited financial results. When listing, at least 1 million shares should be floated, with the public holding at least 20% and the minimum number of public equity holders is 300.

3.6.2 Nairobi Stock Exchange

The Nairobi Stock Exchange (NSE), which has been Kenya’s national stock exchange since its independence in 1953, is a regional stock exchange for Kenya, Tanzania (formerly Tanganyika and Zanzibar) and Uganda. According to Smith *et al*. (2002), the stock exchange was inactive until 1993, when economic reforms kicked in, resulting in privatisation and the relaxation of restrictions on foreign investors and exchange controls. The stock exchange operates as a three–tier exchange made up of the main stock segment, alternative investment segment and the fixed–income security segment. By the end of 2007 it had fifty-eight listings made up of fifty-two equities and six corporate bonds (seventy government bonds also listed on the fixed–income segment). As at the end of 2008, the NSE operated a T+5 system as well as floor based open cry trading. In November 2004, the manual trading system was replaced by an electronic on when the Central Depository and Settlement Corporation was set up. Capital gains tax was suspended in 1985, and the main taxation is now the withholding tax , at 5% for local investors and 10% for non-residents who can own up to 75% of any listed company. For corporate bonds and government treasury bonds, a 15% withholding tax is applied across the board. On listing, at least 25% of the shares must be held by not less than 1,000 public shareholders.

3.6.3 Ghana Stock Exchange

In 1971 the Stock Exchange Act was enacted with the Accra stock exchange incorporated, but it did not operate until 1991. In 1989, the government set up a ten member committee to establish the Ghana Stock Exchange (GSE), which was incorporated in July 1989 as a private company. Trading only commenced on the exchange floors on 12th November 1991, following the official launch of the exchange in January 1991. The GSE, which became a public limited company in 1994, operates three lists with different requirements for equities, but also provides a platform for fixed–income securities to be traded. To list on the first listing, a firm has to have published audited accounts over five years and to have been profitable as well as show strong potential to be profitable. For the second listing the requirement is three years of published accounts and one year for the third listing.

3.6.4 Stock Exchange of Mauritius

The Stock Exchange of Mauritius (SEM) was established as a private company in 1989 with five firms, but rose rapidly to thirty-nine firms in 1995. As at the end of 2006, the SEM was dominated by banks and insurance firms, which who accounted for 36% of the market capitalisation, followed by tourism (24%), investment (14%), commerce (11%), sugar (9%), industry (4%) and transport (2%) (SEM Ltd, 2007). Smith *et al*. (2002), note that the market is small and is not very liquid. However, it is helped by the absence of restrictions on foreign investors who play an active role in the market. The exchange has been operating an over–the–counter system since 1999. Settlement is on a T+3 basis and automated, as is trading and clearing. According to Irving (2005), SEM sponsors regular radio talk programmes and public education to generate local interest and explain stock market investing. Before listing, a company should have published audited accounts for three years, and the accounts have to be at least six months old before listing.

3.6.5 Nigeria stock exchange

The Nigeria Stock Exchange was established in 1960, but according to Jefferis and Smith (2005) until the 1990s the exchange was operating as a forum for trading government bonds rather than equities, and trading was highly regulated. Like most African countries, Nigeria introduced economic reforms in the 1990s, and these resulted in the deregulation of the stock market as well as privatisation, which increased the number of listings. The Nigeria Stock Exchange operates an automated trading system which was introduced in 1999. Smith *et al*.. (2002) state that trading on the exchange has been constrained by restrictions on foreign ownership and long–standing political and economic problems. This means that before 1995 the market was closed to foreign investors, and was thus driven by domestic sentiments. In 1995, restrictions on foreign participation were removed, and this provided a boost for the exchange, though liquidity still remains low.

3.6.6 JSE Security Exchange

The South African stock exchange is the largest is Africa, and the second oldest after the Egyptian Stock Exchange, having been established in 1887 to raise finance for gold mining. Until the early 1990s, apartheid in South Africa caused many foreign investors to avoid investing in the country, including the Johannesburg Stock Exchange (JSE), South Africa's national stock exchange. After the abolishment of apartheid, the new majority government introduced economic reforms, including stock market reforms, allowing foreign investors to participate in the market. Also, an electronic trading system replaced the open cry one in 1996. Foreign investors were discouraged to invest by the foreign exchange system that operated then, whereby they had to use a financial rand instead of the normal rate and the financial rand applied capital transactions. Irving (2005) notes that the increase in foreign inflows also meant that the exchange was vulnerable to volatility in international financial markets like during the Russian and Brazil crisis in 1998 when the JSE fell 30% in one month. At the beginning of this century the JSE changed its name to JSE Security Exchange to reflect its national outlook. New reforms included the introduction of an electronic settlement system and new listing requirements. Transactions were now performed through the Share Transactions Totally Electronic (STRATE) settlement system, and payment was on a T+3 basis. As shown in Table 3.1, liquidity on the JSE is low, and Smith *et al*. (2002) attribute this to the domination of share ownership by large conglomerates which are a result of strict exchange controls on capital accounts that restrict South African firms from exporting capital, hence their only choice is to take over other domestic firms. These restrictions have also led to an increase in recent delisting to other exchanges, particularly the London Stock Exchange. Another challenge currently facing the JSE, according to Jefferis and Smith (2005) is concern over insider trading, given the prevalence of suspicious share price movements prior to major announcements.

3.6.7 Zimbabwe Stock Exchange

Between 1896 and 1902 the Zimbabwe Stock Exchange (ZSE) operated from Bulawayo (Zimbabwe's second largest city) before the operations were halted. In 1946, it reopened again in Bulawayo, then in 1951 had another office in Harare, where it now operates from. Cazenove (1977) described the ZSE as a 'dozy club with two members', but this changed after the introduction of economic reforms in the 1990s (Jefferis and Smith, 2005). In 1991, the government introduced the Economic Structural Adjustment Programme with the assistance of the International Monetary Fund (IMF), and this led to changes in the financial sector, including the stock market. According to Smith *et al*. (2002), the major boost to the market came with the opening of the exchange to foreign investors in May 1993, along with the relaxation of exchange controls. However, there are still restrictions on foreign investor ownership, with individual investors limited to only 10%, and collectively foreign investors can only own a maximum of 40% of any listed company. Foreign participation has decreased since the start of this century owing to the erosion of property rights and the difficulty in repatriating earnings because of foreign shortages and a general rise in political and economic uncertainty (Irving, 2005). Despite this drop in foreign participation, the stock market was the best–ranked performing emerging market on the Standard and Poors Global Index, and Irving (2005) attributes this to lack of alternative investment opportunities since interest rates were unattractive in the face of rising inflation. This view is supported by the evidence of a massive fall in 2004 which was caused by the hiking of the interest rates from 300% at the end of 2003 to over 700% at the beginning of 2004. ZSE trading is paper based with an open cry trading system for the exchange that caters for equities as well as bonds.

3.7 Conclusion

This chapter has presented a review of the relationship between inflation and stocks based on existing theories and current academic arguments. Three main competing theories have been identified: the Fisher effect, the Proxy hypothesis and the Inflation Illusion hypothesis. Apart from minor overlaps, these theories seem to have been popular in different periods, with the Fisher effect occurring prior to the 1970s, after which the failure of empirical evidence to support it resulted in the birth of the Proxy hypothesis. The Proxy hypothesis was topical in the 1980s and 1990s as researchers either confirmed it as the main reasoning behind stock–inflation relations or provided contrary evidence. Modigliani and Cohn suggested the inflation illusion hypothesis in 1979, but this hypothesis only became popular at the turn of this century. Its popularity is a result of the failure by the Proxy hypothesis to comprehensively explain the negative relationship between inflation and stocks. Questions are now being asked about the validity of the Inflation Illusion hypothesis, which is consistent with practitioner behaviour but lacks sound academic backing.

The Proxy and the Inflation Illusion hypotheses are rooted in the existence of negative stock–inflation relations evidence but fail to account for positive findings, especially when long–run data is used and modern techniques that explain long–term relationships are considered. The reality that inflation can be induced by a variety of different shocks as well as being a product of a reactive and proactive government policy demonstrates the complexity that will continue to befall a 'minor assumption based' academic reasoning in the stock–inflation relations. At best, indications are that different economic regimes and structural changes are pivotal in explaining the nature of the relationship between stocks and inflation, hence this relationship will be sensitive to the period used in the analysis and the economic regime of a particular country. This conclusion is based on the existence of different results in time, geographic and economic settings.

This chapter has also confirmed African stock markets as predominantly young and small in terms of capitalisation through tracing of their histories and a review of existing literature. A common feature in all the stock markets is the rapid growth experienced during the 1990s, when economic reforms were introduced. The reforms targeted, among other economic and financial issues, the establishment of new stock markets and the rehabilitation of existing ones in line with global trends. In most of the countries, though, these reforms fell short, especially on the crucial foreign investor participation because of the existence of restrictions. From an international investor perspective, where these restrictions do not exist, African stock markets provide an alternative investment platform for diversification given their low correlation with other major stock markets. The major concern for investors, though, is the liquidity challenge, meaning that most of the markets are not very liquid and operate manual to semi-manual trading and settlement systems that compromise efficiency.

CHAPTER FOUR

HIDDEN INFLATION IN AFRICA

4.0 Introduction

The literature review in the previous chapter explored the relationship between inflation and stocks assuming that the data used in the analysis is accurate. Since the magnitude and level of interaction between these variables can be influenced by the accuracy of the reported figures, there is a need to establish the correctness of the data. Determining the accuracy of time series data can take three forms. The first is the analysis of the raw collection, data input procedures and data storage. The second approach to data accuracy investigations is to carry out an independent physical verification based on a sample of the population, and to compare the results over time with the officially announced data. A third approach is to analyse the collected data, logically infer its accuracy using statistical means and analyse the data relations with other data sets. The advantage of such an approach is that it can be done relatively quickly with reasonable accuracy, though it assumes that the collected data is accurate, thus compromising the robustness of the findings.

The first approach to data accuracy determination noted above requires a systematic review of the procedures used in the collection and storage of data as well as the analysis of the qualifications of data capturers. Such review and analysis could entail physically examining these processes to arrive at an acceptable conclusion on data accuracy. To carry out this review in the countries under consideration can take considerable time and resources which unfortunately this research is unable to undertake. The second approach would involve carrying out a survey in the seven countries, which would require substantial resources and be time consuming, as it would entail getting approval from governments that might be hostile to a process that seeks to condemn their practices. This study will therefore employ the third approach in determining data accuracy, which is the most viable under the circumstances.

Considering the stock market and inflation data sets used in this research, it is difficult to obtain information relating to the weights used to calculate stock market index in the African countries under consideration, thus rendering data analysis complicated. However, the data on inflation weights is readily available as it forms part of the inflation data announced in every country. This chapter will therefore explore the presence of unofficial inflation, or establish if inflation in Africa is appropriately measured, to ensure that results from the ascertainment of inflation–stock relations are robust. To determine the prevalence of unofficial inflation, this research will investigate the existence of hidden inflation for the first time in Africa through the analysis of food and non-food inflation, as well as the relationship between poverty and food weights used in the inflation rate calculation.

The indications from the interaction between food and non-food inflation show the existence of unofficial inflation in Sub-Saharan Africa, given that on average food inflation in Zimbabwe, Kenya and Mauritius increased at a higher rate than non-food items during the five years to January 2007. The statistically significant difference between food and non-food inflation is a concern in these countries as consumer consumption surveys, which are used to determine inflation weights, are conducted more than five years apart. The gaps between these surveys, which are a basis for inflation weight determination, mean that inflation a few years after the survey dates will not be accurate, especially when food inflation, which constitutes a large share of African countries' inflation calculations, increases faster than that of non-food items. Thus the cumulative effect of both statistically significant differences in the increases and the high percentage weight of food inflation in inflation calculation provide sufficient evidence for the existence of hidden inflation.

The remainder of this chapter is structured as follows: Section 4.1 presents the background to this study; Section 4.2 looks at the relationship between poverty and food weights; and Section 4.3 examines the nature of inflation components and weights in Africa. Hidden inflation in Zimbabwe is considered in Section 4.4, while the evidence in other countries is looked at in Section 4.5. Section 4.6 explores inflation in Africa, including the investigation of the causes of inflation in Zimbabwe. The main conclusions are summarised in Section 4.7.

4.1 Study background

A country's inflation could be understated owing to either hidden inflation or repressed inflation within the consumption market which constitute elements of unofficial inflation (Nuti, 1986). The former, as Nuti (1986) states, relates to higher prices than officially recorded, while the latter refers to rising excess liquid balances in the hands of the population with respect to what they would wish to hold if the markets cleared at official prices. Munoz (2006) confirmed the existence of repressed inflation in Zimbabwe and, through an analysis of consumer price index components, this thesis will show evidence that the hidden inflation component of unofficial (unrecorded) inflation is also prevalent in the continent.

According to Nuti (1986), who looked at Soviet-type economies, unrecorded but hidden inflation occurs for three different reasons. First, it occurs because of price rises above the official level, where the official price may lag behind actual prices, with retailing organisations charging premiums to consumers. Prices of basic commodities in Zimbabwe were the subject of government pegging through statutory gazetting of them for more than five years from 2002 to 2007. This strategy was been used as a way of ensuring control of the rocketing nature of prices, but instead it resulted in chronic shortages within the economy. Cheung (1974), in his paper on the Hong Kong market, confirmed that price controls induce shortages and, as Nove (1981) puts it, in a system where price controls exist and product mix can be varied, the price index will always understate price rises. Shortages, according to Katsenelinboigen (1977), lead to the mushrooming of illegal markets commonly known as brown or black markets. Such illegal markets charge above official prices as witnessed in the Soviet Union during the twenty century. Price controls have therefore been one of the reasons for the existence of hidden inflation in Zimbabwe, as the government does not recognise the black market prices despite the ordinary populace buying goods such as fuel and food from this market since 2002. The buying of goods from the expensive black market means more money from the household expenditure is spent on those goods that are not available in the official or legal market. Thus, the concept that a true price index ideally ought to record the price actually paid by the ultimate users (Nuti, 1986) becomes hard to fulfil. The shortages of basic commodities and fuel, and the rocketing of residential rentals in Zimbabwe have thus led to a shift in the consumer basket of the populace, making the current inflation weights an illusion of reality.

Second, hidden inflation occurs when there is progressive forced substitution by consumers of goods which are available, at official prices for goods that are not available and where such substitutes are usually more expensive than government gazetted ones. Apart from hidden inflation brought about by official prices lagging behind black market ones, many substitute goods have emerged in Zimbabwe, especially food products. In trying to beat price controls, bakeries introduced milk bread and rolls in late 2003, products that were not controlled, while at the same time reducing the supply of ordinary bread, forcing consumers to resort to substitutes. Substitutes of this nature are, however, not captured in the inflation index despite the apparent contribution they make to a household basket. Moreover, when the index is calculated such goods are omitted or their importance is not acknowledged. Another systematic substitution noted within the Zimbabwean market is the progressive movement from cheap maize meal to expensive, refined meal products and the removal or reduction in the supply of ordinary flour in favour of cake floor; these substitutes were not controlled as at the end of 2006. Substitution of goods also takes the form of bringing to the market readily available products of inferior quality at a cost higher than is warranted by quality and under sellers' market products will always be sold, even when the price rise is in no way proportionate to the improvement in quality (Nove, 1981).

Third, unofficial inflation occurs when quantity weights in official price indices understate the relative weights of the goods whose actual market prices rise relatively faster than either officially announced or not. Quantity weights different from those appropriate to actual prices, could lead to price index bias either way, and by systematic official understating of weights the result is likely to be the cosmetic data manipulation by authorities (Nuti, 1986). According to

Morrow (1986) relative price movements during inflation give rise to a shift in relative purchasing powers across income brackets, resulting in changes in consumer behaviour. Table 4.1 shows the inflation weights in different African countries. It can be seen that the food component of the weights in Zimbabwe is within six percentage points of those in South Africa, Botswana and Mauritius, while the economic situation in the country is substantially different. The food component in the weights in the different countries is also an area of interest from the view point of poverty levels, especially the fact that over 71% of the population in Zimbabwe lives below the food poverty line (Campell *et al*., 2002) with 72% urban householders defined as poor, including 51% deemed very poor, meaning they cannot afford to buy enough food (Polts, 2006), let alone pay for the other components that make up the inflation basket. Morrow (1986) defines household poverty as a situation where 62% of income is apportioned for the purchase of necessities such as food, shelter and clothing. This means that technically over 71% of people in Zimbabwe spend about 62% or so on food, and despite the fact that the above–mentioned definition of poverty is based on the Canadian population, the 54% allocated for food, shelter and clothing is not reflective of the 51% deemed very poor. The above argument is further complemented by Hollister and Palmer (1973), Mirer (1974), Muellbauer (1974), Irvine and McCarthy (1980) and Shorrocks and Marlin (1982), who note that low income householders suffer disproportionately from inflation because of the high budget share allocated to food, which tends to rise in price faster than other commodities.

Nigeria, whose food contribution to the consumer price index is 64%, has two-thirds of its population living in poverty (Agbogidi and Ofuoku, 2006); while in Ghana food represents contributes 52% with over 50% people living in poverty (Duclos *et al*., 2006); and Kenya, with over 43% (World Bank, 2003) of people living in poverty, has food contributing 51% to the consumer price index. While poverty measurement tools are varied, so are household sizes and education attainment, which tend to aggravate poverty (Okunmadewa *et al*., 2007), and these are different within African countries. The argument against the 32% weighting of food in Zimbabwe in this context cannot be ignored. In this regard, the Zimbabwean inflation basket weights, which are based on the household consumption survey of 2001, look unrealistic given the rise in poverty levels between 2001 and 2007, indicating the presence of hidden inflation in Zimbabwe even in the face of the argument for the differences in the sources of food material and production costs within African countries. Moreover, the fact that over 80% of the Zimbabwean population is considered to be unemployed and the inflation rate is increasing faster than salaries, there is continuous erosion of income. People concentrate on spending for survival, with most of their income devoted to biological and physiological needs noted in Maslow's[4] hierarchy of needs.

4.2 Poverty and food inflation weights

The relationship between poverty and food weights was looked at in general terms in Section 4.1 above. However, to demonstrate this association, data for both poverty and food weights in different countries were collected. The international poverty line measure was used in this case to ensure cross comparison of estimated poverty figures, since countries have different measures and definitions of poverty. Local poverty lines have higher purchasing power than in

[4] In terms of Abraham Maslow's hierarchy of needs, under biological and physiological needs there is: air, food, water, shelter, warmth, sex, sleep, etc. that are basic life needs.

rich countries, where generous standards are used compared to poor ones (World Bank, 2005). International poverty line data, which uses $1 a day expenditure standard, is obtained from the World Development Indicators 2005, and is used to determine the relationship which the World Bank (2005) states is a standard measure to hold the real value of the poverty line constant across countries. In addition to the above, data inflation food weights were collected for each country from their official statistical authority websites.

Care was taken in obtaining this data to ensure that the base year of the poverty survey contained in the World Development Indicators 2005 corresponded with the year in which the household consumer survey data for the weights was carried out. Two years either side of the poverty survey was allowed when accepting the household survey for this purpose thus only eighteen out of ninety countries (data points) were chosen using this decision rule. The choice of two years either side of the survey was based on the recommendations made by Morrow (1986) as well as the rationale that, within a fairly stable economy, poverty levels would not decline dramatically over two years. In the UK, surveys are carried out every year and this is the norm in most developed countries; hence the use of the two years in environments where baskets are reviewed more than five years apart is considered here as an acceptable compromise. Figure 4.1 below presents the scatter diagram for the relationship between poverty and food weights on the basis of $1 per day poverty line.

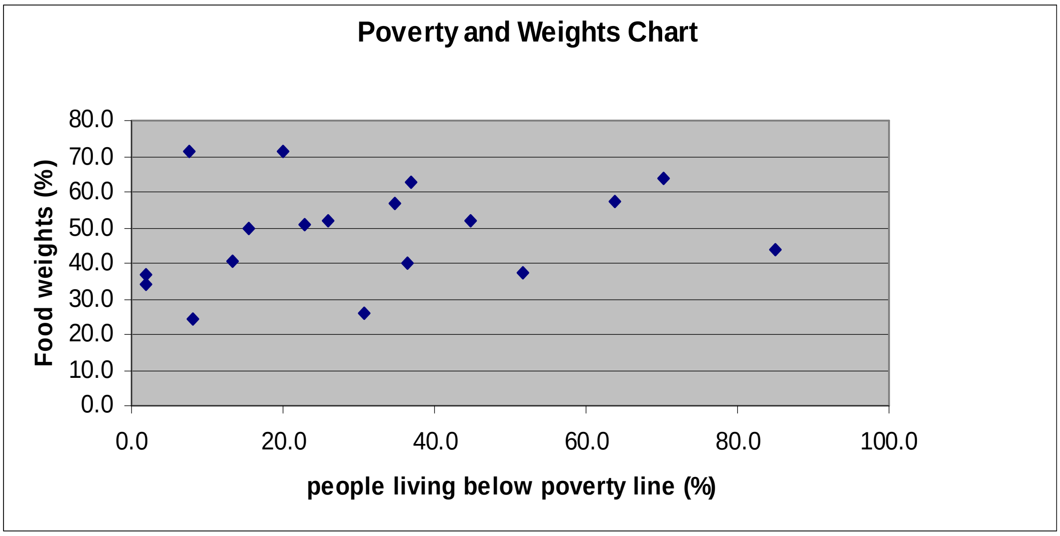

Figure 4.1: $1 per day poverty line and food inflation weights chart

The diagram shows a slight positive relationship between poverty and weights, but this is not conclusive as there are many data points clustered to the top left. The reason for this is that the percentage of people in these countries living on $1 per day is small, indicating that more people live on more than this amount. The correlation coefficient for this relationship is 0.2 and demonstrates that food weights and poverty as defined by the $1 per day poverty line move in the same positive direction. However, this calculated statistic is not convincing, and a formal regression is presented to ascertain the significance of the relationship. Equation 4.1 below is a regression that shows the relationship between poverty and food weights in a more precise form.

$$\underset{}{fw} = \underset{(7.839)}{44.59} + \underset{(0.824)}{0.12}\, pv \qquad 4.1$$

where fw represents food weights and pv the poverty level as defined by the $1 per day poverty line. The coefficient for the poverty variable in this equation has a reported probability of 0.422 as well as a t-statistic of 0.8242, and this clearly shows the statistical insignificance of the $1 per day poverty line in explaining food weight changes. However, R-squared is 0.0407, revealing that only 4.1% of changes in weights are explained by movements in poverty levels as defined by $1 per day poverty line. R-squared further confirms that poverty levels as defined by the $1 per day poverty line are not important in explaining food inflation weights, considering that the regression has an insignificant F-statistic of 0.6793.

The other measure of poverty recommended by the World Bank is the International poverty line as defined by $2 per day expenditure. Figure 4.2 is a scatter diagram based on the relationship between the $2 per day poverty line and food inflation weights.

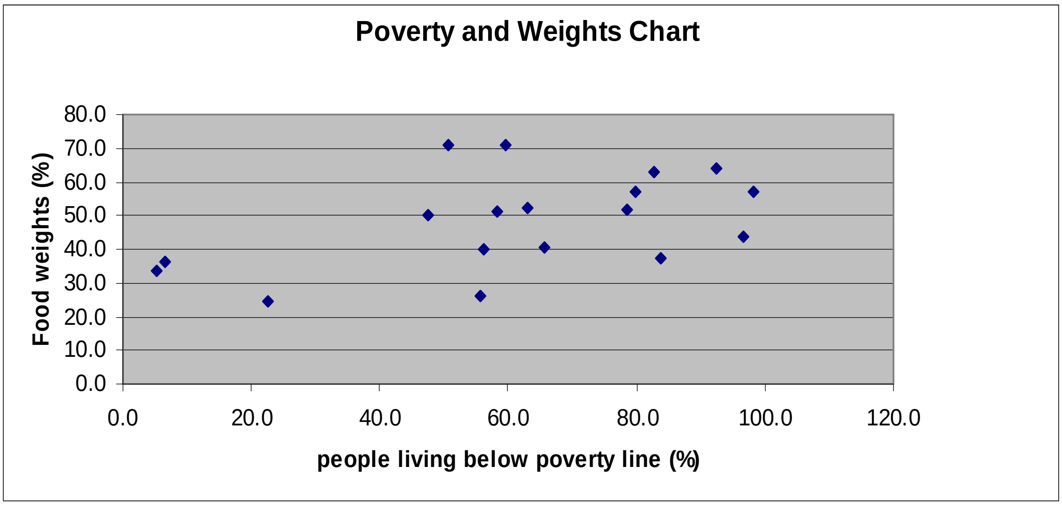

Figure 4.2: $2 per day poverty line and food inflation weights chart

The $2 per day poverty line data and inflation food weights relationship seems to be more linear, as most of the data points are spread such that a positive relationship is clearer than in the case of the $1 per day poverty line. The correlation coefficient for the two variables is 0.5, a figure which is positive and higher compared to the earlier relationship. This submission is further supported by Equation 4.2, which has a 0.223 R-squared indicating that the equation explains over 22.3% of movements in food inflation weights.

$$fw = 33.71 + 0.24\, pv \qquad 4.2$$
(4.505) (2.143)

The impact of the \$2 per day poverty line is confirmed as an explanatory variable in food inflation weights at 5% level of significance, since its probability is 0.0478. The F-statistic of 4.5923 for this regression is also significant at the 5% level. Thus a 1% increase in poverty would warrant a 0.24% movement in food inflation weight adjustment.

If poverty in any of the African countries is increasing there is need to have a more regular consumer consumption survey to ensure accuracy in the calculation of inflation. This situation is more compelling where food inflation is increasing at a higher rate than non-food inflation. The challenge with using this approach, though, is that it assumes food to be the only biological and physiological need while it is not. In fact, it might be that food; clothing and shelter expenditure weights increase together as poverty soars. However, people can live in shacks in Africa without paying rent and can buy second-hand clothing, which is not accounted for in the inflation basket, but they cannot survive without food, hence the rationale for this approach. Moreover, the remainder of the non-food inflation weights could be apportioned such that the biological and physiological needs get a bigger share, thereby reducing or foregoing expenditure on such items as transport, education and eating out.

4.3 African inflation components and weights

The data for the weights provided here is obtained from each country's central statistical offices. All seven Sub-Sahara African countries under consideration are represented in this section, namely Botswana, Ghana, Kenya, Mauritius, Nigeria, South Africa and Zimbabwe.

Table 4.1 presents the weights for the components that make up the countries' consumer price index as at February 2002 and January 2007. The last row of the table gives the base year in which the weights were originally established after a household consumption survey. Since these surveys are expensive, most of these African countries do not update their weights more than every five years. Mauritius updates its inflation weights every five years and its inflation weights shown here under the 2007 column were a result of their seventh Household Budget Survey (HBS) carried out between July 2001 and June 2002. This survey took a sample of over 6,700 households from representative regions. By 2007, Kenya and Ghana were still using weights based on consumer surveys taken in 1997, and so are over ten years old. South Africa's weights under the 2007 column are based on a ten-year-old survey of 2000, while Botswana has the latest consumer basket introduced in 2006. Nigeria's 2003 basket is the second latest basket for this research sample period. Zimbabwe changed its inflation weights in June 2005, but the new weights are based on a consumption survey carried out in 2001. The effect of using weights based on a survey over a year old is that consumer buying patterns change. As a result, the consumer price index will not reflect the basket of goods for the national population. In addition, Morrow (1986) points out that using the fixed weighting system in the computation of the consumer price index tends to produce bias in the index by not taking into account expenditure substitutes practised by consumers in the event of price, taste or income changes. Therefore reweighing at least every four years is recommended.

Table 4.1 offers twelve categories for consumer price index weights. However, South Africa publishes sixteen categories, including a section called 'personal care', which is included under 'other category' in some countries, and in Table 4.1.

Categories	Zimbabwe		Botswana		SA	Kenya	Mauritius		Ghana	Nigeria	
	2002	2007	2002	2007	2007	2007	2002	2007	2007	2002	2007
Food	34	32	26	22	27	51	34	32	52	69	64
Beverage, tobacco	16	5	13	9	3	3	9	9	4	5	2
Clothing & footwear	7	6	6	8	4	9	8	6	10	5	3
Rent, fuel & power	17	16	15	11	23	16	10	9	9	12	18
Furniture, h/hold	8	15	9	7	8	6	8	6	7	4	4
Medical care	2	1	6	3	11	2	3	3	4	1	1
Transport	7	10	20	19	13	6	12	13	6	2	4
Communication	0	1	0	3	3	0	2	3	0	0	0
Recreation, culture	1	6	2	2	3	6	4	5	5	1	1
Education	5	3	4	3	3	0	3	4	0	0	0
Restaurants, hotels	0	2	0	3	0	0	5	5	0	0	0
Misc. G & S	5	4	1	10	4	2	4	5	3	1	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**98**
Base	**1995**	**2001**	**1996**	**2006**	**2000**	**1997**	**1997**	**2002**	**1997**	**1985**	**2003**

Table 4.1: Consumer price index components and weights in Africa

Another separate category offered by South Africa is the fuel and power one, which here is included under rent, fuel and power (also referred to as Housing in this chapter). Finally, South Africa has a separate non-alcoholic beverage and cigarettes, cigar and tobacco sections, which are included in the food and non-alcoholic beverages section as well as the beverage and tobacco sections in other countries under consideration. It can be seen that some countries have zero weights on some of the categories, the reasons for this is: communication, is included in the transport section; education is part of recreation and culture; and restaurants and hotels are part of the miscellaneous category. Unfortunately, separating out the weights of these categories is not possible owing to limited information available in the countries concerned.

Food has the highest weight in the consumer price index of all the countries under study, with the 64% in Nigeria being the highest as at January 2007, followed by Ghana (52%) and Kenya

(51%). The 22% food contribution in Botswana is the lowest of the seven countries, and indications are that more of consumers' money is being spent on transport and housing which, with food, constitute the top three contributors to the inflation index. In contrast, Table 4.2 shows the weights in the United Kingdom, where food contributed 11.5% in the 2002 basket but only 10.3% in 2007, which indicates the relationship between the food component of the inflation weights and the development of a country. The other major contributor to the consumer price index (CPI) in African countries is housing which contributes 23% in South Africa and 18% in the Nigerian inflation figures. This implies that most consumer expenditure in Africa is on survival, in line with the Maslow hierarchy of needs, with food and shelter components contributing over 50% and even 80% in some countries, but just 22% in the UK.

Categories	**2002**	**2007**
Food	115	103
Beverage, tobacco	51	43
Clothing & footwear	61	62
Rent, fuel & power	107	115
Furniture, h/hold	69	68
Medical care	23	24
Transport	140	152
Communication	24	24
Recreation, culture	159	153
Education	17	18
Restaurants, hotels	137	138
Miscellaneous	97	100
Total	**1000**	**1000**

Table 4.2: Consumer price index components and weights in the United Kingdom

Beverages and tobacco, in 2007, contribute 9% in Mauritius and Botswana, representing the highest contribution to the consumer basket compared to other countries, closely followed by 5% for Zimbabwe. The contribution of education is almost similar in the most southerly countries, with Zimbabwe, Botswana and South Africa all having a 3% weight contribution to inflation, and Mauritius a 4% inflation basket contribution.

4.4 Hidden inflation in Zimbabwe

Inflation in Zimbabwe rose from 116.7% to 1,593.6% between 2002 and early 2007, an increase of over 1,400% within five years. Using the presentation in Section 4.2 above, this increase should lead to a household expenditure that is biased towards food, and hence a requirement for more regular revision of inflation weights. This section endeavours to illustrate and prove the effect of miscalculated weights on the overall inflation figure. To demonstrate this, as a first step, year-on-year inflation rates for food and non-food items are explored to check if the increase in the inflation rate in each component is statistically different from the other component. The results in this section will be divided into two periods: January 2003 to May 2005 and June 2005 to August 2007. This division was necessitated by the fact that the inflation weights in Zimbabwe were revised in June 2005. Unfortunately, the revised weights are not based on a consumer survey carried out in that year but one from 2001, when inflation was still in double figures on average as opposed to 267% on average in 2005.

Table 4.3 shows the difference between the movement of food and non-food components of the inflation basket. The table uses the following equation:

$$M = F - NF \qquad 4.3$$

where M is the mean of the difference between food inflation F and non-food inflation NF in Equation 4.3. The results show a positive average mean over both periods, indicating that food inflation has been increasing at a higher rate, and a large increase in the second period.

	Mean[5]	Standard Deviation	T- Statistic
Jan 2003–May 2005	23.8707	60.3065	2.1316
Jun 2005–Aug 2007	286.4148	661.4539	2.2500

Table 4.3: The difference between food and non–food inflation in Zimbabwe

For both periods, given the t-statistic, there is proof at 5% level of significance that food inflation increased at a faster rate on average than non-food inflation. The figures are worrying in the context of rising poverty in the country, and indicate that an upward revision of the inflation food weights would result in a higher inflation rate.

Two approaches can be used to examine the effect of poverty on the distorted inflation figures in Zimbabwe. One is to apply the poverty-weights regression calculated above and presented as Equation 4.2 to arrive at realistic food weights for the country. The other is to use a country with a similar poverty line. The challenge with the latter approach is that even where the level of poverty is similar, this does not necessarily indicate identical food weights because many considerations contribute to food weights, including the source of the food, the state of the agricultural sector, production costs and the machinery used to produce the food. Moreover, the tastes and types of food products eaten in different countries is not always the same. In the context of this argument, Equation 4.2 becomes relevant as it cuts across nations and sources of food production. Using the evidence that poverty increases the percentage of food weights based on Equation 4.2, the Zimbabwean food inflation weights are then revised using the 80% international poverty line for the country as presented by the World Development Indicators 2005. The results show that the food weights component jumps 19 percentage points to 51%, a figure close to that obtained for Kenya and Ghana. The effect of this result is an inflation

[5] The mean in Table 4.3 is the mean of the difference between food and non-food inflation as presented in Equation 4.3.

difference, as shown in Table 4.4, which also shows the understatement of the inflation rate figures in Zimbabwe.

	Jun 2005–Aug 2007	Jan 2003–May 2005
Average Difference	60.9456	4.5037
Standard Deviation	129.2568	9.7652
T–Statistics	2.4500	2.4836

Table 4.4: The difference between re-calculated and official inflation figures

Average difference in Table 4.4 presents the difference between the re-calculated inflation rate and the published figures; the positive mean indicates that re-calculated figures are higher than official ones. The table further shows that on average inflation in Zimbabwe was understated by 4.5 percentage points between January 2003 and May 2005, representing an average of 1.3%. These percentage point differences are all statistically significant at 5% level of significance. The distortion is higher between June 2005 and August 2007, when annual inflation was understated by over 60 percentage points during a period when average inflation was 1,857%; thus the distortion represents a 3.3% understatement. Given the compounding nature of annual inflation rate relation, this distortion translates to over 35% by June 2007.

It is important to note that the above calculations are free from the effect of black market prices, which could increase the understated figures by a couple of percentage points. Since most black market traders in Zimbabwe buy goods at official markets and sell them to customers at a mark–up, usually of not less than 20%, with fuel mark–up at over 100%, the effect of this is twofold. First, since the goods on the black market could only have been included after weight reconstitution, in the case of Zimbabwe the households were, in fact, spending more money on the item, which is found on the black market but is not anticipated by the consumer basket. Second, when the CPI is compiled only official prices are considered, and the black market ones ignored, despite householders failing to get the commodities with gazetted prices which the government uses as a yardstick for price compilation. This means that the actual prices paid by consumers on a product are understated on the index, thus giving credence to the existence of hidden inflation in such cases.

4.5 Evidence of hidden inflation in other Sub-Saharan African countries

Consumer price index weights can be used to determine or infer the accuracy of the inflation rate in a country as noted in Section 4.4. In particular, in countries where the household consumption surveys were carried out only a couple of years ago, the inflation rate might not accurately indicate the true picture of the consumer basket in that country. To explore the accuracy of inflation figures in other African countries, this section will look at the movement of prices for each component of the weights in the five years to January 2007. Analysis in this section excludes South Africa, where appropriate data could not be obtained, and Botswana, which changed its weights in 2006, making the process of little use. For the other countries, the inflation components' monthly index data used for this analysis started on the following months and years: Ghana and Kenya, from February 2002; Mauritius, August 2002; and Nigeria, February 2003. The data from Ghana has a gap between January and June 2004. The start dates were determined by the availability of data from the central banks or Central Statistical Office.

Table 4.5 shows the average difference of the movement in components of the inflation rate in Kenya compared with food inflation, which contributes 51% to the rate. The table uses the following equation:

$$A = F - Y \quad 4.4$$

where A represents the average difference in Table 4.5, while F is food weights and Y represents the other components in the table under the 'Components' column.

Components	Weights	Average difference[6]	St. Deviation	T- Stats	Probability
Housing	11.7	0.8633	3.0482	2.1937	0.0143
Clothing	9.0	1.0124	3.1440	2.4943	0.0064
House Goods	5.8	0.9090	3.0210	2.3306	0.0099
Education	6.0	0.9196	2.9729	2.3960	0.0082
Other	17.0	0.5317	3.1200	1.3199	0.0934

Table 4.5: The difference between food inflation and other inflation components in Kenya

The results above show that food inflation has, on average, been increasing at a faster rate than all the other components of the consumer basket in Kenya. The probability figures for this average superior increase in the food inflation rate are below the 10% level of significance, with most except the 'Other' category passing the 5% level of significance. Surprisingly, these results are not echoed in Table 4.6, which shows that food inflation has been increasing at above non–food inflation over the five years from February 2002.

	Average difference	St. Deviation	T- Stats	Probability
Food & Non-food	0.7887	3.0193	2.0233	0.0217
Clothing & Non-clothing	(0.6835)	1.8464	(2.8675)	0.0021
Housing & Non-housing	(0.5355)	1.8162	(2.2839)	0.0113
Other & Non-other	(0.1702)	2.0499	(0.6432)	0.2611

Table 4.6[7]: The difference between inflation components and others in Kenya

Month–to–month food inflation rose at over 0.78% more than non-food inflation in Kenya. This movement is statistically significant at 5% level of significance since the probability is 2.17%. The food inflation components in Ghana (see Table 4.7) do not increase at a

[6] Average difference in this case refers to the mean of the monthly differences between food inflation and each item listed on the table between February 2002 and January 2007.

[7] Clothing in this table represents the comparison between clothing inflation and non-clothing inflation, while Housing compares housing inflation and non-housing inflation, etc.

statistically significant rate compared with other components, and the only significant difference is the lower increase experienced by clothing items against non-clothing items.

Components	Average difference	St. Deviation	T- Stats	Probability
Food-Non Food	0.1199	6.2104	0.1419	0.4443
Clothing-Non Clothing	(0.8678)	3.6803	(1.7327)	0.0418

Table 4.7: The difference between inflation components and others in Ghana

While non-clothing items are increasing at a faster rate than clothing items, this is not much of a problem since clothing contributes only 10% to the inflation basket. These results could suggest that differential increases in the inflation components are not the main pressure for regular inflation weight reconfiguration. This evidence suggests that population tastes and technological changes are vital to Ghana changing its weights more often than they currently do.

The increase in prices in Nigeria and Ghana, especially the difference between food and other inflation components, are statistically similar over the period. However, transport and housing increase at a faster rate than non-transport and non-housing inflation respectively in Nigeria, which is surprising, given that the country has its own oil. Table 4.8 below presents this evidence.

	Average difference	St. Deviation	T- Stats	Probability
Food & Non Food	(0.4429)	4.1870	(0.7329)	0.2327
Housing-Non Housing	0.6535	3.1549	1.4352	0.0749
Transport-Non Transport	1.3045	4.3116	2.0961	0.0183

Table 4.8: The difference between inflation components and others in Nigeria

The expectation in Nigeria, where there is fuel extraction, is that housing, which includes fuel and transport, would increase at a slower rate than other items since it is an oil producer, while other countries in Africa import the substance. In Mauritius, food inflation also increases faster than non-food inflation at 10% level of significance, as shown in Table 4.9 below.

	Average difference	St. Deviation	T- Stats	Probability
Food-Non Food	0.1373	0.7472	1.3500	0.0885
Housing-Non Housing	0.1221	0.6372	1.4087	0.0793

Table 4.9: The difference between inflation components and others in Mauritius

As noted earlier, the fact that food contributes over 30% to the weights makes this statistically significant increase a concern, especially as weights are changed after five years. These findings would suggest a time series with multiple regimes. The statistically significant higher increase in housing inflation compared to non-housing inflation is not so worrying given that this component contributes only 9% to the inflation rate.

The implication of a component of the weights increasing at a faster rate than other components has two effects on inflation. First, it affects inflation directly since an increase in component will result in a weight proportionate increase in inflation, and this is not a problem since inflation will include this increase. Second, a sustained statistically significant increase results in consumers spending more money on the component than provided for or reflected in the weights, and this can be corrected by conducting regular household consumption surveys. However, the challenge in Africa, as indicated earlier, is that governments cannot afford regular household surveys, and they conduct these more than five years apart, which results in the distortions in the inflation rate calculation between these surveys. The distortion in the inflation rate is also fuelled if the component that increases at a statistically significant rate than others has the highest basket weight in the calculation of the inflation rate. Mauritius, for instance, changes weights every five years, and the concern is the food inflation rate, which is statistically higher than for non–food items between the five year surveys, while it contributes 32% to the computation of inflation. Since food is a basic need, inevitably consumers will continue to forego other expenditure components in the inflation basket if its prices increase faster than other items, in order to maintain the unchanged quantity requirements for this component in line with the hierarchy of needs. Apart from Mauritius, the analysis above is also applicable to Kenya, where the situation is even worse since monthly food inflation increases at over 0.78% more than non–food inflation, and the weights are based on a household consumption survey carried out in 1997. The above evidence points to the need for at least annual consumer surveys to ensure that the inflation rate is more accurate, especially where food is a high–weighted component of the inflation weights in the country.

4.6 Inflation in Sub-Saharan Africa

The first part of this section will look at the statistical description of inflation in Sub-Saharan Africa to assist in understanding the data that will be used later on. As noted in the introductory chapter, the inflation data used in this thesis is from February 1987 to January 2007. The data was obtained from the International Financial Statistics (IFS). However, the consumer price index data from the IFS for Nigeria has two gaps in the months of July and August 2001. To adjust for these gaps, inflation time series data from Nigeria Central Bank, which is short for comparison, as it only runs from January 1996 to December 2002 and has different inflation figures from those supplied by the IFS, was used to estimate the two figures. A ratio approach was used in which June 2001 inflation calculated from the index was compared with the inflation rate for the month provided by the central bank. The result was the inclusion of a 119.32 index value for July 2001 in the time series, resulting in a 0.436% increase in the monthly inflation rate. This figure is between the mean and the 25 percentile of the monthly inflation data. A similar ratio was then used to derive the August 2001 index value of 122.47, a figure between the mean and the 75 percentile of the original time series data.

Zimbabwe consumer price index data from March 2002 to January 2007 was also unavailable from the IFS, but inflation figures available from the Reserve Bank of Zimbabwe were used to extend the IFS time series data. The calculated inflation rate before this data, using IFS data, was similar to the data produced by the central bank, hence the justification for the extension of series.

Monthly and annual inflation characteristics will now be explored, as they present different but important characteristics. The next section investigates the causes of the inflation surge in Zimbabwe from an economic theory viewpoint but supported by a Granger causality perspective. Granger causality tests are conducted using the inflation data presented earlier. The month–to–month and year–to–year inflation rate is calculated using the method described above in Appendix 4.2. Month-to-month inflation thus refers to monthly changes to the CPI in percentage terms, while year-to-year inflation is the CPI value expressed as a percentage compared to the same time the previous year.

Figure 4.3 below presents the monthly and annual inflation for each of the countries except Zimbabwe. The diagrams show that annual inflation in Botswana reached its peak in the early 1990s before hitting single figures between the mid 1990s and the end of the century. A similar trend is witnessed when Kenya and Nigeria are considered, but in these cases the inflation level drops below 20% from above 80% for Nigeria.

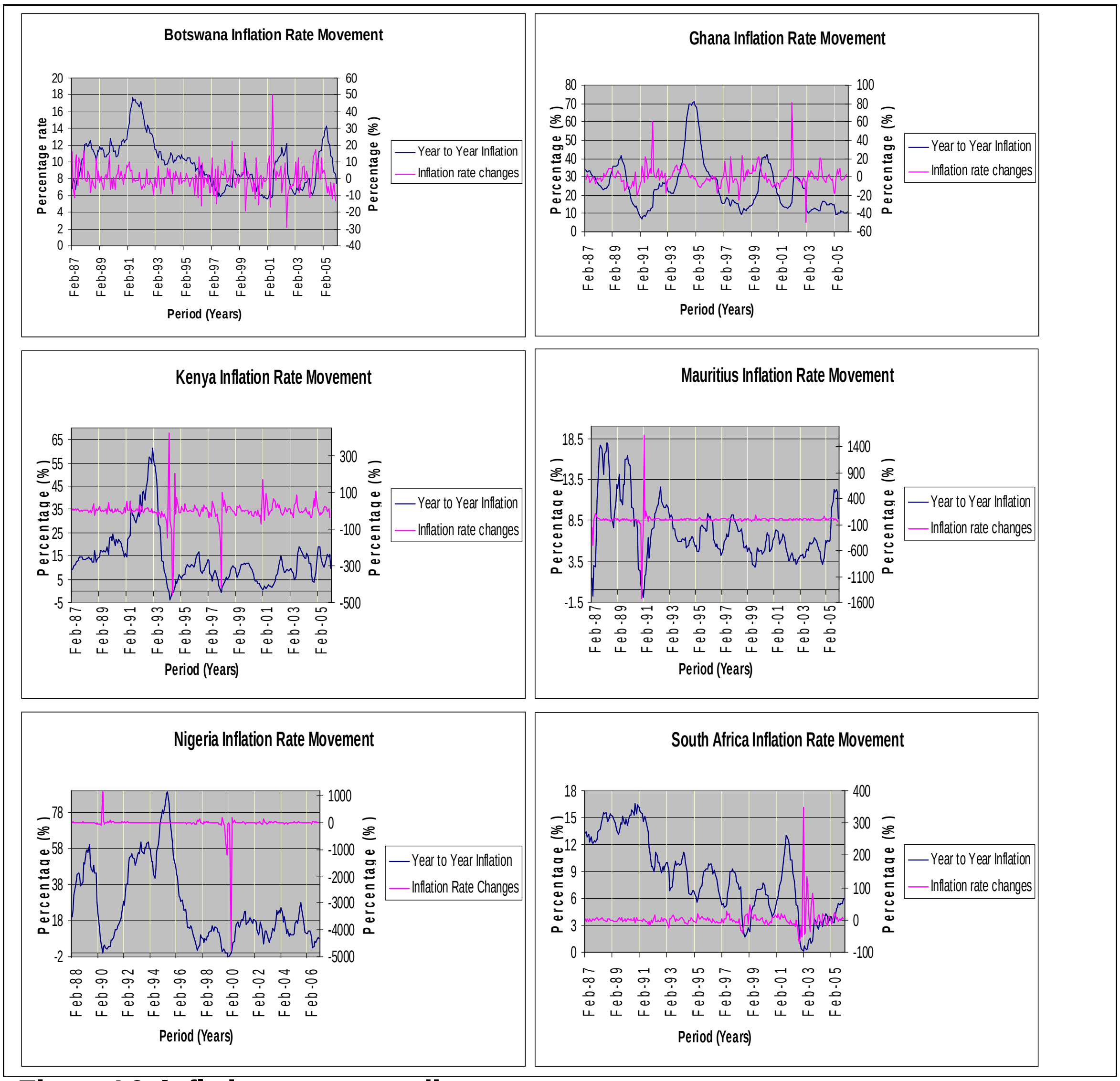

Figure 4.3: Inflation movement diagrams

During the 1990s, most African countries experienced economic structural adjustment programmes, and the trends noted here suggest that these programmes were successful towards the end of the decade. The monthly inflation rate in Mauritius reflects structural breaks in the early 1990s. Similarly, a structural break is noted for South Africa early in this century, where the annual rate has been slowing down. This low inflation rate for South Africa might be driven by the monetary policy, since the government implemented an inflation–

targeting monetary regime. Zimbabwe has been excluded from Figure 4.3 owing to the exponential nature of the inflation rate which makes interpretation difficult.

The diagrams above do not, however provide the accuracy required for analysis thus Table 4.10 and 4.11 below present the statistical description of the data. Table 4.10 shows that in July 2005 Zimbabwean inflation rose by 47% in one month, which can be interpreted as over 1.5% daily increase in price of commodities. Botswana, Mauritius and South Africa are the only African countries in the table that did not reach double figures in monthly percentage changes to CPI, and their mean monthly increases are below 1%. They therefore experience limited monthly inflation shocks compared to Ghana, Kenya, Nigeria and Zimbabwe.

Country	Mean	Median	Maximum	Minimum	Std. Dev.	25 %-ntile	75 %-ntile	Skewness	Kurtosis
Botswana	0.778	0.740	3.226	-0.190	0.496	0.425	1.035	0.912	1.921
Ghana	1.819	1.581	12.797	-3.499	1.849	0.584	2.817	1.159	4.751
Kenya	1.066	0.759	10.276	-3.073	1.815	0.153	1.639	1.746	6.125
Mauritius	0.572	0.408	4.432	-2.042	0.850	0.158	0.758	1.278	3.630
Nigeria	1.778	1.311	11.827	-3.510	2.614	0.143	3.240	0.749	0.830
SA	0.684	0.656	2.703	-0.740	0.547	0.314	1.038	0.329	0.288
Zimbabwe	5.824	2.699	47.000	-2.019	8.199	0.954	6.364	2.401	6.359

Table 4.10: Month to month inflation rate descriptive statistics for Africa

Apart from Botswana, Ghana and Zimbabwe most monthly maximum inflation increases were experienced in the early 1990s or late 1980s, showing that more recently the rates have been under control from month to month possibly owing to economic reforms undertaken by many African countries in the 1990s.

Table 4.11 below shows the year-to-year inflation rate, hereafter referred to as the annual inflation rate, which is the common form of inflation rate figures published by the media worldwide. Maximum annual inflation figures in most of the African countries considered here were experienced in the twentieth century data except for Zimbabwe, where the January 2007 observation was the highest entry at 1,593.6%, the highest inflation rate in the world at the time. Apart from Zimbabwe, which exhibits abnormal inflation figures, the highest inflation for the other six countries was recorded in Nigeria in June 1995 at 89.6%. By comparison, the highest annual inflation rate elsewhere between February 1987 and January 2007 were 10.9% (UK) and 6.3% (US).

Year–to–Year Inflation Rate Descriptive Statistics										
Country	Mean	Median	Max.	Min.	Std. Dev.	25 %-ntile	75 %-ntile	Skew-ness	Kurtosis	JB
Botswana	9.869	9.929	17.691	5.645	2.757	7.573	11.346	0.667	0.220	17.04
Ghana	24.80	22.79	70.817	7.323	13.865	14.220	30.780	1.441	2.269	123.6
Kenya	14.026	11.46	61.542	-3.662	11.926	6.886	16.305	1.862	3.821	260.9
Mauritius	7.229	6.268	18.041	-0.896	3.640	4.930	8.894	0.949	0.962	41.73
Nigeria	25.69	17.40	89.566	-2.486	21.600	10.000	43.561	0.989	0.019	36.70
SA	8.501	8.218	16.591	0.164	4.300	5.240	12.259	0.095	-0.941	8.85
Zimbabwe	145.74	32.84	1593.6	3.222	270.42	20.765	116.35	2.934	8.759	130.0
Year–to–Year Inflation Rate Change Descriptive Statistics										
Country	Mean	Median	Max.	Minim um	Std. Dev.	25 %-ntile	75 %-ntile	Skew-ness	Kurtosis	
Botswana	0.327	-0.107	49.987	-29.207	7.808	-3.931	3.591	1.044	7.397	
Ghana	0.047	-1.160	80.679	-49.654	10.944	-4.573	4.151	2.191	17.762	
Kenya	-1.930	-1.155	420.68	-457.06	65.319	-11.786	12.709	-1.958	27.696	
Mauritius	-1.455	-0.289	1622.2	-1515.6	153.51	-6.341	6.134	0.840	97.391	
Nigeria	-21.78	-0.002	1168.4	-4737.2	337.82	-10.939	11.686	-12.159	170.888	
SA	2.261	-0.404	350.37	-72.330	30.085	-5.204	5.768	7.449	81.703	
Zimbabwe	3.186	2.499	129.72	-40.446	14.483	-3.228	9.437	2.945	25.733	

Table 4.11: Year–to–Year inflation rate descriptive statistics for Africa

The rest of the data on the annual inflation rate is similar to the monthly inflation rate with Botswana, South Africa and Mauritius mean inflation rates below double figures, and South Africa recording the lowest maximum of 16.6%. The average annual inflation rate for the six countries excluding Zimbabwe is 15%, raised by Ghana (24.8%) and Nigeria (25.7%), whose annual inflation rates are the only ones of the countries considered which are above this mean. If Zimbabwe is included, the average rises to 33.7%, over double the average for the other six countries, illustrating the impact of outliers on the mean summary statistics. Another interesting statistic represents the changes in the annual inflation rate, with Mauritius and Nigeria recording four–figure digits maximum changes in the early 1990s. Skewness and kurtosis check if the data is symmetric about the mean value, where a Kurtosis value of 3 represents normal distribution conditions. For annual inflation rate, the kurtosis value below 3 is found on all the inflation data except for Kenya and Zimbabwe, which confirms normality of the data using this criterion. Kenya and Zimbabwe's annual inflation data shows fat tails compared to the normal distribution. The skewness for all the inflation rates are positive, which indicates that the outliers in the data are above the mean, with South Africa, which has a skewness of close to zero at 0.1, reflecting symmetry about the mean value.

Brooks (2002) points out that the Jarque–Bera (JB) uses the property of normally distributed random variable that the entire distribution is characterised by the mean and the variance considered as the first and the second moments. For normality to prevail, the expectation is for the JB statistic to be insignificant. The JB statistics provided in Table 4.11 are all larger than the critical value of 5.99, which is at 5% level of significance and two degrees of freedom. The JB test hypothesis that the residuals of the distribution are normally distributed may, however, not be rejected for South Africa at 1% level of significance and two degrees of freedom, since the test statistic of 8.85 is below the 9.21 critical value.

4.6.1 Causes of inflation surge in Zimbabwe

As noted earlier, there is no real consensus on the causes of inflation, predominantly because the phenomenon is a result of several factors that either act together or in isolation to cause a fall or rise in the cost of living. In most economics literature, though, the causes are grouped in three main categories: cost–push inflation, demand–pull inflation and monetary inflation. Cost–push inflation, which is regarded as the supply side inflation (Beardshow, 1992), is caused by a rise the production input costs. Parkin, Powell and Matthews (1997) consider two main sources of this increase in production costs, which are an increase in money wage rate and in the price of raw materials. An increase in wage rate can be induced by the bargaining power of employees due to either the presence of powerful unions or the shortage of appropriate labour force in the job market. The Zimbabwe Congress of Trade Unions (ZCTU), which is a powerful labour organisation, usually negotiates industry salaries on behalf of workers, linking these to the inflation rate. The challenge for employers in a union–driven market is that wages and salaries are negotiated nationwide with little consideration for individual company or regional situations Thus the only logical reaction of the firm will be to pass the costs to the supply chain. The effect of producers passing on costs by factoring them into the production cost is that the producers' prices increase, especially as the majority of industries in Zimbabwe are mark-up driven. The situation is made worse by the fact that the consumer market in the country is a suppliers' market. Therefore it is more sensitive to supply than demand influences, and the prices of goods tend to go up with the rising cost of production.

To control inflation of this magnitude is contentious, in that governments will have to introduce unpopular policies like wage freeze and price controls, steps which could face resistance from unions and businesses alike. In August 2007, however, the Zimbabwean government did bite the bullet and announce that wages be frozen and that any increase would need government approval. The result of this gazetted statutory bravery by the state was a call for a nationwide strike by the trade unions on 19th and 20th September 2007. This did not receive full worker participation, but it does illustrate the risks associated with such policies. The salary freeze was a last ditch attempt to avoid further collapse and a deepening economic crisis induced by an unpopular government whose policies also included a tripartite consultative forum. In this forum, made up of the state, the trade unions and business, the government had tried unsuccessfully to negotiate a voluntary freeze, cap or limit to salary increases as well as a commodity price freeze. The commodity price freeze was also unsuccessful, as it led to widespread chronic shortages of food and basic commodities. This prompted the government to reverse its policy, since pegged prices meant producers could not even meet their production costs, making it impossible for them to manufacture.

The other cost–push inflation is due to a rise in raw material prices, which has the same effect as that of wage rate increase, though it could be caused by either internal drivers or external forces such as the increase of price of an imported good which forces may be beyond the control of the state. While the official exchange rate in Zimbabwe was Z$250.00 per US$1.00 in January 2007, rationing of foreign currency meant that producers had to look for the currency from the black market at over Z$1,500.00 to the US$1.00. The effect of this was expensive raw materials for the production of goods, which ultimately resulted in a rise in prices and eventually inflation. Raw material shortages were also worsened by the disruptions in the farming sector, where the Government evicted commercial farmers, replacing them with subsistence ones. Commercial farmers produced and supplied agricultural products such as maize, ground nuts, milk and beef to the urban population at local prices. However, after the disruptions, some of the basic commodities had to be imported since most of the resettled farmers produced for their own consumption. This is in addition to the fact that Zimbabwe has always been a net importer of goods and services; thus the economy has always been sensitive to exchange movements.

Granger Causality Tests are used in this study to determine the effect of the exchange rate on the inflation rate in Zimbabwe from February 2002 to January 2007, and the results are presented below in Table 4.12. As noted above, the effect of the exchange rate on inflation was made worse by the displacement of commercial farmers who also produced cotton and tobacco, which were leading earners of foreign currency in the agrarian Zimbabwe economy.

Null Hypothesis:	Obs.	F-Statistic	Probability
EXC does not Granger Cause CPI	60	116.304	5.7E-26
CPI does not Granger Cause EXC		6.95816	5.6E-05

Table 4.12: Granger causality for inflation and exchange rate between 2002 and 2007

Table 4.12 shows that there was a statistically significant bilateral causality between inflation and the exchange rate over the period, since the calculated F-statistics are significant. These results indicate that between 2002 and 2007 the exchange rate in Zimbabwe provided useful information about the movement of the inflation rate, while the inflation rate also contained useful information about the exchange rate. As noted earlier, the fall in agricultural productivity led to a reduction in exports, thereby inducing a balance of trade deficit causing more foreign currency shortages and a fall in the Zimbabwean dollar. The fall in the dollar meant imports became expensive, thus pushing up production costs and inflation as a result.

In addition to cost–push factors, demand–pull inflation influences are also an inflation driver, and are a result of excess demand of goods and services while the economy is at full employment. Excess demand in this case refers to aggregate demand, which is made up of the total of consumer goods expenditure, government spending, investment expenditure and exports, less imports. Parkin, Powell and Matthews (1997) state that this excess aggregate demand could be due to an increase in the money supply, increase in government purchases or an increase in the price level or real GDP in the rest of the world. This cause of inflation is the subject of repressed form of unofficial inflation, which was noted by Munoz (2006) in Zimbabwe, where consumers end up with lots of cash in their hands while products for its disposal are not readily available. Another dimension of demand–pull inflation in Zimbabwe is the occurrence of continuous demand inflation, which Griffiths and Wall (2001) say is a sustained upward movement in the price levels due to a maintained growth in aggregate demand. Government price controls in Zimbabwe induced widespread shortages and a thriving black market, thus demand for goods at official market prices resulted in continuous demand for such goods by consumers who bought for use, consumption or storage. Government expenditure is also one of the factors leading to demand–pull inflation, especially since government purchases are huge and may create excess demand, as ordinary consumers compete for the same goods. In the case of Zimbabwe, government expenditure rose owing to the purchase of agricultural goods as the demand to support newly resettled farmers became a priority.

Despite the above influences of either a cost–push or demand–pull nature, Beardshow (1992) points out that monetarists' thinking is that inflation is entirely caused by a too-rapid increase in the money stock and nothing else. While the influence of monetary shocks acts as a catalyst for either cost–push or demand–pull inflation, the occurrence of push and pull factors in Zimbabwe explained above shows that they have been independently inducing inflation. Supply of money, which can also come in the form of an increase in interest rates, avails more disposable income to consumers and also becomes a catalyst for government expenditure resulting in excess demand and hence a demand–pull inflationary pressure.

Null Hypothesis:	Obs	F-Statistic	Probability
M1 does not Granger Cause CPI	60	1.16016	0.34213
CPI does not Granger Cause M1		2.08397	0.08329

Table 4.13: Granger causality for inflation and money supply between 1997 and 2002

However, there is no evidence that money supply (M1) caused inflation between 1997 and 2002 in Zimbabwe, as the Granger Causality test results show in Table 4.13 above. In fact, there is evidence that inflation provided useful information about movements in money supply rather than vice versa making this a one–way direction causality. This assertion is at 10% level of significance, which is an acceptable level of probability. The monetarist view, however, is not totally dismissed during this period, as interest rates did Granger cause inflation as demonstrated in Table 4.14 below.

Null Hypothesis:	Obs	F-Statistic	Probability
INT does not Granger Cause CPI	60	2.99684	0.01942
CPI does not Granger Cause INT		0.98125	0.43872

Table 4.14: Granger causality for inflation and interest rate between 1997 and 2002

Interest rates between 1997 and 2002 Granger caused inflation and thus provided useful information about the movements of inflation during the period. The results also show that inflation did not cause movement in interest rates since the probability is 0.44, which is not within the acceptable levels of significance. Interest rates also provided useful information about inflation between 2002 and 2007, as shown in Table 4.15 below. This is also one–direction causality from interest rates to inflation. Statistically, inflation did not cause movement in interest rates in Zimbabwe, and this is consistent with economic theory, which shows interest rates providing useful information on inflation.

Null Hypothesis:	Obs	F-Statistic	Probability
INT does not Granger Cause CPI	60	37.8841	1.0E-15
CPI does not Granger Cause INT		1.43587	0.22818

Table 4.15: Granger causality for inflation and the interest rate between 2002 and 2007

The above submission should be considered, however, in the context of the different approaches used to address inflation. If government policy is proactive, then Table 4.15 obtains but if the policies are reactive then inflation would Granger cause interest rates as the government uses interest rates to address inflation challenges. In Zimbabwe, interest rates post–2002 were fixed as the government sought to arrest its own expenditure. Thus its use of interest rates to address inflation challenges was limited.

While money supply did not cause inflation during the 1997 and 2002 period, the situation changed in the five years leading up to January 2007. In fact that money supply (M3) in Zimbabwe rose from 99.5% in January 2002 to 1,638.4% in January 2007, which increase, when compared to the inflation increase of 116.7% to 1,593.6% in the same period, shows the influence of this variable to inflation in the country. However, this rise could be a result of inflation increasing money supply since such a large increase in the inflation rate would have to be supported by a substantial increase in money supply lest cash shortages surface. Table 4.16

below shows that money supply and inflation have a bilateral causality over this period, supporting the above submission.

Null Hypothesis:	Obs	F-Statistic	Probability
M1 does not Granger Cause CPI	60	14.0491	1.6E-08
CPI does not Granger Cause M1		13.5302	2.7E-08

Table 4.16: Granger causality for inflation and money supply between 2002 and 2007

The results show a statistically significant two-way directional causality between inflation and money supply at 5% level of significance. This is consistent with the findings of Kovanen (2004), who also noted that money in circulation provides strong information about movements of inflation in Zimbabwe, compared to other monetary aggregates like interest rates, which were predominantly fixed between 2002 and 2007.

4.7 Conclusion

Inflation in Zimbabwe has increased from 3.22% in June 1988 to 1,593.6% by January 2007, an increase well over 1,500%, and research on inflation in Africa would therefore be incomplete without considering the world's highest inflation rate, which the World Bank correctly projected could reach 100,000% within a year from May 2007. At the end of 2008, the annual inflation rate had risen to 2.4 million percent. The cause of this surge in inflation was a cocktail of factors including the critical shortage of foreign currency, excess demand caused by shortages and price controls, strong trade unions, money supply and inadequate policies to arrest the hyper inflation. Using Granger Causality tests, there is evidence of bilateral causality between inflation and money supply as well as the exchange rate in Zimbabwe between 2002 and 2007. However, the causality runs one way from interest rate to inflation during the same period. Five years prior to 2002 causality was one way only, from interest rates to inflation and inflation to money supply, and there was no bilateral nor any causality found between the exchange rate and inflation. Between 1997 and 2002, currency rationing had not yet been rampant in the country, although a fixed currency regime started in December 1997, explaining the causality differences between the exchange rate and inflation for the two periods.

Although the inflation rate in Zimbabwe has been in hyper-state, the announced official figures have been understated owing to the existence of hidden inflation. This chapter explored why there is credence in reports that inflation in Zimbabwe as officially announced is understated, hence contributing to the current debate on inflation in Africa, and Zimbabwe in particular. The issue of understated inflation figures was looked at from the perspective of weights, recalculating the index using monthly increases and simulated weights, an approach which Nuti (1986) suggests is one of the methods of unearthing hidden inflation. The evidence presented in this chapter shows that annual inflation in Zimbabwe was understated by over 35% by June 2007. The need for the recalculation of weights in Zimbabwe therefore cannot be over emphasised, as the current weights fall short of the practical consumer basket. These findings are new from the hidden inflation angle of unveiling unofficial inflation, and they also support evidence already established by a repressed inflation approach to unofficial inflation carried out by Munoz in Zimbabwe in 2006. Munoz (2006) used a repressed inflation approach to show that inflation in Zimbabwe is understated, but since this approach is not exhaustive, the method used in this study provides further proof of the claims which Munoz put forward on the inflation rate in Zimbabwe. The presence of hidden inflation, however, could be higher than this evidence suggests if black market prices and substitute products are taken into consideration.

Apart from the evidence of hidden inflation in Zimbabwe, there is also concern about the accuracy of inflation figures in other African countries. In particular, the statistically higher increases in food inflation, the largest component of the inflation basket, are worrying especially since most countries in the continent only change their weights after five years, and in some cases over ten years. The effect of this is a household expenditure basket which is outdated, resulting in an incorrect inflation rate, thus suggesting the existence of hidden inflation. Another finding from the empirical work in this study is the significant positive relationship between changes in poverty and the food weights within a consumer basket. Poverty in this case was measured in terms of the International Poverty Line for comparison, which measure looks at the percentage of people within a country living on less than US$2 per day. This finding reinforces the need for countries to carry out consumer consumption surveys more often when people’s living standards, as measured by the consumer price index, are falling.

The importance of obtaining correct inflation rate figures is multidimensional, starting from the rate figures being used by workers in the country to negotiate salary increases to businesses projecting future growth and governments preparing adequate policies to tackle economic challenges. The understatement of figures will therefore deprive the workers of an appropriate or real salary increase. Their income will be eroded over time, which has notoriously happened to the Zimbabwe labour market in the wake of the current hyperinflation. Businesses also fail to meet targets that cover their costs adequately, and even when they do the realised profit after inflation adjustment becomes an investor's trap, as it provides misleading information about the real situation regarding the profitability of the venture. From a policy viewpoint, correct inflation figures help arrest rampant budget deficiency which is a worrying element of high inflation countries, especially those with understated figures. For a government, there might also be a call for the knowledge of correct figures to ensure that mechanisms that are meant to correct inflation surge are adequate to meet the expectations of the economy, and this can be best done by the production of correct and up–to–date inflation figures.

CHAPTER FIVE

FORECASTING INFLATION IN AFRICA

5.0 Introduction

The impact of inflation on the stock market can not only be looked at from the viewpoint of the relationship that exists between these two variables (Ely and Robinson, 1997; Boudoukh and Richardson, 1993; Campbell, 2002; Boucher, 2006), but from the significance that this relationship has within financial markets trading. One of the reasons for wanting knowledge about short– and long–term inflation–stock relations is to ensure market positioning in the case of pending inflation surge or dip. Consequently, looking into the future through forecasting inflation becomes part of the interest in the relationship between the two, as the knowledge about inflation movements provided by forecasting aids stock market stakeholders to act consistently with both the forecast know-how and researched evidence of the relationship. It is in this context that this chapter will endeavour to explore forecasting of inflation in Sub–Saharan Africa as part of the reasoning in understanding the impact of the same on stocks, without which one is forced into a hopeless leap in the dark. The chapter provides the basis for calculating unexpected inflation, a variable used in Chapter 6 to understand the nature of the relationship between stock returns and inflation. In addition, this chapter contributes to current literature by establishing optimum forecasting approaches for the countries studied in this thesis as it considers univariate, bivariate and multivariate forecasting options.

With time series data limitations an incurable historic reality in Africa, univariate and multivariate forecasting approaches will be looked at in this chapter bearing in mind, however, that other forms of predicting inflation, such as the Phillip's curve, have empirically been considered more powerful (Duguary, 1994; Coe and McDermott, 1999; Stock and Watson, 1999; Onder, 2004; Hargreaves, Kite and Hodgetts, 2006). The unavailability of credible unemployment time series data prohibits the use of the Phillip's curve which, in its original state, stipulates that there is an inverse relationship between the rate of change in nominal wages and unemployment where the latter is used as a proxy for excess demand (Bailliu *et al*., 2003; Hargreaves *et al*., 2006). Thus a decrease in unemployment would result in a rise in excess demand, therefore putting pressure on the nominal wage. This approach developed by Bill Phillips in 1958 has now been modified by the substitution of output gap as a proxy for excess demand in place of unemployment (Stock and Watson, 2003). Despite the evidence on the importance of the Phillip's curve to forecasting inflation, Gali *et al*. (2001) have since predicted the death of this approach, with Simone (2000) acknowledging that the autoregressive integrated moving average (ARIMA) models outperform the Phillip's curve for out–of–sample short-term forecasts. More importantly for this research, though, Bailliu *et al*. (2003) point out that the Phillip's curve has been used as a useful framework to explain and forecast inflation only in industrialised countries, and not developing ones, where it has been outperformed by economic variables driven by bivariate and multivariate models.

The use of the multivariate approach to forecasting inflation is premised on the understanding that theory and empirical work have shown that economic variables contain valuable information about inflation movements. The relationship between inflation and economic variables is thus well documented, with studies that have performed a Granger causality test confirming the importance of these variables to inflation (Chhibber *et al*., 1989; Friedman and Kuttner, 1992; Estrella and Mashikin, 1997; Callen and Chang, 1999; Black *et al*., 2000). In particular, the importance of the exchange rate on inflation is considered by Svensson (2000) from three channels: first, the extra demand channel from sensitivity of net trade to the exchange rate; second, the direct exchange rate channel due to the presence of imported goods in the consumer price index; and third, the link between the consumer price index and the exchange rate due to imported intermediate goods. Kara and Nelson (2003) also argue for exchange rate importance by concluding that only a model where imports are modelled as an intermediate good provides a reasonable match with the UK data. This inference is also supported by Durevall and Kadenge (2001) on Zimbabwe data. The nature of the link between inflation and growth is still debatable (Khan and Senhadji, 2001), since the relationship is considered negative for medium and long–term growth, and at some low inflation below 8% (Sarel, 1996) or 2.5% (Ghosh and Phillips, 1998) it is considered positive, and hence useful information for forecasting purposes. Tigene (1989), Chhibber *et al*. (1989), and Chandra and Tallman (1997) find a relationship between inflation and money supply, confirming the variable's importance to forecasting inflation since it has useful information about it.

The relationship between inflation and interest rates in particular, whether a change in nominal interest rates means a change in expected inflation, has been a central challenge in monetary economics (Pearce, 1979; Lanne, 2001). The use of nominal interest rates to forecast inflation, a product of Fisher (1930), has been a widely used approach owing to empirical backing (Gibson, 1972; Pyle, 1972; Pearce, 1979; Fama and Gibbons, 1984; Johnson, 2001). The notion that interest rates move one-on-one with inflation has, however, been attributed to the non-linear dynamics in the composition of both components (Evans and Lewis, 1995; Garcia and Perron, 1996; Lanne, 2006) rather than linear considerations which have been empirically questioned by lack of evidence in some cases (Gargill, 1976; Mashkin, 1992, 1995). Gargill (1976), whose earlier research with Meyer (Cargill and Meyer, 1974) had found short and long interest rates in the US between the 1950s and 1960s to be significantly related to price changes, later realised that the 1950s interest rates were not significant, thus confirming the controversy surrounding the nature of the relationship. In this chapter, the importance of interest rates as a significant predictor of inflation will not be undermined, thus a model of interest rate lagged one month will thus be used as a benchmark for ascertaining the power of multivariate models produced here to forecast inflation in Sub-Saharan Africa.

While the importance of economic variables and multivariate forecasting has been articulated above, the power of univariate models cannot be overlooked, with Stockton and Glassman (1987) pointing out that it is distressing that ARIMA models of inflation produced more respectable forecast performances relative to theoretically based specifications. They conclude that theory has yet to yield only small dividends in terms of improving ability to predict accurately the course of inflation. The power of ARIMA models, which use historic movements of a variable to determine its own future, is also confirmed as having sufficient predictability power in forecasting inflation in Pakistan (Salam *et al*. 2006). The use of ARIMA models in forecasting inflation in Sub-Saharan Africa is thus not just uniquely and procedurally contained in this study, but is grounded on its successes and its use in forecasting inflation in the US (Stockton and Glassman, 1987), Ireland (Meyer *et al*., 1998), Chile (Simone, 2000) and

Japan (Sekine 2001) among other countries. Apart from ARIMA models, another set of univariate models, which will be considered for inflation forecasting in this chapter, is the GARCH model described later. According to Drost and Klaaseen (1997), the use of this method is justified because inflation, like other financial and econometric data sets, exhibits conditional heteroskedasticity, a valuable property for GARCH models. The pioneer paper on GARCH models by Engle (1982), who introduced the concept of autoregressive conditional heteroscedasticity (ARCH), used UK inflation to set up the group of models popularised and generalised by Bollerslev (1986). Univariate agnostics do not, however, assume knowledge of any underlying economic model or structural relationship, and the fact that the models are backward looking means they are poor predictors of turning points unless the turning point represents a return to equilibrium (Meyer *et al*., 1998).

According to Friedman and Kuttner (1992), the importance of inflation varies from country to country as well as period to period, and as such, given the uniqueness of the economic terrain in Africa, inferring results from more developed economies may encourage groundless expectations. Research on forecasting in the continent has been heavily concentrated in South Africa because of the vibrancy of the economy and the financial services sector, with other countries' empirical work based on the causal relationships between inflation and economic variables. Chhibber *et al*. (1989) found that economic variables explain inflation movements in Zimbabwe, while Durevall and Kadenge (2001) noted that, after reforms, the exchange rate and foreign prices were important elements in Zimbabwean inflation, with money supply (M2) ceasing to play a significant role (Feridun and Adebiyi, 2005). Short–term interest rates were also found to have a significant causal relationship in Uganda (Nachenga 2001) and Kenya between 1974 and 1996 using error correction models (Durevall and Ndungu, 2001). Feridun and Adebiyi (2005), who carried out research on Nigeria between 1986 and 1998 using quarterly data, found that Treasury bill (TB) rate, domestic debt and M2 provide the most important information about price movements, with TB rate containing the best information as measured by Mean Absolute Percentage Errors (MAPE). In South Africa, Fedderke and Schaling (2005) employed an augumented Phillips Curve framework to investigate the link between inflation, unit labour costs, output gap, exchange rate and inflationary expectations. Using the multivariate cointegration technique, they found evidence consistent with mark-up behaviour of output prices over unit labour costs. Output gap and real economic conditions are also found by Woglow (2005) to contain useful information for forecasting inflation in South Africa.

Most of the relationship between economic indicators and inflation in Africa is based on causal relations, and the predictability of inflation using these elements needs exploring. Though Feridun and Adebiyi (2005) attempted to fulfil this objective, they looked at only ten years' data in Nigeria, while the present research looks at twenty years' data for seven Sub-Saharan African countries, namely: Botswana, Ghana, Kenya, Mauritius, Nigeria, South Africa and Zimbabwe. The justification of the use of these countries is premised in the scheme of the whole thesis, since these are the countries whose stock markets were functional before-January 1992, the cut-off month for this research. The predictability of interest rates, money supply, GDP and exchange rates will be examined in these countries with the hope of ascertaining which variable had the best inflation forecasting ability during the period, using both in-sample and out-of-sample approaches. The other contribution this chapter seeks to add to knowledge relates to the use of univariate approaches to forecasting inflation in Africa, which has been conspicuously overlooked in existing research.

The remainder of this chapter is structured as follows: Section 5.1 presents the data and its sources as well as statistically describing it. Section 5.2 presents unit root tests; Section 5.3 univariate forecasting; and Section 5.4 univariate model selection and forecasting. Section 5.5 contains cointegration and VECM results, while causality test results are presented in Section 5.6. Further error correction models are discussed in Section 5.7 with Section 5.8 presenting multivariate forecasting results. The main conclusions are then summarised in Section 5.9.

5.1 Data

This section will look at the data used in this research, as well as analysing the movement of different time series data used in this research. The study employs twenty-year monthly consumer price index, money supply, interest rates and exchange rate data from February 1987 to January 2007 for Botswana, Ghana, Kenya, Mauritius, Nigeria, South Africa and Zimbabwe. CPI, exchange rate, interest rate and money supply data for all the seven countries was obtained from International Financial Statistic (IFS), apart from money supply figures for Botswana, which were obtained from Botswana Central Bank. The consumer price index data has been discussed in the previous chapter, and is therefore omitted from this data presentation section. IFS exchange rate figures used here are based on the value of the local currency to a US dollar, and range from official rates (Botswana, Kenya and Zimbabwe) to principal rate (Ghana, Nigeria and South Africa) and market rate (Mauritius). Based on availability, interest rate data for Kenya, Nigeria, South Africa and Zimbabwe is based on t

Treasury bills rate in these countries, while Treasury discounted rate is used for Ghana, money market rate for Mauritius and Bank of Botswana rate for Botswana interest rates. Money supply data is only available for South Africa, Mauritius and Botswana; therefore inflation multivariate forecasting will include the series in these countries.

Interest rate figures for January 2007 were missing in the Zimbabwe data, so the TB rate from Zimbabwe Central Bank was used to complete the series, since all the previous months' data in the IFS data series corresponded with that supplied by the Zimbabwean authorities. Another gap was found in September 1987 for the South African Treasury Bills data, so figure was estimated using a ratio approach, with inter-bank call rate movement as the proxy. The inter-bank call rate was used after the two series showed a significant positive correlation. Finally, the Nigerian interest rate data starts from July 1991 instead of the February 1987 sample start date; hence all series for Nigeria were shortened for multivariate forecasting.

5.1.1 Exchange rate

The Botswana exchange rate is expected follow the same random walk as that of South Africa, as shown on Figure 5.1, since it is pegged to the South African Rand.

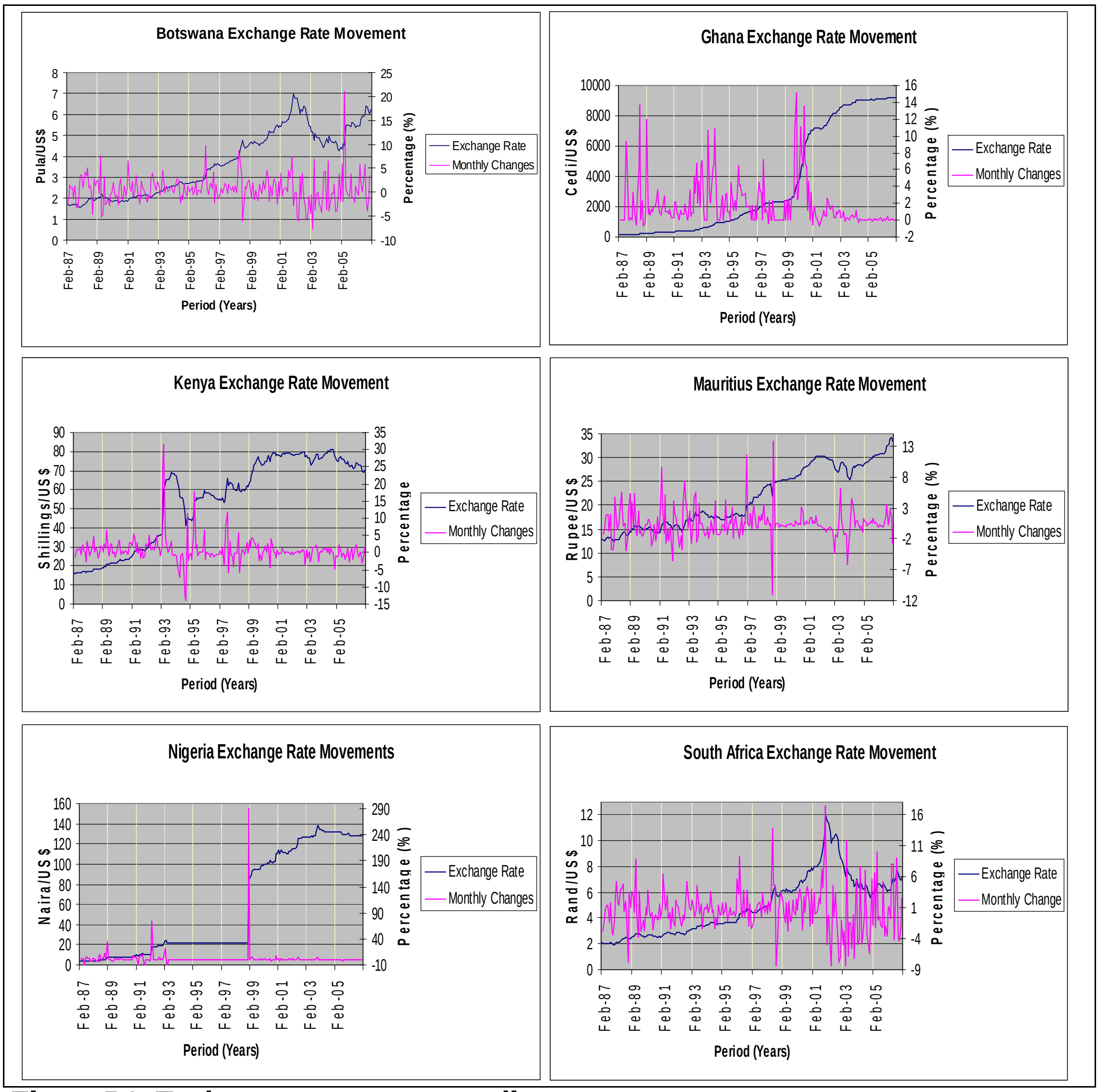

Figure 5.1: Exchange rate movement diagrams

The Nigerian exchange rate diagram indicates that the exchange rate for the greater part of the 1990s, were fixed with a huge devaluation in 1999, while the Ghanaian Cedi has been fairly persistent in terms of its loss of value for most of the period under review. Loss of value seems to be a dominant feature, with Kenya and Mauritius also exhibiting similar treads over time. More description is offered below in Table 5.1, which presents descriptive statistics for exchange rate for the above mentioned African countries in the twenty years leading up to

January 2007. Ghana, which has a mean exchange rate of 3543.05 Ghanaian Cedi to the US dollar (US$), was the weakest during the period under review while a mean of 3.678 Botswana Pula reflects the strength of the currency over this period.

Exchange Rate Descriptive Statistics									
Country	Mean	Median	Maximum	Minimum	Std. Dev.	25 %-ntile	75 %-ntile	Skewness	Kurtosis
Botswana	3.678	3.578	6.983	1.566	1.546	2.124	4.897	0.256	-1.310
Ghana	3543.050	1783.000	9235.470	149.930	3551.883	391.770	7404.200	0.622	-1.388
Kenya	54.621	59.939	81.272	16.041	22.584	29.262	75.254	-0.519	-1.288
Mauritius	21.655	20.085	34.337	12.175	6.284	15.956	28.067	0.200	-1.460
Nigeria	57.147	21.887	137.700	3.738	51.960	11.428	114.075	0.441	-1.668
SA	4.989	4.530	12.127	1.930	2.346	2.826	6.625	0.710	-0.151
Zimbabwe	10.634	0.011	250.000	0.002	42.513	0.005	0.055	4.812	23.475
Exchange Rate Change Descriptive Statistics									
Country	Mean	Median	Maximum	Minimum	Std. Dev.	25 %-ntile	75 %-ntile	Skewness	Kurtosis
Botswana	0.586	0.385	21.084	-7.670	3.005	-0.891	1.972	1.437	8.855
Ghana	1.774	0.814	15.137	-0.693	2.720	0.0003	2.367	2.455	6.678
Kenya	0.685	0.195	31.493	-14.038	3.848	-0.662	1.596	3.337	25.633
Mauritius	0.430	0.254	13.868	-11.050	2.453	-0.751	1.105	1.015	7.425
Nigeria	2.249	0.000	290.981	-11.648	19.710	0.000	0.609	13.554	196.228
SA	0.585	0.348	17.465	-8.442	3.673	-1.311	2.130	0.662	2.554
Zimbabwe	11.315	0.516	1401.570	-11.017	94.148	0.000	2.242	13.838	202.447

Table 5.1: Exchange rate descriptive statistics

An interesting observation in the above table is the zero median of Nigerian data changes, which indicates that the currency was fixed for more than 50% of the observations, while 25% of the Zimbabwean data also seems to have been fixed, given that 25% of the observations did not change. Most maximum values of the exchange rate are in the last five years, while the minimums are at the beginning of the sample period, indicating that African currencies have been weakening against the US$ over the period. The major weakening of a currency was experienced in Zimbabwe in March 2003, when the government devalued the Zimbabwe dollar (Z$) by over 1402% from Z$55 to Z$826. Interestingly, Ghana, with a maximum weakening of 15% and a strengthening of 0.7%, had a more stable currency with limited shocks.

5.1.2 Interest rates

Zimbabwe experienced the highest interest rates during the sample period compared to the rest of the African countries. An average of 54.8% for Zimbabwe, shown in Table 5.2 below, is higher than all the maximum interest rates except for Nigeria's.

Interest Rate Descriptive Statistics									
Country	Mean	Median	Maximum	Minimum	Std. Dev.	25 %-ntile	75 %-ntile	Skewness	Kurtosis
Ghana	27.050	26.190	46.750	9.400	9.566	19.800	33.000	0.220	-0.839
Kenya	15.811	13.990	70.640	0.840	10.854	9.573	18.713	2.589	9.606
Mauritius	8.384	9.030	13.400	1.000	3.337	7.013	10.618	-0.686	-0.300
Nigeria	14.757	14.300	27.500	2.150	4.481	12.400	17.200	0.191	1.000
SA	12.232	11.950	21.620	6.530	3.488	9.508	15.193	0.187	-0.949
Zimbabwe	54.806	28.405	525.000	7.730	89.682	14.513	55.228	3.834	15.685
Interest Rate Change Descriptive Statistics									
Country	Mean	Median	Maximum	Minimum	Std. Dev.	25 %-ntile	75 %-ntile	Skewness	Kurtosis
Ghana	-0.160	0.000	18.182	-22.311	5.215	-0.038	0.651	-0.480	4.828
Kenya	0.805	0.000	103.567	-67.407	14.939	-3.567	3.700	1.398	12.870
Mauritius	1.242	0.000	182.759	-51.744	19.747	-2.093	2.391	5.762	50.204
Nigeria	0.725	0.000	224.898	-43.393	19.314	0.000	1.380	8.487	99.103
SA	0.070	-0.106	23.195	-12.739	3.888	-1.460	1.589	1.122	7.298
Zimbabwe	1.774	0.120	50.222	-66.850	12.291	-1.298	4.818	-0.947	10.941

Table 5.2: Interest rate descriptive statistics

Despite the high mean, only interest rates after 2003 were above this percentage; thus the 55.2 75-percentile figure for Zimbabwe shows that the mean was pulled up by just under 25% of the observations. The effect of the high values in the last four years is further shown by Figure 5.2 below, where rates in Zimbabwe rose briefly in 2000 before falling and rising again in 2003 until 2006, when they came down to 200%, then 66.3%.

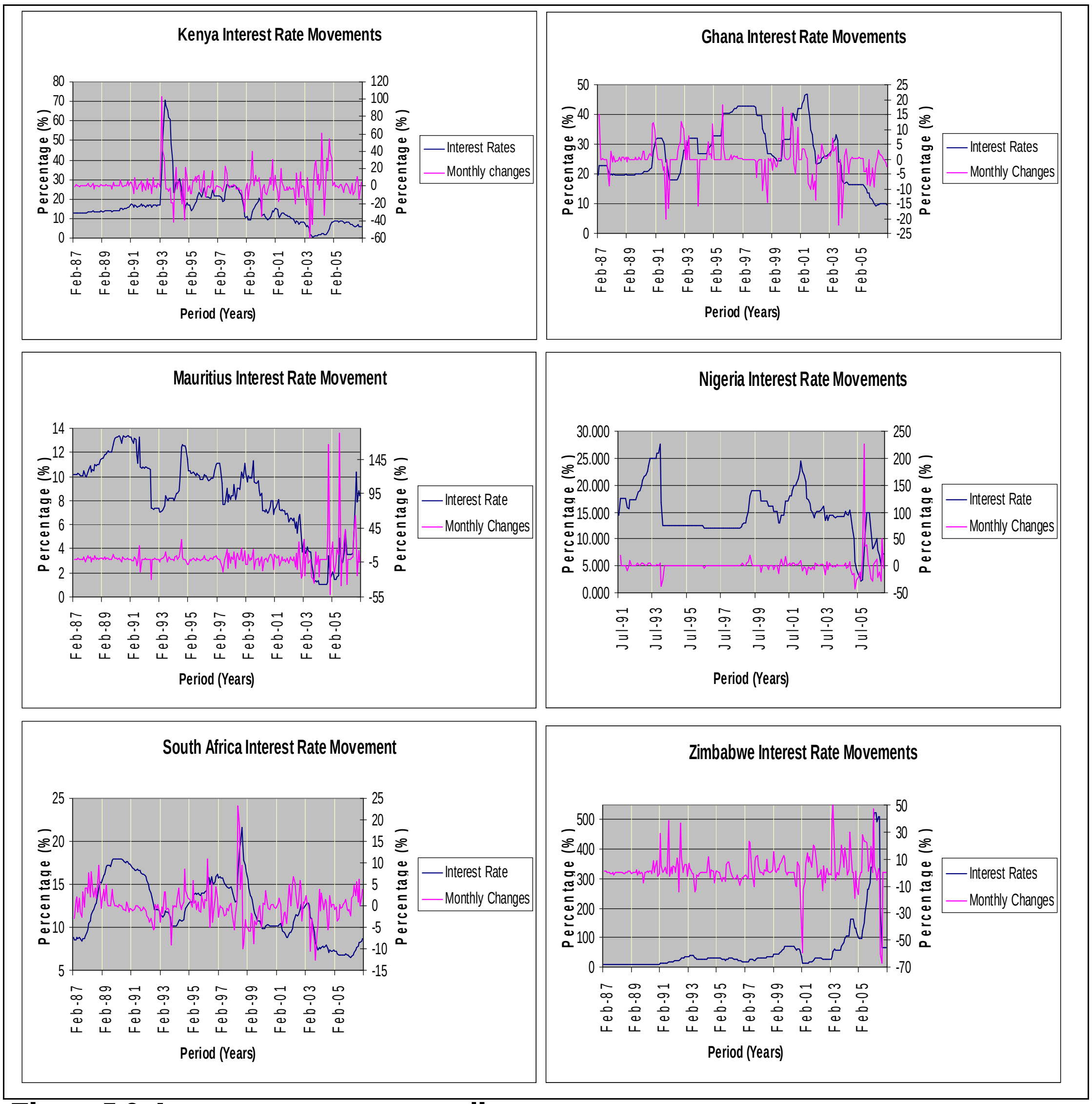

Figure 5.2: Interest rate movement diagrams

Figure 5.2 also shows that Nigeria and Ghana's interest rates have been constant for long periods, indicating a fixed interest rate monetary policy approach especially for Nigeria between 1994 and 1998. Kenya's interest rates were stable in the earlier years of the sample period, but became more volatile from the mid 1990s, while Mauritius' interest rates became volatile in 2002, having been more stable before then. South Africa shows less structural changes in the volatility of the data, with percentage interest rate changes between -10 and 20% compared to -60 and 100% for Kenya.

5.1.3 Money supply

Money supply changes have been controlled for South Africa, Botswana and Mauritius, with a mean of between 1.2 and 1.74% during the twenty years to January 2007. Only Botswana (see Table 5.3) with a maximum monthly increase of 24.6% in one month and a decrease of 19.5%, seems to have experienced some shocks.

Money Supply Descriptive Statistics									
Country	Mean	Median	Maximum	Minimum	Std. Dev.	25 %-ntile	75 %-ntile	Skewness	Kurtosis
Botswana	7967	4635	25957	599	7465	2145	12792	0.968	-0.481
Mauritius	71685	55948	186704	10435	49216	30245	106741	0.695	-0.613
SA	435591	323513	1349290	79587	324988	186755	631836	1.091	0.292
Money Supply Change Descriptive Statistics									
Country	Mean	Median	Maximum	Minimum	Std. Dev.	25 %-ntile	75 %-ntile	Skewness	Kurtosis
Botswana	1.742	1.696	24.609	-19.473	5.557	-0.945	4.372	0.102	3.281
Mauritius	1.221	0.953	5.765	-3.993	1.414	0.288	2.034	0.506	0.980
SA	1.201	1.087	5.587	-2.751	1.394	0.302	2.216	0.118	0.240

Table 5.3: Money supply descriptive statistics

The highest money supply figures are at the end of the sample period, indicating persistence in the variable.

5.2 Unit root test results

This section will look at issues relating to data processing, from seasonally adjusting of the data to logging it and then unit root testing. The merits of these processes have been explored in the methodology chapter; hence this will not be revisited here.

The data was imported from Excel to Eviews, after specifying the sample period as 1st February 1987 to 31st January 2007, and given the following new names: exchange rate (EXC), interest rate (INT), consumer price index (CPI) and money supply (M2/M3 depending on whether it is M2 or M3 money supply series). The descriptive statistics were then recorded for all the uploaded series before seasonally adjusting them using the Census X12 methodology explained in the methodology chapter, creating the following seasonally adjusted series: exchange rate (EXC_SA), interest rate (INT_SA), consumer price index (CPI_SA) and money supply (M2_SA/M3_SA). The seasonally adjusted data was then logged using the equation provided below which represents an example of the logging of the exchange rate data where log refers to the natural logarithm:

$$LE = \log(EXC\_SA) \tag{5.1}$$

The logged series were in each case renamed exchange rate (LE), interest rate (LI), consumer price index (LC) and money supply (LM). The importance of these names is to relate the diagrams and the Eviews output to the original data and the different variables. After being logged the data was ready to be tested for stationarity to ensure that forecasts produced in this analysis were not spurious, since series with a unit root have a tendency to result in spurious regressions and forecasts.

The unit root tests were done for all the series using the Augumented Dickey Fuller (ADF), Phillips–Perron (PP) and KPSS (Kwaiatkowski, Phillips, Schmidt and Shin, 1992) defined and explained earlier at 1%, 5% and 10% levels of significance (LOS). Results were obtained for the tests with an intercept (C), with trend and intercept (T&C), and finally with neither trend nor intercept (None). If the trend was not stationary at levels it was then differenced to arrive at the following new names: exchange rate (DE), interest rate (DI), consumer price index (DC) and money supply (DM), then re-tested for stationarity again. Since three tests are used here, results will be accepted if in the majority of results the tests agree in stationarity especially at levels. By majority here both the Augumented Dickey Fuller and the Phillips–Perron tests with constant and trend will have to provide similar results. If a hypothesis is rejected mutually by both criteria, then KPSS results will be considered. For the ADF, the choice of lag length has been well researched, with different views recommended, but none is considered distinctly superior to the rest, as noted in the methodology chapter. The information criterion is used here, but where the Akaike information criterion (AIC) and the Schwarz Bayesian information criterion (BIC) do not agree, the one with the higher lag length will be adopted. The reason for choosing the one with the higher lag length is to counter the criticism by Ng and Perron (1995), who accuse the information criterion method of lag choice of adopting small number of lag length, thereby increasing the chances of high size distortions (Maddala and Kim, 1998). Below is the table showing the lag length choice for each variable which is tested for stationarity. The maximum lag length used was 14.

Country	CPI	Exchange Rate	Interest Rate	Money Supply
Botswana	4	2	-	6
Ghana	3	7	14	-
Kenya	6	7	2	-
Mauritius	7	0	14	12
Nigeria	5	0	14	-
South Africa	12	0	2	3
Zimbabwe	14	3	3	1

Table 5.4: Lag length choice

In the Phillips–Peron test case the truncation lags were determined automatically by choosing the Newey–West bandwidth.

5.2.1 Consumer price index

Table 5.5 below presents the results of the unit root tests at levels for consumer price index for the seven African countries logged and seasonally adjusted data series. The results show that using the ADF and PP tests with trend and intercept, all series have a unit root at all levels of significance. Nigeria and South Africa unit root tests with intercept for both the ADF and the PP, as well as ADF with intercept for Botswana, show that the hypothesis of the series having a unit root is not accepted at all levels of significance, and are thus considered stationary on this criterion.

	Augumented Dickey Fuller		Phillips–Perron		KPSS	
Country	**Constant**	**Trend & C**	**Constant**	**Trend & C**	**Constant**	**Trend & C**
Botswana	-2.04	-1.03	-2.42	-0.83	1.93	0.45
Ghana	-1.45	-1.16	-1.92	-0.67	1.94	0.30
Kenya	-1.86	-1.46	-1.94	-0.98	1.83	0.43
Mauritius	-2.85*	-3.65**	-1.66	-1.79	1.92	0.42
Nigeria	-3.13**	-2.61	-5.23***	-2.59	1.49	0.35
South Africa	-5.33***	-2.17	-6.81***	-1.55	1.88	0.49
Zimbabwe	4.32	4.37	12.23	6.90	1.76	0.45
Critical Values						
1%	-3.46	-4.00	-3.46	-4.00	0.74	0.22
5%	-2.87	-3.43	-2.87	-3.43	0.46	0.15
10%	-2.57	-3.14	-2.57	-3.14	0.35	0.12

The unit root test results for the consumer price index, the asterisk (*) represents cases where the Null is rejected at 10% level of significance, double asterisk (**) represents where the Null is rejected at 5% and triple asterisk (***) at 1% level of significance.

Table 5.5: Unit root test results for the consumer price index at levels

The Botswana, Nigeria and South Africa series passed the test for the unit root hypothesis under the Augumented Dickey Fuller and the Phillips-Perron tests with trend and intercept they are considered to have a unit root, and hence are not stationary on the conditions mentioned earlier. Since all the CPI data has a unit root, a first difference is taken to arrive at a new series named DC (inflation rate), and this is then tested for a unit root, which is the first difference of the earlier series, LD. The results of the unit root tests are presented below in Table 5.6. They show that all series no longer have a unit root, with the unit root hypothesis rejected except for the Zimbabwe series without trend and intercept at all levels of significance for the Augumented Dickey Fuller test. The Zimbabwe series does, however, pass the unit root test for the PP test at all levels of significance with trend and intercept. Since the two tests do not agree on whether or not to reject the hypothesis for a unit root in the series, the KPSS test results are then considered. The KPSS results for Zimbabwe show that the series is non-stationarity since the hypothesis for stationarity is rejected at all levels of significance.

	Augumented Dickey Fuller			**Phillips–Perron**			**KPSS**	
Country	**C**	**T&C**	**None**	**C**	**T&C**	**None**	**C**	**T&C**
Botswana	-5.89*	-13.65*	-1.6***	-14.31*	-14.46*	-4.90*	0.68*	0.14**
Ghana	-4.30*	-4.51*	-2.34**	-9.04*	-9.42*	-3.73*	0.4**	0.09***
Kenya	-7.18*	-7.41*	-2.73	-12.40*	-12.45*	-10.08*	0.46**	0.14**
Mauritius	-7.73*	-7.87*	-5.04	-14.82*	-14.85*	-12.47*	0.29***	0.05***
Nigeria	-2.7***	-10.08*	-2.08**	-9.47*	-10.90*	-6.53*	1.02	0.24
South Africa	-5.30*	-7.01*	-1.8***	-8.38*	-10.72*	-3.89*	1.50	0.08***
Zimbabwe	0.10	-1.67	0.82	-2.40	-6.84*	-0.91	1.43	0.36
Critical Values								
1%	-3.46	-4.00	-2.57	-3.46	-4.00	-2.57	0.74	0.22
5%	-2.87	-3.43	-1.94	-2.87	-3.43	-1.94	0.46	0.15
10%	-2.57	-3.14	-1.62	-2.57	-3.14	-1.62	0.35	0.12

The unit root tests results for the inflation rate, the triple asterisk (***) represents cases where the Null is rejected at 10% level of significance, double asterisk (**) represents where the Null is rejected at 5% and one asterisk (*) at 1% level of significance. 'A' stands for constant, 'T&C' trend and constant and 'None' without trend or constant

Table 5.6: Unit root test results for the inflation rate

The Zimbabwe data, which is not stationary at first difference, is then further differenced to arrive at the series DD which is also tested for a unit root. The results for ADF and PP tests with trend and intercept are -17.058 and -36.34 respectively, thus showing that the series is stationary after the second difference, which makes it a series integrated to the second order, I(2).

The results for the rest of the unit root tests are presented in Appendix 5.1, with all the series having a unit root at the level except for Mauritius money supply series, which shows that the series has no unit root at the level using both the ADF and PP tests with trend and intercept at all levels of significance (LOS); but its diagram in Figure 5.2 shows clear non-stationarity. The Mauritius money supply series is, however, non stationary when the KPSS test for both intercept and trend with intercept is considered at all levels of significance. Since the series does meet the earlier criteria for acceptance it is used at levels without differencing in the next sections of this chapter. Another observation is that the Zimbabwean interest rate, which rejects the hypothesis for a unit root at the level using the ADF test with trend and intercept, does not reject this hypothesis using the PP test. As a result of the conflict in the ADF and PP test results, the KPSS with a trend and intercept is then considered, and this shows that the series is not stationary at all levels of significance; thus it is a candidate for first differencing where it is found to be stationary. Finally the Mauritius interest rate series is found to have a unit root when it is differenced using the ADF test with trend and intercept at all levels of significance, but this is in conflict with the PP results, which show the series as not having a unit root. The KPSS test with trend and intercept results for the differenced Mauritius interest rates shows the series as stationary at all levels of significance; thus the series is considered integrated to the first order, I(1), for the purposes of this research.

5.3 Univariate models

This section will explore univariate-forecasting models for African inflation as measured through the consumer price index. Autocorrelation tests were carried out for all the series to check if the ARIMA family of models are appropriate for the series, after which ARIMA models were estimated and tested for normality. After the estimation of the ARIMA models, the series were tested for the presence of ARCH effects, and series that showed the presence of ARCH effects in the residual became candidates for GARCH family models. The last model to be considered is an AR(1), which it will be compared with the rest of the other models in the last part of this section, which looks at the forecasting result of all the models for three, six and twelve months' out-of-sample and in-sample forecasts. The criterion to be used to choose the best forecasting model is then the model with the best results using two of Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Theil Inequality Coefficient (TIC). Where there is no agreement on a particular model, then the model with one of the above and a better bias proportion (BP) will be chosen as the best forecast model for inflation in a particular country for either out–of–sample or in–sample at three, six or twelve months.

5.3.1 The ARIMA models

For the ARIMA models to be considered effective for a series there is need for autocorrelation to exist such that past values of the series are related to the current; thus past values can be used to predict future values. The summary of the autocorrelation test for each country is presented in Table 5.7 below. Apart from the first Mauritius value, the rest of the results show that there is autocorrelation in the data as they are above the critical values at 5% levels of significance at different degrees of freedom (DOF). Since the rest of the Mauritius calculated values are above the critical values at other degrees of freedom, it will be considered for ARIMA modelling in this research as well.

DOF	$\chi^2_{(0.05)}$	Q-statistics						
		Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa	Zimbabwe
1	3.84	6.8	75.8	17.1	1.4	38.5	77.6	152.1
2	5.99	13.8	132.1	39.7	19.1	77.6	143.7	299.3
3	7.81	29.4	183.8	55.0	19.1	101.0	192.6	432.9
4	9.49	39.8	221.6	55.0	19.1	122.4	222.7	549.2
5	11.07	41.2	252.7	56.9	20.9	149.9	264.0	671.2
6	12.59	47.4	273.5	64.3	21.2	164.4	295.5	774.9
7	14.07	54.2	288.8	67.2	23.1	179.8	318.7	871.6
8	15.51	57.7	303.5	78.0	26.5	196.9	343.6	969.1
9	16.92	59.3	316.5	84.4	26.6	210.6	369.5	1054.6
10	18.31	65.9	324.4	90.0	29.1	222.1	391.2	1125.9
11	19.68	71.9	326.0	94.4	33.6	231.8	404.4	1191.5
12	21.03	74.8	326.9	94.5	37.3	235.7	406.9	1238.1
13	22.36	74.8	327.0	95.4	48.3	238.1	415.4	1291.5
14	23.68	76.4	327.4	95.4	54.5	243.5	429.2	1333.8
15	25.00	77.2	328.0	98.5	55.0	248.8	446.1	1375.9

Table 5.7: Autocorrelation test results for the inflation rate

To identify the best ARIMA model that fits the data, this research used the matrix method with a maximum model of five AR and five moving averages (MA) considered. An ARIMA (5,1,5), i.e. (AR,d,MA) where d is the order of integration (one in this case), was first performed with the Alkaike and Schwarz information criterion written in an Excel spread sheet until an ARIMA (1,1,1). After the final results of this Excel matrix were obtained, the best ARIMA model provided the lowest value for each information criteria. If the two ARIMA models (Akaike and the Schwarz) obtained different results, then both models were taken for the diagnosis tests and forecasting to see how they fared compared to other univariate models, on condition that all their coefficients were statistically significant. Where one lagged function was statistically insignificant it was eliminated from the model to ensure that only the significant lag functions remained.

All the African countries apart from South Africa, whose ARIMA is a (2,1,4), provided two ARIMA models using the above information selection criterion. The equations for these models are shown below with Botswana's two ARIMA models being (3,1,3) and (1,1,1); Ghana (4,1,3) and (1,1,1); Kenya (5,1,4) and (1,1,2), Nigeria (5,1,5) and (1,1,1); Mauritius (5,1,4) and (4,1,3) and Zimbabwe, which is integrated to the second order and has (4,2,4) and (1,2,1) models. For the equations below, where the probability is not provided, the level of significance on that particular value will be 5% LOS or below. In the equations below, dc represents the differenced CPI series, while in the Zimbabwe case dd is the second difference of the series. The time lag is represented by $t-1$, $t-2$, etc., where $t-1$ is a single lag, $t-2$ two lags and so on. In the case of Nigeria, the BIC equation whose integers are all significant shows that current inflation rate is influenced by a single lag in both the autoregressive and the moving average functions.

Botswana ARIMA Models

AIC[8]

$$dc_t = 0.008 + 0.56dc_{t-1} - 0.58dc_{t-2} + 0.89dc_{t-3} - 0.47u_{t-1} + 0.67u_{t-2} - 0.78u_{t-3} \qquad 5.2$$

BIC

$$dc_t = 0.008 + 0.95dc_{t-1} - 0.85u_{t-1} \qquad 5.3$$

All the coefficients of both the AIC and the BIC ARIMA models are statistically significant at 5% LOS, since none of the probabilities are above this number. The diagnosis and the

[8] AIC is the model determined through the use of the Akaike information criterion, while BIC is based on the Schwarz results.

forecasting tests will thus determine which one of these two models is a better fit for the inflation data in Botswana.

Ghana ARIMA Models

AIC

$$dc_t = 0.018 + 1.33dc_{t-1} + 0.12dc_{t-2} - 0.39dc_{t-3} - 0.06dc_{t-4} - 0.99u_{t-1} - 0.32u_{t-2} + 0.28u_{t-3}$$

(0.02) (0.92) (0.55) (0.64) (0.99) (0.73) (0.47) 5.4

BIC

$$dc_t = 0.018 + 0.89dc_{t-1} - 0.53u_{t-1} \qquad 5.5$$

The above results show that the coefficients of the Akaike model are not statistically significant save for the first lag of the autoregressive function whose probability is below 5% LOS. Coefficients of Equation 5.5 variables are, however, statistically significant which is somewhat surprising, since the first lag of the moving average function was statistically insignificant in Equation 5.4. The phrase “somewhat surprising” is used here because the explanation for the distortions in the significance of the coefficients could be a result of autocorrelation in the elements of the equation. Given these results, the Akaike ARIMA model is eliminated, and Equation 5.5 is considered the appropriate ARIMA model for Ghana.

Kenya ARIMA Models

AIC

$$dc_t = 0.011 + 1.62dc_{t-1} - 0.97dc_{t-2} + 0.45dc_{t-3} - 0.61dc_{t-4} + 0.34dc_{t-5} - 1.54u_{t-1} + 1.14u_{t-2}$$
$$- 0.59u_{t-3} + 0.43u_{t-4} \text{ (0.2)} \qquad 5.6$$

(0.12)

BIC

$$dc_t = 0.0109 + 0.53dc_{t-1} - 0.42u_{t-1} + 0.31u_{t-2} \qquad 5.7$$

In the Kenyan, case the ARIMA model based on the Schwarz criterion has statistically significant coefficients, a similar result to the Botswana and Ghana cases already looked at. The Akaike ARIMA model results show that the third lag of the autoregressive function and the moving average are statistically insignificant at 5% and 10% LOS. R-squared for this equation is 0.239, which indicates that 23.9% of the inflation movements in Kenya are explained by this equation, which has a significant F-statistic of 7.413. If the insignificant third lag autoregressive function is eliminated from Equation 5.6, the Akaike information criterion figure becomes bigger, which is not the desired outcome and thus Equation 5.6 is considered the optimum Akaike ARIMA model despite the insignificant coefficients.

Mauritius ARIMA Models

AIC

$$dc_t = 0.0058 + 1.06dc_{t-1} + 0.24dc_{t-2} - 1.12dc_{t-3} + 0.36dc_{t-4} + 0.15dc_{t-5} - 1.04u_{t-1} + 0.03u_{t-2}$$
$$+ 0.88u_{t-3} - 0.29u_{t-4} \quad (0.54) \quad (0.12) \quad (0.19) \quad (0.93) \quad (0.09) \qquad 5.8$$

BIC

$$dc_t = 0.0056 + 1.85dc_{t-1} - 1.25dc_{t-2} - 0.02dc_{t-3} + 0.26dc_{t-4} - 1.86u_{t-1} + 1.54u_{t-2} - 0.37u_{t-3}$$
$$(0.93) \qquad 5.9$$

Equation 5.8 shows that a number of coefficients are statistically insignificant, and eliminating the second lag of the moving average function results in the following Equation 5.10;

$$dc_t = 0.0058 + 1.03dc_{t-1} + 0.27dc_{t-2} - 1.12dc_{t-3} + 0.33dc_{t-4} + 0.16dc_{t-5} - 1.01u_{t-1} + 0.89u_{t-3}$$
$$- 0.28u_{t-4} \qquad 5.10$$

All the coefficients in the above equation are significant at 10% LOS, but coefficients of the fourth lag of both the autoregressive and moving average functions are insignificant at 5% LOS. Eliminating the fourth lag of the moving average function, however, results in the

Akaike information criterion figure becoming bigger, which, as noted above, is not desirable. As for the Schwarz model, only one coefficient is insignificant, and removing it from the equation results in the following Equation 5.11:

$$dc_t = 0.0059 + 1.76dc_{t-1} - 1.18dc_{t-2} + 0.23dc_{t-4} - 1.7u_{t-1} + 1.34u_{t-2} - 0.34u_{t-3} \qquad 5.11$$

The above equation's coefficients are all significant and would thus be considered as the optimum Schwarz ARIMA models.

Nigeria ARIMA Models

AIC

$$dc_t = 0.017 + 1.25dc_{t-1} - 0.63dc_{t-2} + 0.56dc_{t-3} - 1.08dc_{t-4} + 0.79dc_{t-5} - 1.08u_{t-1} + 0.69u_{t-2}$$
$$- 0.66u_{t-3} + 1.23u_{t-4} - 0.67u_{t-5} \qquad 5.12$$

BIC

$$dc_t = 0.0185 + 0.91dc_{t-1} - 0.67u_{t-1} \qquad 5.13$$

All the coefficients of the above ARIMA models are statistically significant and would thus be carried forward to the diagnosis stage of this model search. The calculated R-squared for the Akaike model is 0.3462 which means the model explains 34.62% of the movements in the inflation rate and this is a better result than the 0.2628 figure for the Schwarz model. Both equations are statistically significant with 39.7368 and 11.1728 F-statistics for the Akaike and the Schwarz models respectively.

South Africa ARIMA Model

$$dc_t = -0.0045 + 0.39dc_{t-1} + 0.6dc_{t-2} - 0.12u_{t-1} - 0.47u_{t-2} - 0.17u_{t-3} - 0.34u_{t-4} \qquad 5.14$$

(0.82) (0.52)

The coefficient of the first lag moving average function is statistically insignificant as well as the constant, and knocking off the constant followed by the next insignificant function results in Equation 5.15:

$$dc_t = 0.31dc_{t-1} + 0.68dc_{t-2} - 0.5u_{t-2} - 0.17u_{t-3} - 0.334u_{t-4} \quad 5.15$$

All the components of this equation are now statistically significant.

Zimbabwe ARIMA Models

AIC

$$dd_t = 0.0004 + 1.41dd_{t-1} + 0.12dd_{t-2} - 0.64dd_{t-3} + 0.01dd_{t-4} - 2.25u_{t-1} + 1.24u_{t-2}$$
$$+ 0.4u_{t-3} - 0.38u_{t-4}$$ (0.75) (0.96)

(0.43) 5.16

BIC

$$dd_t = 0.0007 - 0.31dc_{t-1} - 0.4u_{t-1} \quad 5.17$$

(0.42)

Equation 5.16 has three insignificant coefficients. However, knocking off the one with the highest probability results in the Akaike figure becoming bigger rather than smaller, so the model is retained in its current form. As for the Schwarz ARIMA model, the elimination of the insignificant constant results in the following Equation 5.18:

$$dd_t = -0.31dc_{t-1} - 0.39u_{t-1} \quad 5.18$$

This equation now has significant components and explains 35.17% movements in the inflation rate in Zimbabwe. The diagnostic tests for the equations are given in Appendix 5.2.

5.3.2 The GARCH models

Only the general GARCH model will be considered here. It will be looked at from two angles, the first being generated by regressing the series with a constant, and then the second through creating a GARCH out of an ARIMA model. The series should, however, show the existence of ARCH effects before it is considered for this type of model. The first part of this section therefore considers testing for ARCH effects; the second part constructs the GARCH models starting with one regressed using a constant followed by one constructed out of an ARIMA model, and the last part will test these models to check if there are any ARCH effects remaining in the model. As noted in the methodology chapter, it is best to estimate a GARCH (1,1) as it captures all the volatility for financial data. Table 5.8 below presents the results of the ARCH effects test for the inflation series with the following null and alternative hypotheses:

$H_{0:}$ No ARCH effects

$H_{1:}$ There are ARCH effects

The results below show that the Mauritius and the Zimbabwe series exhibit the existence of ARCH effects in them as their calculated values are above the 5% LOS critical values of 3.84, 11.07 and 25 for 1, 5 and 15 degrees of freedom respectively. Thus the null hypothesis that there are no ARCH effects is rejected.

	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa	Zimbabwe
Obs*R-sq.-1 lag	0.61	3.00	1.91	14.80*	3.74	3.24	61.85*
Obs*R-sq.-5 lags	1.00	3.98	24.72*	32.82*	9.50	5.77	73.21*
Obs*R-sq.-15 lags	6.44	5.17	41.68*	63.00*	13.68	10.33	108.24*
The figures with asterisk (*) are above the critical values and the Null hypothesis for no ARCH effects in this case is not rejected.							

Table 5.8: ARCH LM test

For the Kenyan series, the hypothesis is not rejected for the 5% LOS with one degree of freedom, but is rejected for five and fifteen degrees of freedom. Given these results, GARCH models were estimated for the Kenya, Mauritius and Zimbabwe time series. The GARCH model results for these three countries are presented in Table 5.9 below based on the following Equation 5.19:

$$\sigma_t^2 = \omega + \beta \varepsilon_{t-1}^2 + \lambda \sigma_{t-1}^2 \qquad 5.19$$

where σ_t^2 is the conditional variance (the GARCH term), ω is the mean, β is the coefficient of the ARCH term (ε_{t-1}^2) measured as the lag of the squared residual from the mean equation which measures news about volatility from the previous period and λ is the coefficient for the GARCH term in the previous period.

		ω	β	λ
Kenya	GARCH (1:1)	0.000015	0.0872	0.8579
	GARCH from ARIMA (AIC)	0.000004	0.4858	0.4339
	GARCH from ARIMA (BIC)	0.000042	0.4574	0.4448
Mauritius	GARCH (1:1)	0.000001	-0.0443	1.0044
	GARCH from ARIMA (AIC)	0.000012	0.5588	0.2222
	GARCH from ARIMA (BIC)	0.000001	0.5286	0.2025
Zimbabwe	GARCH (1:1)	-0.000005	0.0856	0.9519
	GARCH from ARIMA (AIC)	0.000001	-0.0241	1.0391
	GARCH from ARIMA (BIC)	-0.000004	0.0619	0.9747

Table 5.9: GARCH model results for the inflation rate

The residuals for these models were saved and the ARCH LM test conducted to confirm if there are still any ARCH effects in the models and this test was performed at 5% level of significance with the results in Table 5.10.

		F-Stats	Obs*R-sq
Kenya	GARCH (1:1)	0.00572	0.00577
	GARCH from ARIMA (AIC)	0.07084	0.07146
	GARCH from ARIMA (BIC)	0.01960	0.01977
Mauritius	GARCH (1:1)	0.00004	0.00004
	GARCH from ARIMA (AIC)	0.26763	0.26974
	GARCH from ARIMA (BIC)	0.24252	0.24446
Zimbabwe	GARCH (1:1)	1.47444	1.47789
	GARCH from ARIMA (AIC)	10.7756	10.36406
	GARCH from ARIMA (BIC)	3.23316	3.21546

Table 5.10: Arch LM test for the inflation GARCH models

The table above presents results for an ordinary GARCH estimated using a constant, Akaike ARIMA and Schwarz ARIMA; apart from the Zimbabwe results, the rest are insignificant, indicating that the models no longer have ARCH effects. The GARCH estimated using the Akaike ARIMA for Zimbabwe series is the significant one; thus the null no ARCH effects in the model at 5% level of significance after one degree of freedom is rejected, and this model will not be considered for forecasting purposes.

5.4 Univariate model selection and forecasting

In line with the earlier discussion, forecasting of inflation is important in the context of this research as it provides the tools required to determine unexpected inflation. Moreover, the need to establish the relationship between the stock market and inflation is to ensure investor marketing positioning in the face of pending inflation; hence the need for an optimum inflation forecasting model. So far in this chapter, the models have been selected and for each ARIMA, and GARCH models where applicable, forecasting will be done to choose the best model for each country and this will represent the best univariate forecasting model. In each case the chosen model is compared with the autoregressive (AR) with one lag, i.e. AR(1) benchmark to ascertain its strength. Both in-sample (prior to February 2006 period) and out-of-sample (after February 2006 period) forecasting was carried out for one month, three months, six months and one year. For selecting the best forecasting model, the models were ranked in terms of the different forecasting selection criteria explained in the methodology section, i.e. RMSE, MAE, MAPE, TIC and BP. The problem with this method is that it assumes that the said criteria are equally important or weighted, which is not the case, but in the absence of a known weighting system the system was considered appropriate. For the one-month forecasts RMSE and MAPE were used, since the other criteria are not suited for one period ahead forecasting.

5.4.1 Out–of–sample one month results

Table 5.11 below shows the results of the out–of–sample one month forecasts for all the countries using the models defined by Equations 5.2 to 5.18 above. For Botswana and Nigeria, the results indicate that the Schwarz ARIMA model forecast results are better than the Akaike ARIMA model. However, the AR(1) benchmark has better results than both models using either the RMSE or MAPE, since the calculated figures are the smallest. In Ghana and South Africa, the ARIMA model's results forecast is better than the autoregressive model which acts as the benchmark. In cases where the GARCH models are considered, like Mauritius, Kenya and Zimbabwe, these models forecast better than the ARIMA and the AR(1). The only difference is that in Mauritius the GARCH estimated from either Akaike or Schwarz information criteria do not outperform the ordinary GARCH (1,1), while in Kenya and Zimbabwe the model's (GARCH) forecast results are poorer than those obtained from ARIMA and AR (1).

OUT OF SAMPLE FORECASTING RESULTS			
Country	**Model**	**RMSE**	**MAPE**
Botswana	ARIMA-S	0.000774	8.775944
	ARIMA-K	0.001011	11.46227
	AR(1)	0.000205*	2.318581*
Ghana	ARIMA	0.00674*	234.4248*
	AR(1)	0.00832	289.3922
Kenya	ARIMA-S	0.017111	47.67583
	ARIMA-K	0.017312	48.23538
	GARCH	0.027696	77.1681
	GARCH-AK	0.00635	17.69309
	GARCH-AS	0.003597*	10.02342*
	AR(1)	0.012758	35.5469
Mauritius	ARIMA-S	0.006083	658.5228
	ARIMA-K	0.005599	606.2245
	GARCH	0.003191*	345.4854*
	GARCH-AK	0.004205	455.2954
	GARCH-AS	0.004405	476.9253
	AR(1)	0.005986	648.0648
Nigeria	ARIMA-S	0.010556	70.06521
	ARIMA-K	0.020452	135.7524
	AR(1)	0.002171*	14.40854*
South Africa	ARIMA	0.001552*	87.29564*
	AR(1)	0.0030650	172.43
Zimbabwe	ARIMA-S	0.1275	85.47012
	ARIMA-K	0.16369	109.7302
	GARCH	0.149339	100.1104
	GARCH-AK	0.155793	52.86693*
	GARCH-AS	0.120784*	80.96802
	AR(1)	0.139545	93.54485

ARIMA-K and ARIMA-S denote Schwarz and the Akaike information criteria derived ARIMA respectively. The figures with asterisk (*) have the lowest number, therefore best result for each country using the different forecasting measures.

Table 5.11: One month out–of–sample forecasting results for inflation univariate models

5.4.2 In–sample one month results

For the in-sample case, Botswana, Kenya and Mauritius ARIMA models fit the data better than the benchmark or the GARCH in the case of Kenya. The autoregressive model lagged once fits the South Africa and Nigeria data better, as shown in Table 5.12 below, but is among the worst fit for the rest of the other countries.

IN SAMPLE FORECASTING RESULTS			
Country	**Model**	**RMSE**	**MAPE**
Botswana	ARIMA-S	0.006234	40.99243
	ARIMA-K	0.005437*	35.7518*
	AR(1)	0.007364	48.41957
Ghana	ARIMA	0.00530	98.5082
	AR(1)	0.00638	118.5841
Kenya	ARIMA-S	0.048096	75.61099
	ARIMA-K	0.046392*	72.9328*
	GARCH	0.055415	87.11772
	GARCH-AK	0.050218	78.94797
	GARCH-AS	0.049239	77.40875
	AR(1)	0.053097	83.47358
Mauritius	ARIMA-S	0.019090*	74.83750*
	ARIMA-K	0.022785	89.32190
	GARCH	0.021394	83.86927
	GARCH-AK	0.019747	77.41034
	GARCH-AS	0.019964	78.26152
	AR(1)	0.020074	78.69332
Nigeria	ARIMA-S	0.00261	52.09457
	ARIMA-K	0.00282	56.27754
	AR(1)	0.002388*	47.65372*
South Africa	ARIMA	0.001222	37.21094
	AR(1)	0.000469*	14.27911*
Zimbabwe	ARIMA-S	0.043173	281.2981
	ARIMA-K	0.011297	73.60971
	GARCH	0.015183	98.92664
	GARCH-AK	0.002812*	1.932635*
	GARCH-AS	0.039391	259.6552
	AR(1)	0.042892	279.4648
ARIMA-K and ARIMA-S denote Schwarz and the Akaike information criterion derived ARIMA respectively. The figures with asterisk (*) have the lowest number thus best result for each country using the different forecasting measures.			

Table 5.12: One month in-sample forecasting results for inflation univariate models

Unlike in the out–of–sample case, GARCH models do not fit the data well except in Zimbabwe, where a GARCH generated from an Akaike ARIMA model is a better fit of the data than all other models.

5.4.3 Longer period forecast results

In this section we look at the results for out–of–sample forecasting and establish if the models fit the data well by looking at the in–sample results. This will be done country by country with each model ranked as noted above and explained below.

BOTSWANA FORECASTING RESULTS							
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**
Out–of–Sample Forecasts	**3 Months**	ARIMA-S	0.000706*	0.000666*	7.599789	0.038413*	0.889854
		ARIMA-K	0.000947	0.000813	9.34428	0.051121	0.737248
		AR(1)	0.000769	0.00067	7.498353*	0.044721	0.480633*
	6 Months	ARIMA-S	0.003387	0.02622	58.60543	0.204338	0.599356
		ARIMA-K	0.003511	0.002762	60.79219	0.209989	0.618743
		AR(1)	0.002426*	0.001898*	42.1654*	0.158996*	0.285367*
	12 Months	ARIMA-S	0.003801	0.003318	73.30134	0.245241	0.762194
		ARIMA-K	0.003949	0.003475	76.14458	0.252187	0.774335
		AR(1)	0.002751*	0.002353*	52.63782*	0.193264*	0.556478*
In–Sample Forecasts	**3 Months**	ARIMA-S	0.00372	0.003202	29.36344	0.184664	0.036542
		ARIMA-K	0.003249*	0.002856*	26.66724	0.159515*	0.023233*
		AR(1)	0.004362	0.003184	26.0533*	0.227323	0.149605
	6 Months	ARIMA-S	0.005802	0.004364	28.97002	0.284449	0.52977
		ARIMA-K	0.005568*	0.004143*	27.29242*	0.270757*	0.534213
		AR(1)	0.005616	0.004227	28.14883	0.272703	0.514721*
	12 Months	ARIMA-S	0.005422	0.004486	47.38178*	0.307476	0.329739
		ARIMA-K	0.005261	0.004417	48.66731	0.29465	0.307051
		AR(1)	0.004937*	0.004113*	49.86042	0.264343*	0.175912*
The figures with asterisk (*) have the best models in each forecast period using a particular forecast determination criterion.							

Table 5.13: Forecasting results for Botswana inflation univariate models

For the in–sample case, the ARIMA which is Akaike generated fits the series data better using most forecast benchmarks or criteria for the three and six months periods. These findings are consistent with the one–month results contained above for Botswana, where AR(1) was a better forecasting model for out–of–sample and the Akaike information criteria generated ARIMA was a better fit of the data using in–sample forecasting. The above results also show that for three months out–of–sample forecasts, the ARIMA from the Schwarz lag information criterion are better using RMSE, MAE and TIC forecast benchmarks. However, using MAPE and BP, the ARIMA models are poor forecasts compared to the AR(1), and also fall short on all benchmarks for both the six and twelve months forecast periods. The power of the AR(1) in forecasting inflation for these periods is further supported by evidence from South Africa, which is presented in Table 5.14 below.

SOUTH AFRICA FORECASTING RESULTS							
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**
Out of Sample Forecasts	**3 Months**	ARIMA	0.001602*	0.001317*	220.9957*	0.290988*	0.608398*
		AR(1)	0.03856	0.00372	523.7942	0.485704	0.906785
	6 Months	ARIMA	0.003676	0.003122	142.3973*	0.42163	0.250154
		AR(1)	0.00287*	0.002384*	268.726	0.242048*	0.201262*
	12 Months	ARIMA	0.003214	0.002591	89.28373*	0.383918	0.367709
		AR(1)	0.002755*	0.002445*	165.3389	0.230545*	0.343899*
In-Sample Forecasts	**3 Months**	ARIMA	0.001117*	0.001022*	56.01427*	0.208825*	0.005421*
		AR(1)	0.002925	0.00269	142.4909	0.366107	0.845882
	6 Months	ARIMA	0.001272*	0.001074*	50.0905*	0.17926*	0.036934*
		AR(1)	0.003659	0.003375	148.794	0.359497	0.850495
	12 Months	ARIMA	0.002494*	0.002047*	120.0126*	0.430037	0.306294
		AR(1)	0.002755	0.002445	165.3389	0.230545*	0.230545*
The figures with asterisk (*) have the best models in each forecast period using a particular forecast determination criterion.							

Table 5.14: Forecasting results for South Africa inflation univariate models

Apart from the AR(1) dominance in longer period forecasting in South Africa for the one and three months out–of–sample forecasts, the ARIMA model is more powerful than other univariate models including for three and six months in–sample forecasts. The contradiction with these results is that the three months in–sample results presented above suggest that the ARIMA models are ideal fits for short–term South African data, but Table 5.12 provides a different picture since the results show that AR(1) is a better fit for the data. This contradiction is also noticed when the Nigerian inflation forecast results presented in Table 5.15 are analysed and compared with the results in Table 5.12.

Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
Out–of–Sample Forecasts	3 Months	ARIMA-S	0.018783	0.013844	52.40298*	0.647345	0.532648
		ARIMA-K	0.024814	0.023311	149.0393	0.862961	0.882507
		AR(1)	0.013381*	0.11069*	75.13414	0.346136*	0.093226*
	6 Months	ARIMA-S	0.016007*	0.012606*	396.5127	0.653655	0.005341*
		ARIMA-K	0.01984	0.1687	333.7656*	0.837706	0.147415
		AR(1)	0.017599	0.015675	752.2642	0.523336*	0.211709
	12 Months	ARIMA-S	0.01501*	0.012497	447.7647	0.605071	0.047717
		ARIMA-K	0.015193	0.01174*	244.9112*	0.683958	0.029206*
		AR(1)	0.017476	0.01569	715.0854	0.546541*	0.381708
In–Sample Forecasts	3 Months	ARIMA-S	0.016094	0.014573	156.6024	0.872475	0.819883
		ARIMA-K	0.01198*	0.009922*	105.3574*	0.753688*	0.685927*
		AR(1)	0.018393	0.01777	212.0878	0.827748	0.933416
	6 Months	ARIMA-S	0.028939	0.02629	263.7333	0.811877	0.8253
		ARIMA-K	0.031314	0.026988	228.8005*	0.797833	0.742789*
		AR(1)	0.026916*	0.025092*	239.9004	0.770754*	0.869038
	12 Months	ARIMA-S	0.020683	0.016999	213.7878	0.547905	0.161982
		ARIMA-K	0.019644	0.016559	177.1761*	0.550017	0.095436*
		AR(1)	0.017476*	0.01569*	715.0854	0.546541*	0.381708
The figures with asterisk (*) have the best models in each forecast period using a particular forecast determination criterion.							

Table 5.15: Forecasting results for Nigeria inflation univariate models

For the rest of the results, there is no real consistency exhibited in the above findings, possibly owing to the number of benchmarks and models considered. In the Ghana case, though, where only two models are compared for this univariate forecasting method, the results which are presented below in Table 5.16 show that the ARIMA model is superior to the AR(1) for all periods using all forecast benchmarks. The results in Table 5.16 show that when forecasting inflation in Ghana using a univariate approach there is need to determine an ARIMA model rather than just using an AR(1).

Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
Out–of–Sample Forecasts	3 Months	ARIMA	0.006452*	0.006175*	205.9785*	0.416612*	0.916*
		AR(1)	0.009726	0.009577	297.9949	0.511521	0.969601
	6 Months	ARIMA	0.004687*	0.003784*	108.3464*	0.216536*	0.375756*
		AR(1)	0.007621	0.006996	166.558	0.294528	0.842701
	12 Months	ARIMA	0.00565*	0.005084*	92.81622*	0.25071*	0.671241*
		AR(1)	0.0088	0.008408	142.3756	0.334486	0.912967
In–Sample Forecasts	3 Months	ARIMA	0.006527*	0.006198*	99.5504*	0.320295*	0.901633*
		AR(1)	0.009427	0.009046	144.2346	0.405407	0.920835
	6 Months	ARIMA	0.00477*	0.003419*	53.24849*	0.216947*	0.4855*
		AR(1)	0.007963	0.006711	94.95162	0.31252	0.7102
	12 Months	ARIMA	0.007531*	0.006586*	70.69316*	0.281498*	0.110913*
		AR(1)	0.009421	0.009086	102.7589	0.31399	0.373127
The figures with asterisk (*) have the best models in each forecast period using a particular forecast determination criterion.							

Table 5.16: Forecasting results for Ghana inflation univariate models

This assertion cannot be made in cases where there are many models to choose from, as in the Kenyan case whose results are shown in Table 5.17 below. The table shows that using the RMSE and TIC, the benchmark AR(1) is a better out–of–sample forecast than other model innovations. However, this benchmark is less preferable for the other periods out of sample using the MAPE and BP measures, where the GARCH models performed better.

For in–sample forecasting there is also a mixture of results using different measures, with the ARIMA innovations performing better using most of these.

Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
Out–of–Sample Forecasts	3 Months	ARIMA-S	0.025519	0.024393	182.635	0.547877	0.258959
		ARIMA-K	0.024279	0.022204	155.4511	0.554037	0.192884
		GARCH	0.020328	0.016665	81.38351*	0.657633	0.01146*
		GARCH-AK	0.02361	0.019915	159.5712	0.482852	0.441139
		GARCH-AS	0.026076	0.021868	187.9453	0.494064	0.55751
		AR(1)	0.016397*	0.014171*	91.62198	0.414652*	0.119394
	6 Months	ARIMA-S	0.02641	0.025179	291.2633	0.686511	0.543762
		ARIMA-K	0.025729	0.024408	346.5329	0.689101	0.524741
		GARCH	0.020781	0.018306*	185.7196*	0.769872	0.18282*
		GARCH-AK	0.026886	0.024586	366.6575	0.652368	0.698442
		GARCH-AS	0.028203	0.025384	323.6535	0.651148	0.735375
		AR(1)	0.020349*	0.018336	219.9485	0.61819*	0.4789
	12 Months	ARIMA-S	0.019184	0.015105	159.6037	0.570648	0.148488
		ARIMA-K	0.018321	0.01345	181.4109	0.519295	0.271029
		GARCH	0.015921	0.012982	115.1296*	0.616681	0.001485*
		GARCH-AK	0.019425	0.014787	201.8513	0.509006	0.414955
		GARCH-AS	0.020282	0.014829	174.0195	0.546662	0.265078
		AR(1)	0.015122*	0.011888*	125.181	0.501702*	0.086785
In–Sample Forecasts	3 Months	ARIMA-S	0.032647	0.024029	58.09397	0.687156	0.541743
		ARIMA-K	0.030179*	0.021545*	47.91133*	0.602583*	0.509655
		GARCH	0.033067	0.023852	56.20698	0.694931	0.520303
		GARCH-AK	0.034035	0.026381	74.40463	0.752514	0.600808
		GARCH-AS	0.032317	0.02355	55.32211	0.673413	0.531008
		AR(1)	0.031496	0.022132	48.42334	0.634805	0.480386*
	6 Months	ARIMA-S	0.022573	0.0131*	174.0227*	0.619385	0.156606
		ARIMA-K	0.021182*	0.013166	174.6611	0.554577*	0.151423
		GARCH	0.023875	0.014989	265.7888	0.660155	0.137798
		GARCH-AK	0.023682	0.014554	204.9304	0.655708	0.153814
		GARCH-AS	0.022404	0.013685	223.5821	0.599633	0.123784
		AR(1)	0.022955	0.041934	315.1931	0.598319	0.084558*
	12 Months	ARIMA-S	0.017514	0.011578	465.2762	0.575514	0.026207
		ARIMA-K	0.015839*	0.009237*	302.9816*	0.533881*	0.057689
		GARCH	0.017857	0.010874	395.7788	0.610088	0.039479
		GARCH-AK	0.017245	0.011033	474.1955	0.560211	0.015801
		GARCH-AS	0.017355	0.011649	477.4108	0.561069	0.01841
		AR(1)	0.017471	0.011472	504.6633	0.556076	0.006829*

The figures with asterisk (*) have the best models in each forecast period using a particular forecast determination criterion.

Table 5.17: Forecasting results for Kenya inflation univariate models

In each period there are six models considered for the five forecast measures (RMSE, MAE, MAPE, TIC and BP), and finding the best model in this case will have to be linked to one particular measure, disregarding the advantages of the rest. One way of determining the best model would be to convert the results into a z-score, which will limit the impact of big numbers that are produced by MAPE. The z-score is found by subtracting the mean of each column of results for a given forecast period from the actual recorded result, then dividing the outcome by the standard deviation of the same group of results. Since all forecast measures considered here are best when the result is minimised, the model with the smallest z-score becomes the best for the forecast period.

Table 5.18 below shows the z-score of the forecast results for Kenya. The models with total scores with asterisks are the best for the forecast period. The total in the right–hand column is the sum of the z-scores for each innovation. AR(1) is the best forecast model for out–of–sample forecasts in Kenya for three, six and twelve months; this is contrary to the finding in Table 5.11 which showed that the GARCH was a better forecast for shorter periods, i.e. one month. The z-score results also indicate that the Akaike generated ARIMA innovation fits the Kenya data better than all the other models for all the periods, and this is consistent with the earlier findings in Table 5.12.

Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP	Total
Out–of–Sample Forecasts	3 Months	ARIMA-S	0.764	1.187	0.864	0.276	-0.023	3.068
		ARIMA-K	0.428	0.612	0.270	0.351	-0.347	1.314
		GARCH	-0.644	-0.841	-1.350	1.609	-1.238	-2.463
		GARCH-AK	0.246	0.012	0.360	-0.514	0.872	0.976
		GARCH-AS	0.915	0.524	0.981	-0.378	1.444	3.485
		AR(1)	-1.709	-1.495	-1.126	-1.343	-0.708	-6.381*
	6 Months	ARIMA-S	0.506	0.727	0.032	0.166	0.083	1.514
		ARIMA-K	0.301	0.501	0.799	0.216	-0.013	1.803
		GARCH	-1.186	-1.288	-1.432	1.765	-1.750	-3.891
		GARCH-AK	0.649	0.553	1.078	-0.489	0.869	2.660
		GARCH-AS	1.045	0.787	0.481	-0.512	1.056	2.857
		AR(1)	-1.316	-1.279	-0.957	-1.145	-0.246	-4.943*
	12 Months	ARIMA-S	0.553	0.989	0.002	0.607	-0.333	1.818
		ARIMA-K	0.135	-0.305	0.652	-0.563	0.492	0.410
		GARCH	-1.027	-0.671	-1.323	1.657	-1.323	-2.687
		GARCH-AK	0.669	0.741	1.261	-0.798	1.461	3.334
		GARCH-AS	1.084	0.773	0.432	0.061	0.452	2.802
		AR(1)	-1.414	-1.527	-1.024	-0.964	-0.748	-5.677*
In–Sample Forecasts	3 Months	ARIMA-S	0.268	0.264	0.142	0.250	0.275	1.199
		ARIMA-K	-1.586	-1.202	-0.916	-1.383	-0.521	-5.608*
		GARCH	0.583	0.160	-0.054	0.400	-0.257	0.832
		GARCH-AK	1.310	1.652	1.836	1.511	1.741	8.051
		GARCH-AS	0.020	-0.019	-0.146	-0.016	0.009	-0.151
		AR(1)	-0.596	-0.855	-0.863	-0.761	-1.247	-4.323
	6 Months	ARIMA-S	-0.210	-0.477	-0.945	0.120	0.799	-0.713
		ARIMA-K	-1.633	-0.471	-0.934	-1.513	0.611	-3.940*
		GARCH	1.121	-0.312	0.712	1.147	0.114	2.782
		GARCH-AK	0.924	-0.350	-0.387	1.035	0.698	1.919
		GARCH-AS	-0.383	-0.426	-0.050	-0.378	-0.396	-1.633
		AR(1)	0.180	2.037	1.605	-0.411	-1.825	1.586
	12 Months	ARIMA-S	0.427	0.667	0.381	0.369	-0.065	1.780
		ARIMA-K	-1.951	-1.918	-1.785	-1.271	1.641	-5.285*
		GARCH	0.914	-0.110	-0.547	1.731	0.654	2.642
		GARCH-AK	0.045	0.065	0.500	-0.234	-0.629	-0.252
		GARCH-AS	0.201	0.746	0.543	-0.200	-0.487	0.803
		AR(1)	0.366	0.550	0.907	-0.396	-1.115	0.312

The z-score total figures with asterisk (*) have the best models in each forecast period.

Table 5.18: Forecasting results z-scores for Kenya inflation univariate models

While the GARCH models do not seem to do well as a forecast tool for inflation in Kenya, the findings were not the same for Mauritius and Zimbabwe, where the models are better than ARIMA innovations for out–of–sample forecasts. The detailed results for these two countries are contained in Appendix 5.3, which presents the same information as provided in Tables 5.17 and 5.18 above in each case.

FORECASTING RESULTS					
Type of forecast	**Forecast Period**	**Model**	**Kenya**	**Mauritius**	**Zimbabwe**
Out–of–Sample Forecasts	**3 Months**	ARIMA-S	3.068	4.749	-2.309
		ARIMA-K	1.314	4.362	3.018
		GARCH	-2.463	-2.350	0.388
		GARCH-AK	0.976	-4.525*	2.707
		GARCH-AS	3.485	-4.304	-2.635*
		AR(1)	-6.381*	2.068	-1.169
	6 Months	ARIMA-S	1.514	-0.427	-1.901
		ARIMA-K	1.803	-0.063	2.305
		GARCH	-3.891	3.958	-0.012
		GARCH-AK	2.660	-3.049*	2.775
		GARCH-AS	2.857	-2.607	-2.199*
		AR(1)	-4.943*	2.188	-0.967
	12 Months	ARIMA-S	1.818	0.417	-1.270
		ARIMA-K	0.410	-0.180	1.019
		GARCH	-2.687	3.637	-0.457
		GARCH-AK	3.334	-3.033*	2.958
		GARCH-AS	2.802	-2.517	-1.399*
		AR(1)	-5.677*	1.676	-0.851
In–Sample Forecasts	**3 Months**	ARIMA-S	1.199	-5.116*	-1.484
		ARIMA-K	-5.608*	3.478	6.704
		GARCH	0.832	4.967	-0.726
		GARCH-AK	8.051	0.090	-2.741*
		GARCH-AS	-0.151	0.739	-1.009
		AR(1)	-4.323	-4.157	-0.745
	6 Months	ARIMA-S	-0.713	-2.126*	-2.370
		ARIMA-K	-3.940*	4.105	5.994
		GARCH	2.782	1.849	3.554
		GARCH-AK	1.919	-1.252	-2.619
		GARCH-AS	-1.633	-0.809	-2.797*
		AR(1)	1.586	-1.767	-1.762
	12 Months	ARIMA-S	1.780	1.416	-5.060*
		ARIMA-K	-5.285*	1.448	4.664
		GARCH	2.642	-1.151	-0.287
		GARCH-AK	-0.252	-1.709*	2.417
		GARCH-AS	0.803	-0.731	-0.807
		AR(1)	0.312	0.727	-0.926
The z-score total figures with asterisk (*) have the best models in each forecast period.					

Table 5.19: Summary forecasting results z-scores for univariate models

Table 5.19 above presents the summary of the total z-scores for Kenya, Mauritius and Zimbabwe, the only countries where the GARCH inflation innovations were possible. The table also shows that for short periods in Zimbabwe and Mauritius the AR(1) fits the data better than other models. This finding is inconsistent with the contents of Table 5.12, which shows the ARIMA innovations fitting the short–term data better than the AR(1) in Mauritius and the GARCH in Zimbabwe. In summary, the univariate forecasting results show that AR(1) performed well for out-of-sample forecasting of inflation in Botswana and Kenya as well as for twelve months in-sample forecasting in Botswana, Nigeria and South Africa. Therefore the ARIMA and GARCH models arrived at in these countries are not effective in forecasting inflation. The GARCH model made up from the ARIMA innovations performs well in Mauritius and Zimbabwe out-of-sample forecasting, as presented above in Table 5.19.

5.5 Cointegration and VECM

In this section, cointegration will be considered in order to ascertain long-run relationships between inflation and other economic variables. As noted earlier in this chapter, the Zimbabwean interest rate, exchange rate and money market are all integrated to the first order, while inflation is a second order series. Thus bivariate and multivariate models will not be considered, since same order series are more effective to work with. In any case, Chapter 4 looked at the relationship between inflation changes and other economic variables in Zimbabwe. Thus the first part of this section will ascertain if there is a long–term relationship between inflation and each variable using two cointegration approaches, the Engle–Granger 2–Step and the Johansen methodology, which were presented in Chapter 2. The purpose of this exercise is to ensure that models arrived at later on are not spurious but a product of an existing relationship between the variables. The second part of this section will explore the causality relationship between the variables and inflation, while the third presents models which are carried out using the information obtained from the cointegration and causality results. The final part of this section will then present the forecast results for both bivariate and multivariate innovations.

The process of arriving at the conclusion for cointegration was explored in Chapter 2 and the tables below present the unit root test results for the residuals obtained from regressing each variable with inflation as the dependent variable in the cointergrating equation. Table 5.20 below shows the results of the unit root test performed on the residuals of the regression between the exchange rate and inflation, with the former as the independent variable.

	Augmented Dickey Fuller			Phillips–Perron			KPSS	
Country	**A**	**T&C**	**None**	**A**	**T&C**	**None**	**A**	**T&C**
Botswana	-5.90*	-13.56*	-5.92*	-14.21*	-14.36*	-14.23*	0.68*	0.14**
Ghana	-4.56*	-4.71*	-4.57*	-9.43*	-9.72*	-9.45*	0.31***	0.08***
Kenya	-7.59*	-6.78*	-7.60*	-12.70*	-12.82*	-12.73*	0.47*	0.15**
Mauritius	-7.72*	-7.87*	-7.74*	-14.83*	-14.86*	-14.85*	0.29***	0.05***
Nigeria	-2.67**	-9.96*	-2.68*	-9.38*	-10.79*	-9.40*	1.01	0.24
South Africa	-5.26*	-6.98*	-5.27*	-8.35*	-10.71*	-8.36*	1.51	0.08***
Critical Values								
1%	-3.46	-4.00	-2.57	-3.46	-4.00	-2.57	0.74	0.22
5%	-2.87	-3.43	-1.94	-2.87	-3.43	-1.94	0.46	0.15
10%	-2.57	-3.14	-1.62	-2.57	-3.14	-1.62	0.35	0.12

Unit root test results for the residual series of the inflation and exchange rate regression. The triple asterisk (***) represents situations where the Null is rejected at 10% level of significance, the double asterisk (**) represents where the Null is rejected at 5% and one asterisk (*) at 1% level of significance. ‘A’ stands for constant, ‘T&C’ trend and constant and ‘None’ without trend or constant.

Table 5.20: Unit root test results for residuals of inflation and the exchange rate

These results indicate that Mauritius and Ghana inflation–exchange rate regression residuals do not have a unit root and thus are stationary using the three test criteria. Botswana and Kenya fail the KPSS stationarity test and can only be regarded stationary at 5% level of significance on the stationarity hypothesis. South Africa can only be rejected when considering the unit root with and intercept only. The Nigerian exchange rate is, not surprisingly, non stationary at all levels of significance, since its exchange rate was fixed for the greater part of the sample period, while its inflation was moving freely. Thus, using this method, no evidence of a long–term relationship between the two variables is found. Similar results to those presented above were also obtained for interest rates, as shown in Appendix 5.4. Again there is no evidence of a long-term relationship between inflation and interest rates in Nigeria over this period, owing mostly to the fact that interest rates were predominantly fixed between 1994 and 1999.

The relationship between inflation and money supply was studied in only three countries where data was available, Botswana, Mauritius and South Africa. In these countries a similar pattern of results to the relationship between inflation and interest rates as well as exchange rate was observed, and is shown in Appendix 5.4. Results for the unit root test of residuals of the inflation–trading partner inflation regression are presented in Table 5.21. The main trading partner for both Botswana and Mauritius is South Africa, from where these countries import predominantly foodstuffs. Kenya obtains most of its imports from the United Kingdom, while Nigeria imports from USA. Ghana imports from Nigeria. For South Africa, the trading partner was not included in this analysis since it has many trading partners who contribute to its imports. These tend to change each year, with most imports on average coming from Germany owing to the import of parts for German cars such as BMW, assemble in South Africa. In this case world inflation was used to determine if exported inflation has an influence on South African inflation. Inflation in the USA is used for the South African case as a proxy for world inflation and the results are the same as the findings involving other variables.

UNIT ROOT TESTS FOR RESIDUALS-CPI & TRADING PARTNER CPI								
	Augmented Dickey Fuller			Phillips–Perron			KPSS	
Country	**A**	**T&C**	**None**	**A**	**T&C**	**None**	**A**	**T&C**
Botswana	-13.54*	-13.66*	-13.56*	-14.27*	-14.31*	-14.29*	0.30***	0.14**
Ghana	-4.61*	-4.73*	-4.62*	-9.31*	-9.56*	-9.32*	0.29***	0.09***
Kenya	-7.17*	-7.41*	-7.19*	-12.40*	-12.46*	-12.42*	0.48*	0.14**
Mauritius	-7.86*	-7.91*	-7.87*	-14.97*	-14.96*	-15.00*	0.15***	0.05***
Nigeria	-2.71***	-10.13*	-2.72*	-9.51*	-10.78*	-9.53*	1.02	0.23
Critical Values								
1%	-3.46	-4.00	-2.57	-3.46	-4.00	-2.57	0.74	0.22
5%	-2.87	-3.43	-1.94	-2.87	-3.43	-1.94	0.46	0.15
10%	-2.57	-3.14	-1.62	-2.57	-3.14	-1.62	0.35	0.12
Unit root test results for the residual series of the inflation and country trading partner's inflation regression. The triple asterisk (***) represents situations where the Null is rejected at 10% level of significance, the double asterisk (**) represents where the Null is rejected at 5% and one asterisk (*) at 1% level of significance. 'A' stands for constant, 'T&C' trend and constant and 'None' without trend or constant.								

Table 5.21: Unit root test results for residuals of inflation and trading partner inflation

As noted in the methodology chapter, the Engle–Granger 2–step method has been found not to have enough power to ascertain the existence of a long-term relationship between variables. The Johansen technique (methodology) is the most used methodology to determine the existence of a long-term relationship between various series. Before using the Johansen technique, the appropriate lags for the Vector Autoregressive (VAR) to be used in this test must be determined.

Lags of up to eight were considered to determine the appropriate VAR, and the AIC in each case was noted and recorded. The VAR with the lowest value of AIC was then taken to be the best for the variables under consideration. Table 5.22 below shows the results of this process. Three lags for Botswana and Ghana are appropriate for the VAR based on the AIC, while five lags are ideal for Kenya and Mauritius, as presented in the table below.

Lags	2	3	4	5	6	7	8	9	10
Botswana	-8.158	-8.211*	-8.203	-8.170	-8.181	-8.168	-8.168	-8.144	-8.120
Ghana	-6.298	-6.301*	-6.268	-6.230	-6.196	-6.199	-6.174	-6.160	-6.130
Kenya	-5.635	-5.622	-5.618	-5.641*	-5.636	-5.607	-5.600	-5.578	-5.566
Mauritius	-7.052	-7.023	-7.002	-7.052*	-7.034	-7.024	-7.006	-6.987	-6.964
Nigeria	-5.045	-5.054	-5.062	-5.087	-5.09*	-5.061	-5.023	-4.978	-4.957
South Africa	-8.478	-8.454	-8.438	-8.482	-8.501	-8.487	-8.503	-8.515*	-8.510
The lags with asterisk (*) are the chosen lag lengths.									

Table 5.22: VAR lag choice for a multivariate model with all variables

For Nigeria and South Africa, six and eight lags respectively are appropriate for the VAR using the AIC, which, however, is not ideal in the case of serial correlation (Feridun and Adebiyi, 2005). Table 5.23 below shows the cointegration results for Botswana, and suggests one cointegrating relationship between inflation, money supply, exchange rate and imported inflation at both 5% and 1% significance levels.

Hypothesised Rank (r)	Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value
r=0	0.113849	57.27745	47.21	54.46
r≤1	0.073763	28.75264	29.68	35.65
r≤2	0.042187	10.66921	15.41	20.04
r≤3	0.002103	0.496853	3.76	6.65

Table 5.23: Likelihood ratio test results for Botswana cointegrating rank

This suggestion is based on the premise that the likelihood ratio is greater than the 5% and 1% critical values. The Null Hypothesis, that there is at most one cointegrating vector, is rejected, which means that only one cointegrating relationship exists. The above results are similar to what obtains in Ghana, Mauritius and Nigeria, where the Johansen test statistics show a rejection of the Null Hypothesis that states, which there is no cointegrating vector. In Kenya, though, no cointegrating vector is reported, as noted in Appendix 5.4, while three cointegrating vectors are noted at 5% significance level in South Africa, as presented in Table 5.24 below. At 1% level of significance, Table 5.24 suggests only two cointegrating relationships between inflation and the other variables since the Null Hypothesis that there are at most three cointegrating vectors is rejected.

Hypothesised Rank (r)	Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value
r=0	0.161557	98.00317	68.52	76.07
r≤1	0.106844	57.47522	47.21	54.46
r≤2	0.077941	31.48658	29.68	35.65
r≤3	0.05204	12.82303	15.41	20.04
r≤4	0.002307	0.531225	3.76	6.65

Table 5.24: Likelihood ratio test results for South Africa cointegrating rank

The next step is to determine the cointegrating vector which explains the long–term relationship between inflation and the variables under consideration in each country. This is found through normalising the inflation component of the cointegrating vector. Table 5.25 shows the coefficients of each variance. In most African countries there is a negative significant long–term relationship between inflation and the depreciation of the exchange rate, which is an expected scenario embedded in the economic theory that such depreciation makes imports, and therefore production cost, expensive in a net importing country.

Inflation Rate	Exchange Rate	Interest Rate	Imported Inflation	Money Supply	C
Botswana	0.4880* (0.1436)	X	-1.2008* (0.1870)	-0.2618* (0.0789)	2.5386
Ghana	-0.5096* (0.0491)	0.2095* (0.0433)	-0.4093 (0.0518)	X	0.8800
Kenya	-1.3049* (0.5205)	-0.3320** (0.1613)	-3.0651 (1.8667)	X	15.6276
Mauritius	0.0956 (0.2407)	-0.0040 (0.0457)	-1.1497 (0.4570)	-0.0844* (0.3317)	1.2330
Nigeria	-4.9269* (0.9447)	7.1681* (1.2474)	43.6009* (8.9959)	X	-203.404
South Africa	-0.0892* (0.0173)	-0.0715* (0.0159)	-3.1657* (0.2056)	0.1740* (0.0436)	8.0574

'X' indicates cases where the data was not available, so no test was conducted. A single asterisk (*) on the results represents situations where the coefficient is significant at 5% level of significance and a double asterisk (**) represents significance at 10%. Standard errors are in parentheses below the coefficient estimates.

Table 5.25: Normalised cointegration coefficients for all variable model estimates

In a net exporter of basic commodities, the depreciation of the currency encourages exports, and supply to the local market is reduced, leading to a rise in aggregate demand and subsequently to an inflation surge. It is important to note, though, that the negative coefficient presented in Table 5.25 represents appreciation in the currency because measurement here is the national currency to the US dollar; thus a positive movement is a depreciation of the currency. The above–mentioned relationship does not, however, appear to hold for Botswana, where there is a positive relationship between the deprecation of the currency and a rise in the inflation rate over time. This is not surprising because the currency is anchored equally on both the South African Rand and the IFM Special Drawing Rights (SDRs). Thus, in the long term, a depreciation of the South African Rand is met with an appreciation of the Botswana Pula, since the Rand will be falling against the US dollar which contributes over 40% to the SDRs. Moreover, Botswana imports from South Africa, so that when the Rand appreciates (Pula depreciates) and the South African inflation decreases, Botswana buys the goods cheaply, leading to a decrease in US inflation rate at a time when the currency depreciates. This situation is further helped by the fact that both countries operate in the Southern African Customs Union (SACU), a trade–free zone. The indications from these interrelations is possibly the absence of transmitted costs owing to the absence of major banks in Botswana which would imply that most importing companies bank in South Africa in Rands or engage in forward contracting to stay neutral to currency movements.

As for the interest rates, they have a significant long–term negative relationship with inflation in South Africa and Kenya, while a positive relationship is noted in Ghana and Nigeria. The negative relative relationship in South Africa is not surprising, given the inflation targeting regime in the country and the bilateral causality between inflation and the interest rate, which suggests the use of monetary policy to regulate inflation movements. Imported inflation also has a significant negative relationship with inflation in South Africa and Botswana, while in Nigeria it has a positive relationship. The Botswana case has been explained above, while the Nigeria scenario is positive and significant, suggesting world inflation neutrality or the belief that a rise in world inflation would lead to a rise in the inflation rate of a net import *ceteris paribus*. The fact that the Nigerian exchange rate was fixed during the greater part of the sample period possibly explains this positive long–term relationship which is free of the exchange rate parity relations.

To determine the short-run reactions to the above relations, Table 5.26 below presents the error-correction coefficients in the Vector Error Correction Model which corresponds with the above cointegration relationships. This shows the speed of adjustment back to long-term equilibrium. The results are based on the inflation rate being the explanatory variable.

Vector Error Correction Coefficients and Standard Errors					
Inflation	Dependent Variables				
ECM(-1)	Inflation Rate	Exchange Rate	Interest Rate	Imported Inflation	Money Supply
Botswana	-0.0067* (0.0027)	0.0218 (0.0194)		0.0082* (0.0025)	0.0844* (0.0285)
Ghana	-0.0282* (0.0073)	-0.0191 (0.0159)	-0.0708** (0.0323)	-0.0510* (0.0138)	
Kenya	-0.0023 (0.0025)	0.0142* (0.0060)	0.0314 (0.0246)	0.0013* (0.0003)	
Mauritius	0.0114** (0.0047)	0.0061 (0.0149)	0.0317* (0.1033)	0.0093* (0.0025)	0.0206* (0.0062)
Nigeria	-0.0016 (0.0011)	0.0077 (0.0074)	-0.0258* (0.0070)	-0.0004* (0.0001)	
South Africa	-0.0252** (0.0124)	-0.4596* (0.1334)	0.0879 (0.1153)	-0.0049 (0.0074)	-0.1114* (0.0406)
Asterisk (*) represents situations where the coefficient is significant at 5% level of significance and double asterisk (**) represents significance at 10%. Standard errors are in parentheses below the coefficient estimates.					

Table 5.26: Vector error correction model coefficients and standard errors

The results presented above show a significant negative error correction term, which indicates that there is a tendency for these variables to revert back to their long–term relationships.

To determine which variables explain movements in inflation rate in the short run, Table 5.27 below explores the variance decompositions for the above estimated cointegrations relations which were constructed using a VAR with orthogonal residuals for one, three, six, twelve and twenty months. According to Sims (1980), Litterman and Weis (1985) and McMillan (2001), who looked at the relationship between the stock market prices and economic variables variance decompositions conclude that of the form can directly address the contribution of these variables in the forecasting of the inflation rate, something that will be further explored later in this chapter.

Variance Decompositions for Inflation Rate							
Series	Months	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
Exchange Rate	1	0.048	0.135	0.195	0.059	0.582	1.553
	3	0.255	0.332	1.282	0.607	1.530	4.394
	6	0.662	0.653	3.314	0.759	2.814	4.719
	12	0.784	0.917	3.368	0.797	2.883	5.644
	24	0.802	0.981	3.394	0.798	2.888	5.799
Interest Rates	1		0.118	0.132	0.485	0.258	1.849
	3		0.440	0.820	0.874	3.216	2.729
	6		1.471	1.259	0.868	3.657	4.240
	12		2.270	1.419	0.854	3.742	7.458
	24		2.447	1.423	0.853	3.777	7.974
Imported Inflation	1	0.368	0.226	0.138	0.000	0.444	5.070
	3	0.314	0.880	1.444	0.252	1.607	5.384
	6	4.408	0.841	2.936	0.902	1.932	5.905
	12	5.958	0.920	3.170	1.389	2.415	6.595
	24	6.170	0.980	3.193	1.415	2.468	6.737
Money Supply	1	1.033			0.176		0.320
	3	2.384			0.431		0.648
	6	2.544			0.612		1.505
	12	2.573			0.616		2.471
	24	2.575			0.628		2.994

Table 5.27: Variance decompositions for the inflation rate

The choice of the number of months under consideration here is in the context of the forecasting range which will be considered later, where the best variable is to be selected and compared with the univariate cases. The indications are that after one year, money supply explains about 1.03% of variations in Botswana inflation, constituting the highest figure in this category. The situation changes after six months when the imported rate explains a substantial amount (4.4%) of the variations. The possible explanation for this is that imported inflation effects are lagged, since goods will have to be transported and this could take some time. These results are also echoed in Mauritius, where the interest rate explains 0.5% of variations in the inflation rate compared to none for imported inflation. The Mauritius and Botswana cases above are different, however, from the situation in Ghana, where, surprisingly, imported inflation explains more of the variations in the movement of inflation in the country after one and three months. However, these figures are low at less than 1%, and the only substantial explanatory power is achieved by interest rates after six months, explaining 2.4% of inflation variations after two years. The role of imported inflation is consistently substantial in explaining inflation variations in South Africa over the greater part of the periods under consideration, with figures ranging from 5.1% after one month to 6.7% after two years. In Nigeria, interest rates explain the greater part of the variations in inflation rate movements compared to the other variables, except for one month where the exchange rate seemingly explains more of the variations.

5.6 Causality tests

Since variance decomposition is an exogeneity test it implies that restrictions are placed on both the current and the lagged shocks of the explanatory variable to determine its effect on the dependent variable. While this is important in determining the speed at which the inflation rate adjusts to changes in the considered variables, there might be need to establish how the variable's current and lagged shocks affect inflation; thus a test of causality is carried out. The causality test helps ascertain if the inflation rate Granger causes any of the economic and financial variables or the causality flows towards inflation instead. The importance of this exercise is also to aid forecasting, since a variable that Granger causes inflation would be having important information about inflation movements, and this complements the variance decomposition results presented above as well as the findings of the cointegration test. Table 5.28 below presents the results of the causality tests on Botswana using all the variables considered for cointegration above.

Null Hypothesis:	Obs	F-Statistic	Probability
DE does not Granger Cause DC	236	3.64115	0.01350
DC does not Granger Cause DE		0.69339	0.55693
DM does not Granger Cause DC	236	1.04579	0.37307
DC does not Granger Cause DM		1.34475	0.26062
DSA does not Granger Cause DC	236	2.65718	0.04915
DC does not Granger Cause DSA		4.28603	0.00575

DM above represents money supply; DE, exchange rate; DC, the inflation rate; DSA, South African inflation the main trading partner for Botswana.

Table 5.28: Granger causality test results for Botswana

The above findings show that the exchange rate in Botswana and the South African inflation rate Granger cause inflation, thus they have useful information about movements in inflation in Botswana. Interestingly, inflation in Botswana also Granger causes inflation in South Africa, which is surprising since the latter does not import significant goods from the former. There is no evidence that money supply has useful information about inflation movements in

Botswana. Table 5.29 presents the Granger causality results for Ghana; these show no evidence of the exchange rate having useful information about inflation movements.

Null Hypothesis:	Obs	F-Statistic	Probability
DE does not Granger Cause DC	236	1.37890	0.24996
DC does not Granger Cause DE		0.41138	0.74498
DI does not Granger Cause DC	236	2.97433	0.03247
DC does not Granger Cause DI		1.01778	0.38554
DN does not Granger Cause DC	236	2.59673	0.05317
DC does not Granger Cause DN		0.71829	0.54197

DI above represents interest rates; DE, exchange rate; DC, the inflation rate; DN, Nigerian inflation the main trading partner for Ghana.

Table 5.29: Granger causality test results for Ghana

Interest rates and imported inflation Granger cause inflation in Ghana, with the causality non-bilateral as it moves only towards inflation. The role of interest rates, exchange rates and imported inflation on the movement of inflation is also evident in Kenya, as outlined below in Table 5.30. The F-statistic for the test of causality with a Null Hypothesis that interest rates do not Granger cause inflation is significant at 5% level of significance, which reflects the usefulness of interest rates on inflation rate movements.

Null Hypothesis:	Obs	F-Statistic	Probability
DE does not Granger Cause DC	234	5.46756	9.1E-05
DC does not Granger Cause DE		2.20213	0.05508
DI does not Granger Cause DC	234	2.90622	0.01456
DC does not Granger Cause DI		0.78065	0.56457
DU does not Granger Cause DC	234	2.38389	0.03930
DC does not Granger Cause DU		1.54314	0.17747

DI above represents interest rates; DE, exchange rate; DC, inflation rate; DU, UK inflation, the main trading partner for Kenya.

Table 5.30: Granger causality test results for Kenya

The exchange rate results on the same hypothesis as above show a statistically significant F-statistic at 1% level of significant, and the reverse Null that inflation has useful information about movements in exchange rate is significant at 5% LOS, an indication of a bilateral causality. As in the Ghana case, there is evidence to show that imported inflation has useful information about movements in the inflation rate. The Ghana and Kenya results are not, however, reflected in the South African case in this regard.

Null Hypothesis:	Obs	F-Statistic	Probability
DI does not Granger Cause DC	230	4.97003	4.5E-06
DC does not Granger Cause DI		2.14207	0.02740
DE does not Granger Cause DC	230	3.94107	0.00012
DC does not Granger Cause DE		0.75845	0.65495
DM does not Granger Cause DC	230	1.44880	0.16904
DC does not Granger Cause DM		0.51063	0.86599
DU does not Granger Cause DC	230	1.53220	0.13817
DC does not Granger Cause DU		0.73305	0.67833

DM above represents money supply; DE, exchange rate; DC, inflation rate; DU, German inflation, the main trading partner for South Africa.

Table 5.31: Granger causality test results for South Africa

The results of the causality test in South Africa are shown in Table 5.31 above, and the role of imported inflation can only be confirmed at 14% LOS, which is outside the standard significance levels of 1, 5 and 10%. Bilateral causality existed between interest rates and inflation in South Africa during the 20 years covered by this study. This is not surprising because South Africa practises inflation targeting and uses the interest rates to regulate inflation movements, which is a monetarist approach, as indicated in the previous chapter. Also seen in the results is the influence of inflation targeting on movements in the rate, owing to the usefulness of the exchange rate. South Africa manages the exchange rate to boost exports, and such a strategy makes imports expensive. Goods that depend on imported raw materials then suffer, as the cost of production soars. This is further compounded by the fact that the country imports fuel.

Tables 5.32 and Table 5.33 show the results of the Granger causality test for Mauritius and Nigeria respectively. In both cases, there is no evidence of any of the variables, including imported inflation, having useful information about movements in the inflation rate.

Null Hypothesis:	Obs	F-Statistic	Probability
DE does not Granger Cause DC	234	0.64202	0.66786
DC does not Granger Cause DE		0.56517	0.72665
DI does not Granger Cause DC	234	0.62379	0.68179
DC does not Granger Cause DI		0.41276	0.83965
DM does not Granger Cause DC	234	1.43549	0.21247
DC does not Granger Cause DM		0.28171	0.92283
DS does not Granger Cause DC	234	1.50337	0.18976
DC does not Granger Cause DS		0.18815	0.96687
DM above represents money supply; DE, exchange rate; DC, inflation rate; DI, interest rates and DS, South Africa inflation, the main trading partner for Mauritius.			

Table 5.32: Granger causality test results for Mauritius

In the case of Mauritius, only imported inflation has the closest F-statistics to statistical significance using standard levels of significance, and the F-statistic is significant at 19% LOS. Money supply, which Granger causes inflation at 22% LOS, is the other notable figure in Table 5.32. The findings in Nigeria also do not show meaningful results as presented in Table 5.33, where the exchange rate is significant at only 16% LOS, which is outside the standard acceptable levels of significance. The Nigerian results are not surprising, especially since the interest rates and the exchange rate were predominantly fixed during the period under consideration.

Null Hypothesis:	Obs	F-Statistic	Probability
DE does not Granger Cause DC	180	0.79141	0.57784
DC does not Granger Cause DE		0.72089	0.63331
DI does not Granger Cause DC	180	1.59088	0.15267
DC does not Granger Cause DI		1.42494	0.20780
DU does not Granger Cause DC	180	1.05987	0.38881
DC does not Granger Cause DU		0.46342	0.83465

DE above represents exchange rate; DC, inflation rate; DI, interest rates and DS, United States inflation, the main trading partner for Nigeria.

Table 5.33: Granger causality test results for Nigeria

In summary, for most African countries interest rates and exchange rate, where they have not been fixed, have contained useful information about movements in the inflation rate, and thus can be used as effective tools to forecast and regulate inflation movements.

5.7 Further error correction models

Having looked at the role of each variable in the movements of the inflation rate, this section will now produce models that could be used to forecast inflation in these African countries. Earlier, the VECM were produced, which assisted in checking the speed of adjustment to long–term equilibrium. Now models made up of significant lags of the dependent variables are produced to determine if bivariate and multivariate innovations forecast inflation better than the univariate cases considered above. To achieve this, the autoregressive distributed lag (ADL) model approach was used with the best model arrived at after omitting lags which are insignificant between one and twelve. To determine the insignificant lags, those with t-statistic outside the standard levels of significance are discarded until the lowest AIC is achieved or until all values are within 5% probability level, whichever comes first. Three types of ADL models were considered, the first involving inflation as the dependent variable with lags of either exchange rate, interest rates, money supply or trading partner as the independent variables. The second model type involved making the lags of the above–mentioned variables and that of inflation in the same model; and the final ADL–type model had lags of significant variables and inflation after discarding the insignificant ones. For the multivariate case, hereafter referred to as the third ADL–type model, a test for multicolinearity had to be performed before deriving the models, since the assumption using the OLS estimation is that the variables should not be correlated with each other. According to Brooks (2002), if no relationship among variables exits, then there is an orthogonal case where adding or removing a variable from the regression equation would not cause values of the coefficient of the other variable to change. Table 5.34 below presents the correlation matrix for Botswana multivariate model variables. There is no evidence of multicollinearity, as all the correlation coefficients are close to zero.

	Inflation	Exchange Rate	Money Supply	Trading Partner
Inflation	1.00000	-0.04917	-0.06675	0.22319
Exchange Rate	-0.04917	1.00000	0.05134	-0.03858
Money Supply	-0.06675	0.05134	1.00000	0.06262
Trading Partner	0.22319	-0.03858	0.06262	1.00000

Table 5.34: Multicollinearity test results for Botswana

Appendix 5.5 presents the rest of the multicollinearity test results. The results show that in most African countries inflation and interest rates moved positively in the same direction. There is no consensus on the movement of the exchange rate and inflation as both weakening and strengthening of African currencies was met with mixed movements in the inflation rate.

After obtaining the appropriate ADL models as noted above, the next step is to produce error correction models (ECM) based on the residuals obtained earlier on for the Engle–Granger 2–Step cointegration method. Since all cases where inflation was paired with other variables exhibited stationary residuals, these residuals are then considered when determining the ECM. This involves adding a lagged value of the residuals to the ADL equation obtained as outlined above. The use of the ECM in this case is to ensure that the short–run behaviour of the cointegrated series is linked to its long–run observations to ensure sound forecasting results from the models. Appendix 5.5 presents all the final ECM equations for each country using different variables. Equation 5.19 below highlights the ECM equation for the multivariate Mauritius case.

$$\begin{aligned} dc_t = {} & \underset{(2.17)}{0.00237} + \underset{(4.19)}{0.27} dc_{t-2} - \underset{(-2.07)}{0.14} dc_{t-5} + \underset{(1.80)}{0.12} dc_{t-7} + \underset{(1.66)}{0.11} dc_{t-10} - \underset{(-2.47)}{0.15} dc_{t-11} - \underset{(-2.77)}{0.17} dc_{t-12} \\ & + \underset{(1.52)}{0.03} de_{t-10} + \underset{(1.81)}{0.01} di_{t-5} + \underset{(1.73)}{0.09} dm_{t-11} + \underset{(1.57)}{0.16} ds_{t-1} + \underset{(1.45)}{0.14} ds_{t-8} + \underset{(0.38)}{0.03} \varepsilon_{t-1} \end{aligned} \qquad 5.19$$

Where dc represents the inflation rate, de the exchange rate, dm money supply, ds imported inflation, t time and e error correction term. The equation is interpreted as follows:

- If there was a 1% increase in the inflation rate two, seven and ten periods ago, there will be a 0.27%, 0.12% and 0.11% increase in the current inflation rate respectively.
- If there was a 1% increase in the inflation rate five and eleven periods ago, there will be a 0.14% and 0.15% decrease in the current inflation rate respectively.
- If there was a 1% increase in the exchange rate ten periods ago, there will be a 0.03% increase on the current inflation rate and an increase of 0.01%, 0.09%, 0.16%, and 0.14% would be realised if interest rates, money supply and South African inflation increased five, eleven, one, and eight periods ago respectively.

R-squared for this model is 0.2419, which means the independent variables of this model explain 24.19% of inflation movements, and since the F-statistic is 5.37, this model is significant. Money supply eight months ago is the less statistically significant of all the variables on the model with the least t-statistic of 1.45 and a level of significance of 14.94%, while interest rate five periods ago is the most significant independent variable after inflation lags, with a probability of 0.07.

Having obtained the above ECM, the next step is to carry out diagnostic tests to check if the models pass the normality test. The diagnostic tests are contained in Appendix 5.6.

5.8 Multivariate forecasting results

The forecasting approach in this section will be the same as that presented earlier, when univariate forecasting was considered. Out-of-sample and in-sample forecast results will be presented for one, three, six and twelve month periods. In Appendix 5.7, the results of the various models considered above are presented for one-month out-of-sample and in-sample forecasts. Table 5.35 below shows the forecast results for Nigeria for one month. Current interest rates seem to be a better predictor of inflation using both the RMSE and MAPE forecast criteria out–of–sample and in–sample. The performance of each model is shown with the results with asterisks being the best for each forecast measure for either out–of–sample or in–sample. These show that imported inflation innovations outperform the rest of the other models for out–of–sample forecasting in Nigeria.

NIGERIA FORECASTING RESULTS				
Type of forecast	Forecast Period	Model	RMSE	MAPE
Out–of–Sample Forecasts	One Month Ahead	Exchange Rate	0.002127	14.11763
		Exchange Rate & Inflation	0.015436	102.4578
		Interest Rates	0.017933	119.033
		Interest Rate & Inflation	0.009005	59.77275
		Trade Partner Inflation	0.000344*	2.286313*
		Trade Partner & Inflation	0.016712	110.9261
		Multivariate	0.01311	87.01657
In–Sample Forecasts	One Month	Exchange Rate	0.001832	36.55831
		Exchange Rate & Inflation	0.002049	40.90064
		Interest Rates	0.002384	47.57266
		Interest Rate & Inflation	0.005737	114.5027
		Trade Partner Inflation	0.000138*	2.750716*
		Trade Partner & Inflation	0.000575	11.47339
		Multivariate	0.005526	110.2754
The results with asterisks (*) are the best for each forecast measure.				

Table 5.35: One month forecasting results for Nigeria inflation multivariate models

Appendix 5.7 presents the rest of the other African countries' one–month forecasting results for in-sample and out-of-sample. The results show that interest rates have better forecasting power than other variables in Ghana and Kenya out-of-sample, thus the notion that interest rates are better predictors of inflation is confirmed. In–sample forecasting has mixed results, although imported inflation in South Africa is mostly similar to the Nigerian case.

For over–one–month forecasts, the story is somewhat different, as indicated in Appendix 5.8 and summarised in Table 5.36 below. For three months out-of-sample forecasting, no variable is outstanding in all the countries, though interest rates are key to predicting inflation in Kenya and Ghana. The three months results, however, are inconsistent with the short-term results presented above for Ghana and Nigeria, where the exchange rate and imported inflation respectively are prominent.

Multivariate Forecasting Summary						
Out–of–Sample	**Botswana**	**Ghana**	**Kenya**	**Mauritius**	**Nigeria**	**South Africa**
3 Months	MS	INT	INT	Multi	EXC	EXC &CPI
6 Months	TP&CPI	EXC	INT	INT&CPI	TP&CPI	EXC
12 Months	TP&CPI	EXC	INT	TP&CPI	TP&CPI	EXC
In–Sample						
3 Months	Multi	Multi	TP&CPI	INT	Multi	TP&CPI
6 Months	EXC&CPI	Multi	TP&CPI	INT&CPI	INT	MS
12 Months	EXC	EXC	Multi	Multi	INT	INT&CPI
MS above represents money supply; INT, interest rates; EXC, the exchange rate; CPI, the inflation rate; TP, the country's main trading partner inflation; 'Multi' represents cases where the multivariate equation of all the variables are best.						

Table 5.36: Multivariate forecasting results summary

Beyond three months, innovations that include an autoregressive component of the inflation rate are better forecasters of medium to long-term inflation out–of–sample in Africa. The importance of imported inflation is key in Nigeria and Botswana, where movement of inflation in South Africa is a good out-of-sample predictor of inflation six and twelve months ahead. This is not surprising, since Botswana imports most of its foodstuffs as well as fuels from South Africa. These products contribute a weight of over 25% in the calculation of inflation in Botswana and over 30% in driving South African inflation. The same can be said of Mauritius, where food inflation contributes over 30% to the total inflation rate figure. Mauritius, also imports some foodstuffs from South Africa, but owing to the distance between the countries movement of inflation in South Africa only forecasts Mauritius inflation twelve months ahead.

Another interesting result from the above table is the dominance of the interest rate in forecasting inflation in Kenya for out-of-sample and Nigeria in-sample. This observation is important for policymaking in that monetary policy can then be tailored to control or target inflation in the short or long term. The exchange rate is also prominent for out–of–sample forecasting of South African inflation, a finding which is consistent with the causality test, which showed that the exchange rate in the country Granger causes the inflation rate. The role of the exchange rate could be attributed to the fact that South Africa imports fuel and parts to manufacture vehicles. These components contribute a high percentage to overall inflation as reflected by transport and fuel inflation. The assertion of the effects of exchange rate on inflation in South Africa is further supported by the importance of world inflation on three months in–sample forecasting an indication that oil price movements do influence prices. In other countries, the in-sample forecast results show the dominance of multivariate innovations as favourable forecasting tools in Africa. Just as in the out–of–sample case, the role of money supply in predicting inflation in Africa is not prominent, a result consistent with the causality tests discussed.

5.9 Conclusion

The journey to determining what would be the better tools to forecast inflation in Africa has taken this research from univariate forms of forecasting; to cointegration meant to ascertain the relationship between variables and inflation; vector error correction models whose coefficients helped to determine the speed of adjustment of each variable to long–term association; Granger causality which looked at the direction of causality as a way to establish if movements in a variable have useful information about inflation in Africa; variance decomposition; and finally multivariate forecasting for different periods in and out of sample. The conclusions, drawn from these different techniques, have enabled an understanding of inflation forecasting in Africa. In particular, it has been shown that bivariate and multivariate forecasting models are better predictors of inflation in Africa, and innovations that include past values of the inflation rate seem to improve the forecast results in the short, medium and long term, as well as in and out of sample. A summary of the forecast results is given in Table 5.36. Using causality tests, there is enough evidence to show that imported inflation has useful information about changes in the inflation rate. This is not surprising because African economies are young and therefore depend on imports to aid production. Moreover, most of the countries considered import fuel, leaving most of them at the mercy of oil price movements. This assertion is further supported by the findings that demonstrate that the exchange rate has useful information about changes in the inflation rate. Another interesting result is the lack of evidence to show that money supply has useful information about the inflation movements in all the African countries; this is possibly a result of tight monetary policy restrictions, in particular relating to money supply. These causality results point to the fact that most African countries would find it difficult to control inflation when there is a rise in the inflation rate in the rest of the world. However, since causality with the interest rate was established, monetary policy could be useful in regulating and ensuring inflation levels do not go out of control.

The cointegration results in this chapter show that for all the countries there is at least one cointegrating relationship between the inflation rate and the variables considered in each country. Apart from the Botswana case, there is evidence for a negative significant long–term relationship between inflation and innovations in the exchange rate in Africa. This indication is rooted in the economic theory that an appreciation of a country's exchange rate makes imports cheaper and for Africa, which imports oil, production costs are reduced as most industries are still fuel driven. The surprise finding in relation to the exchange rate effect is the negative relationship between imported inflation and changes in the inflation rate in the long run in most African countries except Nigeria. The expectation, using the above argument, would have been that a fall in world inflation would lead to a depreciation of the exchange rate, thus making local production costs cheaper since imports would be cheap and the actual good prices would have gone down. The unexpected results could be a sign of policy measures to counter the effects of imported inflation, especially for South Africa, which practises inflation targeting, and Botswana with its quasi-inflation targeting policy. The long–term relationship between inflation and interest rates is a mixed bag in Africa, with an unsurprisingly positive relationship in Nigeria and Ghana, where the rate was fixed for the greater part of the research period. The negative relationship between inflation and interest rate is a product of the theory that inflation affects spending and saving decisions, asset prices and cash flow, all of which result in an opposite relationship.

The VECM results presented in this chapter indicate that innovations in imported inflation and interest rates have the tendency to revert back to a long-run equilibrium in their relationship with the local inflation rate. The influence of imported inflation and interest rates shocks is further reflected by the variance decompositions, which show that innovations in these variables explain a substantial amount of variations in the movement of inflation in Africa. Using the variance decomposition technique, however, shows that the role of the exchange rate as a better explanatory power is limited in Africa, with the variable more useful after one month in Kenya and Nigeria. The forecast results are mixed, however, when compared to the variance decomposition findings, owing to the use of a various forecast result measures. In general, though, bivariate and multivariate models tended to have better prediction power than univariate ones in Africa for both short– and long–term, in-sample as well as out of sample, save for short horizon in-sample forecasting in South Africa, where the ARIMA models are more useful and the medium–term out–of–sample forecast for Mauritius, where the GARCH models were more powerful.

Finally, it is important to note that the above information would be useful for policymakers, as variables with useful information about movements in the inflation rate or they are good predictors which could be exploited to regulate inflation changes. As noted above, information about the changes in world inflation and interest rates are useful in Africa; hence forecasting inflation in the continent needs to embrace this finding. In addition, the exchange rate is an important variable that needs consideration when forecasting inflation in South Africa as it Granger causes inflation and has also a long–term relationship with inflation rate. Exchange rate innovations tend to revert to the long–run relationship with the inflation rate, thus they have better out-of-sample forecasting power compared to other variables in both the short and medium–term.

CHAPTER SIX

THE RELATIONSHIP BETWEEN INFLATION AND STOCK MARKET RETURNS IN AFRICA

6.0 Introduction

The relationship between inflation and stock market returns is still an open subject in the area of empirical finance, especially in the context of stock price reaction to inflation movements. Though research on this relationship has been intensifying in most countries, especially the United States of America, since the 1970s, the relationship has not, however, been explored in Africa in similar depth; this chapter endeavours to achieve this. In this chapter a range of econometric techniques are used to ascertain the nature of the relationship and what could influence the end results. The analysis in this chapter will also present a brief discussion of the descriptive statistics of stock markets in Sub-Saharan Africa. Since inflation has been discussed in depth in previous chapters, this chapter will focus more on the existence, nature and form of the relationship between stock returns and inflation in the continent.

Two cointegration approaches are adopted in analysing the long–term relationship between stock returns and inflation: the Engle–Granger 2–step method and the Johansen technique. The Engle–Granger method looks at the stationarity of the residual series taken from a regression of current values of each variable over time, while the Johansen technique establishes a long–run relationship by using a vector autoregressive system which incorporates lagged values of a variable. A test for structural breaks in the series will also be performed to establish if the nature of the relationship could have been influenced by any structural breaks or regimes. After looking at the effects of structural breaks the thesis will then consider if the relationship is influenced by the state of economic activity. The final part of this analysis will involve establishing the significance of the existence of a relationship between unexpected inflation and month–end stock market returns. The existence of such a relationship raises concerns about the use of month–end stock market data because it demonstrates that month–end data would not have accounted for all the inflation innovations. The absence of a relationship between unexpected inflation and month–end stock market returns infers that inflation expectations would have been incorporated in the stock market price innovations; hence, in such a case, month–end data analysis provides a statistically credible picture about stock–inflation relations.

This chapter is organised as follows: Section 6.1 shows the data as well as the descriptive statistics. Section 6.2 presents the empirical evidence in the ascertainment of the nature of the relationship between stock market prices and inflation. The chapter summary is in Section 6.3, before the conclusions in Section 6.4.

6.1 Data and unit root tests

Empirical work in this chapter uses data from seven African equity markets which were established before 1992. The cut–off year whose justification is contained in Chapter One, relates to the age of the stock markets and availability of long–term data to ensure credible results. Stock market data was obtained from DataStream or Bloomberg, depending on which source provided the longest time series data. Table 6.1 below shows the sources of data for each country as well as the start date in each case; all the series end in January 2007.

Country	Source of Data	Data start date	Number of Months
Botswana	DataStream	December 1995	134
Ghana	Bloomberg	November 1990	183
Kenya	DataStream	January 1990	193
Mauritius	DataStream	July 1989	134
Nigeria	DataStream	July 1991	187
South Africa	DataStream	February 1987	240
Zimbabwe	DataStream	February 1987	240

Table 6.1: Sources of data for each country and number of observations

Stock market data for Nigeria in DataStream is over twenty years, and the analysis could have been started in February 1987. However, the available inflation times series data stretches to only July 1991, explaining the length of the stock market data. All the data provided here is in local currency to ensure movements reflect stock market forces rather than currency depreciation or appreciation. The Zimbabwe series is industrials rather than all share index, since the stock market produces mining and industrial stock market data separately with no combined series during the sample period. Creating a combined index out of the separate indexes would need capitalisation data for each company as well as index calculation rules, which exercise is not within the scope or interest of this study. The stock market indexes for the rest of the countries are capitalisation-weighted; thus the effect of major companies' movements is more easily transferred to that of the index than if it were equally weighted. While capitalisation-weighted indexes are used in most major indexes, like the FTSE and NASDAQ, the challenge with its use in most African indexes is that there are fewer counters in most of the stock exchanges. The effect of these few counters is to compound the bias caused by large corporations, especially under capitalisation-weighted indexes. Despite this disadvantage of using capitalised weighted indexes in Africa, an equally-weighted index approach would also lead to a bias towards small index firms, some of which are capitalised at less than 10% of large corporations.

Table 6.2 below presents descriptive data for monthly nominal stock returns in each of the Sub-Saharan countries under consideration. In nominal terms, monthly stock returns were positive on average during the period under consideration. The highest nominal monthly average returns at 6% were obtained in Zimbabwe during this period, and the lowest were in Kenya and Mauritius at 1%. The maximum return of 89% in Zimbabwe occurred in January 2006, possibly responding to the government's decision not to increase interest rates for the first time in eight months before this date. This explanation is supported by the evidence that when interest rates were then increased the next month, stocks fell by 18%. The increase in this case fell short of investor expectations.

Country	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB
Botswana	0.023	0.016	0.364	-0.101	0.052	2.455	16.194	1098
Ghana	0.024	0.007	0.412	-0.212	0.073	1.680	10.120	473
Kenya	0.010	0.001	0.413	-0.207	0.070	1.559	10.049	475
Mauritius	0.010	0.009	0.163	-0.206	0.045	-0.127	7.414	108
Nigeria	0.025	0.020	0.274	-0.249	0.063	0.289	5.998	72
South Africa	0.011	0.014	0.172	-0.297	0.064	-0.958	6.278	144
Zimbabwe	0.060	0.039	0.890	-0.644	0.180	1.457	9.808	546

Table 6.2: Monthly nominal stock returns descriptive statistics

Moreover, when the monthly increase in interest rates fell from 36% to 2.5% stock returns rose from 18.9% on average to 86.4% within three months prior to January 2006. The minimum of -64.4% is also linked to a jump in interest rates, showing the sensitivity of the stock market returns to interest rate movements in Zimbabwe.

South Africa and Mauritius skewness is negative. Skewness measures the asymmetry of the distribution of the series around its mean. This suggests that the outliners are below the mean of the monthly returns, which is different from the rest of the countries, where the outliners are above the mean, since the skewness is positive. In general, a positive value for skewness shows that the distribution has a long right tail, while the negative skewness implies a long left tail on the distribution.

Country	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB
Botswana	0.2742	0.2548	0.7642	-0.1576	0.2250	0.2874	2.5297	3
Ghana	0.285	0.148	1.385	-0.413	0.414	0.809	2.965	20
Kenya	0.106	0.070	1.416	-0.448	0.361	1.020	3.935	38
Mauritius	0.110	0.144	0.429	-0.364	0.158	-0.494	2.887	5
Nigeria	0.298	0.311	1.146	-0.477	0.330	0.030	3.200	0
South Africa	0.131	0.168	0.652	-0.476	0.218	-0.423	2.787	7
Zimbabwe	0.643	0.492	4.215	-0.950	0.903	1.304	5.391	119

Table 6.3: Annual nominal stock returns descriptive statistics

If annual returns are considered, the nature of the results is fundamentally similar, as shown in Table 6.3. The main difference between the monthly and the annual returns is that the kurtosis for most countries except Zimbabwe are close to 3, showing evidence of a normal distribution in the annual returns for these countries. Kurtosis is a measure of a series distribution's flatness and, as noted in Chapter 5, the kurtosis of the normal distribution is 3. Hence, if it exceeds 3, the distribution is peaked (leptokurtic) relative to the normal, and if the kurtosis is less than 3, then the distribution is flat (platykurtic) relative to the normal.

Another normality test is the Jarque-Bera (JB), which tests whether a series is normally distributed using a test statistic which measures the difference of the skewness and kurtosis of a particular series, comparing these with those of a normal distribution. According to Eviews (2004), under the null hypothesis of a normal distribution, the JB statistic is distributed with two degrees of freedom. Thus the reported probability is the probability that a Jarque-Bera statistic exceeds (in absolute value) the observed value under the null hypothesis. A small probability value, therefore, leads to the rejection of the null hypothesis of a normal distribution. Using the Jarque-Bera statistic results shown in Table 6.3, the normality of the residuals of the distributions is rejected at the 5% level (critical value 5.99) except for Botswana, Mauritius and Nigeria. South Africa stock return residual can only be considered to follow a normal distribution at the 10% level since the JB statistic is below the 9.21 critical value.

Considering nominal returns as a measure of investment return can be misleading in the face of high inflation, and hence the need to consider the real stock returns to ascertain if investor income is not eroded by inflation. Real returns are calculated by subtracting inflation from the nominal rate of return as provided in Equation 6.1 below:

$$r_t = R_t - \pi_t \qquad 6.1$$

Where r_t represents the real rate of stock return, R_t is the nominal stock return rate and π_t is the inflation rate. Tables 6.4 and 6.5 below present the monthly and the annual real return figures respectively for each country.

Country	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB
Botswana	0.016	0.008	0.343	-0.107	0.052	2.265	14.766	881
Ghana	0.007	-0.004	0.391	-0.238	0.072	1.408	8.774	315
Kenya	-0.001	-0.010	0.413	-0.197	0.069	1.579	10.232	498
Mauritius	0.005	0.004	0.114	-0.086	0.033	0.276	3.471	3
Nigeria	0.007	0.000	0.291	-0.221	0.061	0.744	6.250	99
South Africa	0.003	0.011	0.100	-0.312	0.052	-1.530	8.998	452
Zimbabwe	0.006	0.012	0.719	-0.750	0.168	0.369	8.649	323

Table 6.4: Monthly real stock returns descriptive statistics

Kenya, whose nominal monthly returns were 1%, experienced negative average real returns of 0.1% between 1990 and 2007. This evidence is a major worry for investors in the country, since they endeavour to get above–inflation returns to guard against the erosion of their principal capital. If the results in the country showed a negative skewness, then this negative result would have been attributed to negative outliners. However, skewness is positive, suggesting that the results would have been more negative had it not been for the positive outliners. The rest of the countries show evidence of positive real monthly returns, with Botswana's real stock returns at 1.6% between 1995 and 2007.

Country	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	JB
Botswana	0.195	0.167	0.683	-0.273	0.230	0.271	2.567	2
Ghana	0.078	-0.057	1.204	-0.551	0.434	0.870	2.955	23
Kenya	-0.014	-0.084	0.982	-0.457	0.309	1.074	3.539	37
Mauritius	0.053	0.087	0.366	-0.435	0.160	-0.570	2.819	7
Nigeria	0.089	0.099	0.666	-0.554	0.289	-0.050	2.354	3
South Africa	0.050	0.085	0.630	-0.573	0.230	-0.400	2.819	6
Zimbabwe	0.043	0.165	1.797	-1.556	0.600	-0.299	3.146	4

Table 6.5: Annual real stock returns descriptive statistics

The South Africa returns remain negatively skewed after accounting for inflation, while Mauritius shows that the outliers of the real returns are above the mean. Negative skewness in a data set that reflects a positive mean and median is welcome in this context because it presents evidence of a higher real return, which is an investor's delight. The median for Ghana and Kenya for both the monthly and annual real returns show that more than half of the real returns in these countries for the periods under consideration are negative. The negative skewness of the annual real stock returns in Mauritius, Nigeria and Zimbabwe shows a different picture to what was shown by the monthly real returns, which were positive. This could present a worry for medium–term stock market investors in these countries and encourage short–term stock investment.

6.1.1 Unit root tests

Before empirical work can be undertaken it necessary to ascertain if the series are stationary, and the reasons for unit root testing were highlighted in the methodology chapter. In this section, three tests are conducted along the same lines as in the previous chapters, and the decision in ascertaining whether a series has a unit root or is non-stationary will not be changed in this section.

	Augmented Dickey Fuller		Phillips–Perron		KPSS	
Country	**Constant**	**Trend & C**	**Constant**	**Trend & C**	**Constant**	**Trend & C**
Botswana	-0.95	-2.09	-0.88	-1.94	1.38	0.26
Ghana	-1.18	-1.96	-1.19	-2.07	1.63	0.10
Kenya	-1.89	-2.00	-1.32	-1.41	0.33	0.20
Mauritius	1.67	-0.08	1.53	-0.08	1.10	0.28
Nigeria	-1.00	-1.96	-1.07	-1.85	1.54	0.20
South Africa	0.37	-2.37	0.30	-2.68	1.98	0.12
Zimbabwe	4.11	3.32	5.67	3.81	1.74	0.39
Critical Values						
1%	-3.46	-4.00	-3.46	-4.00	0.74	0.22
5%	-2.87	-3.43	-2.87	-3.43	0.46	0.15
10%	-2.57	-3.14	-2.57	-3.14	0.35	0.12

Table 6.6: Stock index unit root tests at the level

Table 6.6 presents the results of unit root and stationarity tests conducted on the logged values of the index. These results show that all the indexes were found to have a unit root. These unit root test results, however, are not in harmony with the stationarity test which confirm stationarity for South Africa and Ghana at the 5% level for the KPSS test with trend and constant. Using the stationarity KPSS test with only a constantc the results confirm stationary at all significance levels for Kenyan data, which is surprising seeing that Figure 6.1, which represents the series, does not look mean reverting at all. However, the same test with constant and trend shows the series as non–stationary at the 5% level. The conflicts could also be a reflection of the structural breaks in the data, given that the diagram in Figure 6.1 exhibits two clear break points: one is just before 1994 and the other is in 2002.

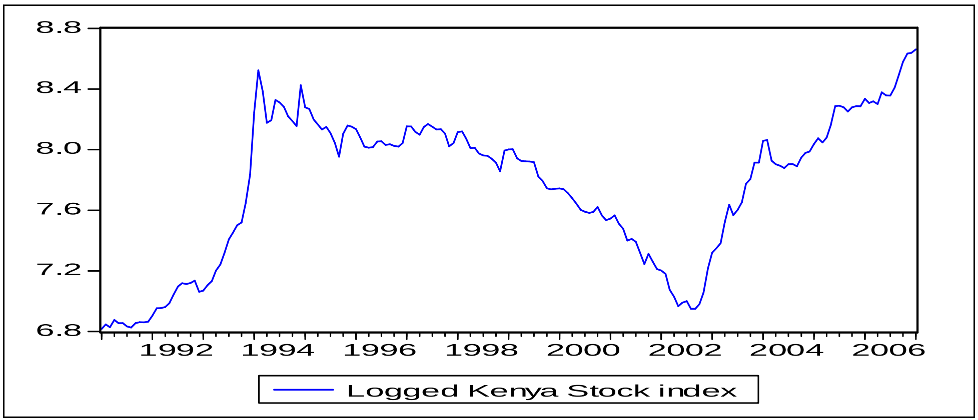

Figure 6.1: Line chart showing logged values of the Kenyan stock prices

The KPSS test with trend and constant which also show stationarity for the South Africa and Ghana series is not consistent with the visual presentation of the series for both countries, as these do not exhibit mean reversion. Given the graph presentations and the decision rule, which confirm unit root within a series if there is no conflict between the ADF and Phillip–Perron test results, all series are taken to be non-stationary.

	Augmented Dickey Fuller		Phillips–Perron		KPSS
Country	**Constant**	**None**	**Constant**	**None**	**Constant**
Botswana	-8.82	-7.75	-8.82	-7.95	0.10
Ghana	-9.26	-4.43	-9.44	-9.04	0.09
Kenya	-3.78	-3.63	-9.91	-9.73	0.21
Mauritius	-10.04	-9.66	-10.05	-9.67	0.46
Nigeria	-10.02	-6.18	-10.11	-9.33	0.13
South Africa	-14.83	-14.45	-14.85	-14.50	0.11
Zimbabwe	-2.77	-0.45	-12.76	-12.31	1.01
Zimbabwe (dd)	-8.15	-8.12	-80.05	-77.17	0.15
Critical Values					
1%	-3.46	-4.00	-3.46	-4.00	0.74
5%	-2.87	-3.43	-2.87	-3.43	0.46
10%	-2.57	-3.14	-2.57	-3.14	0.35

Table 6.7: Stock index unit root tests at the first difference

The unit root test for the first difference of the stock index in most of the countries shows evidence of stationarity and the rejection of the hypothesis for the existence of a unit root in the series. These results combine with those in Table 6.7 to confirm the stock prices index series in these countries as I(1), and their monthly stock returns when differenced are thus stationary. The Zimbabwe case reflects contradictory results combined with other African countries' first difference series in that ADF and KPSS tests show evidence of non–stationarity and existence of a unit root at the 5% level, while the Phillips–Perron test does not reject the hypothesis for the presence of a unit root. Figure 6.2 below is the diagrammatic presentation of the first difference of the Zimbabwe stock market series and it clearly reflects the existence of a structural shift around 2000, prior to which the series is mean reverting.

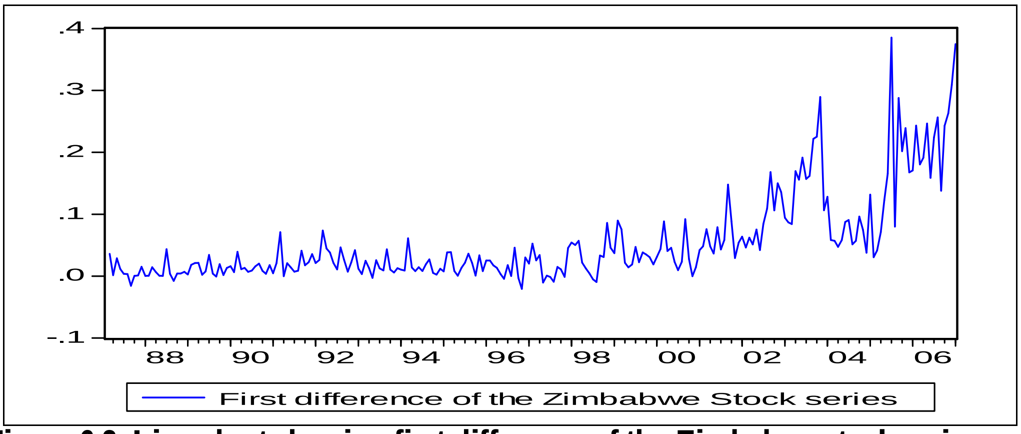

Figure 6.2: Line chart showing first difference of the Zimbabwe stock series

The second difference of the Zimbabwe stock index series, however, is stationary using all the tests as shown in Table 6.7, where the results are represented as Zimbabwe (dd); thus the index is considered to be integrated to the second level, i.e. I(2).

The annual stock returns unit root tests for South Africa and Ghana show the existence of a unit root in the series at the 5% level using the ADF test as well as the Phillips–Perron test for South Africa. The KPSS stationarity test shows that most of the series are stationary except for Zimbabwe, while the Kenya and Mauritius series do not reject stationarity at 5% level but at the 1% level instead.

	Augmented Dickey Fuller		Phillips–Perron		KPSS	
Country	**Constant**	**Trend & C**	**Constant**	**Trend & C**	**Constant**	**Trend & C**
Botswana	-2.01	-1.65	-2.58	-2.72	0.27**	0.09**
Ghana	-2.97**	-3.06	-2.78	-2.82	0.07**	0.06**
Kenya	-1.76	-1.72	-2.41	-2.39	0.22**	0.21*
Mauritius	-1.15	-1.97	-1.95	-2.30	0.42**	0.18*
Nigeria	-2.33	-2.40	-2.53	-2.57	0.18**	0.09**
South Africa	-2.99**	-3.08	-3.91*	-3.89**	0.15**	0.06**
Zimbabwe	0.22	-1.07	-1.29	-2.29	0.87	0.24
A single asterisk denotes significance at the 1% level and a double asterisk is 5% level of significance						

Table 6.8: Annual stock returns unit root tests at the levels

These results mean that annual stock returns in South Africa could be considered a 1(0) in this case, though Figure 6.3 below, which is the diagrammatic represents of the annual stock returns series, does not show convincing evidence of mean reversion. For this reason this will be excluded from empirical investigations using the cointegration method, since it will not be a suitable candidate for cointegrating with the inflation series which is a I(1) series (Ely and Robinson, 1997).

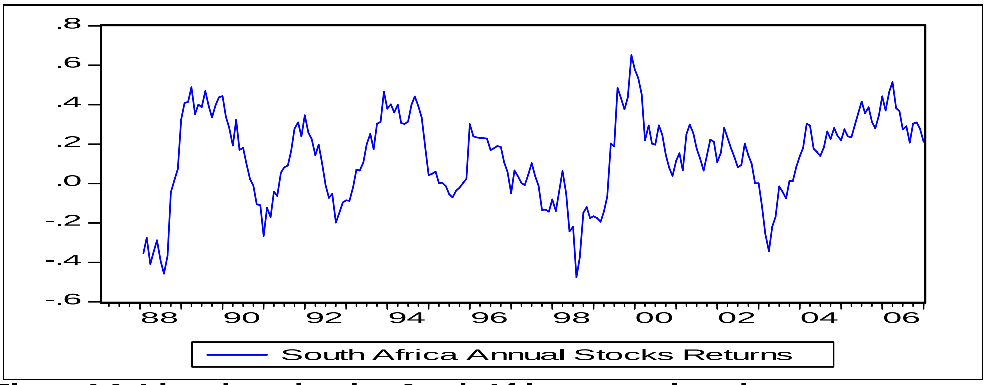

Figure 6.3: Line chart showing South African annual stock returns

These findings are puzzling in that stock returns (monthly or annual) are expected to be stationary. However, these results could reflect the existence of bubbles and structural breaks in these markets or they may reflect the effects of macroeconomic variables, possibly inflation.

6.2 Empirical evidence

To determine the long–run relationship between inflation and stocks this research will primarily employ the two cointegration approaches contained in the methodology chapter: the Engle–Granger 2–Step cointegration method and the Johansen Technique. For cointegration to be established there is need to ascertain if the stock and inflation series are integrated to the same level. Three relationships will be explored here: the relationship between the stock market index and consumer price index; then stock market index and annual inflation rate; and annual stock returns and annual inflation rate in countries where the annual stock returns were not stationary. The last relationship is controversial, however, since stock returns are normally expected to be stationary. The relationship between stock market prices and annual inflation rate will help ascertain if stock markets in Africa react to the annual inflation rate instead of monthly inflation announcements, since the former is given more prominence in press headlines.

Country	Augmented Dickey Fuller	Phillips–Perron
Botswana	-1.97*	-1.89**
Ghana	-2.97*	-2.12*
Kenya	-1.88**	-1.25
Mauritius	-0.48	-0.64
Nigeria	-2.33*	-2.05*
South Africa	-1.33	-1.66**
Zimbabwe	-2.50*	-2.55*
A single asterisk denotes significance at the 5% level and a double asterisk is 10% level of significance		

Table 6.9: Unit root tests for residuals of monthly stock returns and inflation

Table 6.9 above shows the results of the unit root tests performed on the residuals of the regression between stocks and inflation regression. The results for Zimbabwe, contained in Table 6.9, relate to the changes in movement of both the return series rather than the actual movements of the original data, since stock and consumer price indexes are I(2). Thus, for the Zimbabwe case, the findings in Table 6.9 relate to evidence of a relationship between changes in monthly stock returns and changes in the inflation rate. In other African countries, except Mauritius, there is evidence of a long–run relationship between monthly stock returns and the inflation rate.

Country	Augmented Dickey Fuller	Phillips–Perron
Botswana	-2.03*	-2.64*
Ghana	-2.96*	-2.77*
Kenya	-2.00*	-2.71*
Mauritius	-1.12	-1.90**
Nigeria	-2.92*	-2.96*
Zimbabwe	-2.93*	-3.46*
A single asterisk denotes significance at the 5% level and a double asterisk 10% level.		

Table 6.10: Unit root tests for residuals of annual stock returns and inflation

South Africa and Kenya show contradictory results using the ADF and the Phillip–Perron tests, with the ADF test revealing cointegration at the 10% level for Kenya and the Phillip–Perron showing evidence of a long–run relationship for South Africa. There are no major contradictions in the results for the relationship between annual inflation rate and annual stock market return in most countries, as shown in Table 6.10 above. Mauritius is the only country where the relationship is not clear, as the ADF test rejects long–run equilibrium between the two series, while the Phillip–Perron test confirms cointegration at the 10% level. Another revelation from these results is that the confidence of the evidence for this relationship is stronger, since residuals are found to be stationary at the 5% level. Results for South Africa are not reflected here, since the annual stock series does not have a unit root, which is a prerequisite for cointegration analysis.

Country	Augmented Dickey Fuller	Phillips–Perron
Botswana	-0.90	-0.94
Ghana	-2.10*	-1.78**
Kenya	-1.66**	-1.49
Mauritius	0.66	0.61
Nigeria	-1.20	-1.63**
South Africa	-1.08	-2.13*
Zimbabwe	-2.37*	-3.00*
A single asterisk denotes significance at the 5% level and a double asterisk at 10% level.		

Table 6.11: Unit root tests for residuals of monthly stock returns and annual inflation

To determine if there is a long–run relationship between stock market, as determined by the stock market index movements and annual inflation rate, the residual of the regression between the two series were tested for stationarity. Table 6.11 shows the results, and again some contradictions in the test results are noted for the Kenya, Nigeria and South Africa series. Botswana and Mauritius show no evidence of a long–run relationship between stock market returns and annual inflation, while both the ADF and the Phillips–Perron test results confirm the existence of such a relationship in Zimbabwe and Ghana. Now that a long–run relationship between stock returns and inflation has been confirmed in most countries except Mauritius, the next step is to check the nature of the relationship.

Long-run relationship between stock returns and inflation ($SP_t = c + \beta CP_t$)		
Country	**c**	β
Botswana	-9.08 (0.36)*	3.27 (0.08)*
Ghana	0.94 (0.13)*	1.32 (0.03)*
Kenya	5.26 (0.27)*	0.56 (0.06)*
Nigeria	2.60 (0.10)*	1.46 (0.02)*
South Africa	-0.51 (0.15)*	1.45 (0.03)*
Zimbabwe	5.00 (0.05)*	0.97 (0.01)*

SP represents monthly stock returns and **CP** is the monthly inflation rate. Standard errors in parentheses below the coefficient (β) and constant (**c**) estimates. A single asterisk denotes a value that is significant at 5%.

Table 6.12: Monthly stock returns and monthly inflation long–run relationship

Table 6.12 shows that stock prices and inflation have a positive relationship in line with the Fisher Hypothesis, which noted that the expectation from investing in stocks markets is that it achieves above–inflation returns to protect their purchasing power (Levi and Makin, 1979; Ely and Robinson, 1997; Choudhry, 2001). For the annual series, the situation is different with only Kenya, Nigeria and Zimbabwe results confirming a positive relationship between the variables, as shown in Table 6.13. Mauritius and Ghana, whose results indicate a negative relationship, as shown in Table 6.13, have coefficients that are statistically insignificant which means the nature of the long–run relationship cannot be confirmed as negative at the 5% level.

Long-run relationship between stocks and inflation ($S_t = c + \beta I_t$)		
Country	**c**	**β**
Botswana	0.50 (0.09)*	-2.81 (1.11)*
Ghana	0.32 (0.06)*	-0.17 (0.28)
Kenya	-0.14 (0.03)*	2.02 (0.20)*
Mauritius	0.14 (0.05)*	-0.52 (0.77)
Nigeria	0.10 (0.04)*	0.95 (0.13)*
Zimbabwe	0.03 (0.05)*	1.03 (0.06)*
S represents annual stock return changes and **I** is the annual inflation rate change. Standard errors in parentheses below the coefficient (β) and constant (**c**) estimates. A single asterisk denotes a value that is significant at 5%.		

Table 6.13: Annual stock returns and annual inflation long-run relationship

All other beta coefficients are significant at the 5% level, and thus in general the long–run relationship between annual inflation and annual stock returns in Africa, expect in Botswana, can be considered to be positive. These results are consistent with those in Table 6.12 above. Table 6.14 provides a different picture in that a negative relationship is established between annual inflation and stock price index at the 5% level for countries where the unit root tests for residuals were found to be stationary using either the ADF or the Phillips–Perron test.

Long-run relationship between stocks and inflation ($SP_t=c+\beta I_t$)		
Country	**c**	β
Ghana	7.32 (0.20)	-3.38 (0.87)
Kenya	7.84 (0.05)	-0.72 (0.33)
Nigeria	10.11 (0.10)	-4.85 (0.39)
South Africa	6.89 (0.07)	-13.69 (0.73)
Zimbabwe	6.98 (0.10)	4.29 (0.12)
SP represents monthly stock returns and **I** is the annual inflation rate change. Standard errors in parentheses below the coefficient (β) and constant (**c**) estimates. A single asterisk denotes a value that is not significant at 5%.		

Table 6.14: Monthly stock returns and annual inflation long-run relationship

6.2.1 Error Correction Model (ECM)

Empirical research shows that even when there is a positive long–run relationship, the short–run dynamics could present a different view, and the error correction model (ECM) helps to ascertain the nature of the relationship as well as the ability of the variables to return into equilibrium in the next period. Ely and Robinson (1997) argue that the negative relationship between stock prices and inflation has been derived from regressions over relatively short time periods, suggesting that long–term series analysis would provide a positive relationship. In Table 6.15 the ECM for the relationship between stocks and inflation is presented. The negative coefficient for the error term in all the countries is a welcome result in that it shows that stocks are able to revert back into equilibrium in the next period in case of an error in the current one. However, only in the Zimbabwe and Nigeria cases is the negative coefficient statistically significant, which prompts lack of confidence in other countries' negative error term coefficients. Apart from South Africa, the coefficients for inflation are statistically significant and positive, which suggests that stocks respond positively to monthly inflation movements and this result is consistent with the earlier findings presented in Table 6.12 on the nature of the long–run relationship. The R^2 in most countries is between 1% and 5%, which indicates the percentage of movements in stocks that is explained by the right–hand side of the ECM.

Error Correction Model (ECM) for monthly stock returns and monthly inflation rate: $\mathbf{DS_t = c + \beta DC_t + \varepsilon_{t-1}}$					
Country	**c**	β	ε	R^2	F-Statistic
Botswana	0.01 (0.01)	1.71 (0.89)**	-0.03 (0.02)	0.05	3.32*
Ghana	0.01 (0.01)**	0.65 (0.31)*	-0.02 (0.01)	0.03	2.94**
Kenya	0.00 (0.01)	0.59 (0.26)*	-0.01 (0.33)	0.03	3.03**
Nigeria	0.02 (0.01)*	0.43 (0.18)*	-0.03 (0.02)*	0.05	5.03*
South Africa	0.01 (0.01)*	-0.30 (0.77)	-0.02 (0.02)	0.01	0.71
Zimbabwe	0.01 (0.01)	0.95 (0.15)*	-0.05 (0.02)*	0.15	21.10*
DS represents monthly stock returns, **DC** is the monthly inflation rate and **ε** the error term. Standard errors in parentheses below the coefficient (β) and constant (**c**) estimates. A single asterisk denotes significance at the 5% level and a double asterisk is at the 10% level of significance.					

Table 6.15: ECM for monthly stock returns and monthly inflation rate

The F-Statistics for Zimbabwe and Nigeria are significant at the 5% level, indicating the significance of the whole equation in explaining movements in stocks. Mauritius does not appear in the above table because no long–run relationship was found between stocks and inflation; therefore ECM dynamics are not considered.

Table 6.16 presents the error correction model for the relationship between annual inflation and annual stock returns in countries where the residuals were stationary. All the error terms have negative coefficients; these are statistically significant at the 10% level with Kenya, and with Nigeria significant at the 5% level.

Error Correction Model (ECM) for annual stock returns and annual inflation rate: $\mathbf{AR}_t = c + \beta \mathbf{DI}_t + \varepsilon_{t-1}$					
Country	**c**	β	ε	R^2	F-Statistic
Botswana	0.00 (0.01)	0.96 (0.93)	-0.05 (0.03)**	0.04	2.31**
Ghana	0.00 (0.01)	-0.33 (0.40)	-0.04 (0.02)**	0.02	2.12
Kenya	0.00 (0.01)	0.44 (0.30)	-0.08 (0.03)*	0.08	7.89*
Mauritius	0.00 (0.01)	-1.66 (0.79)*	-0.07 (0.04)**	0.06	3.94*
Nigeria	0.00 (0.01)	0.06 (0.27)	-0.07 (0.02)*	0.05	4.62*
Zimbabwe	0.01 (0.01)	0.15 (0.26)	-0.05 (0.03)**	0.02	1.77

AR represents changes in annual stock returns, **DI** is the annual inflation rate change and **ε** the error term. Standard errors in parentheses below the coefficient (β) and constant (**c**) estimates. A single asterisk denotes significance at the 5% level and a double asterisk is at the 10% level of significance.

Table 6.16: ECM for annual stock returns and annual inflation rate

The Mauritius annual inflation coefficient is significant at the 5% level, however, the rest of the coefficients are not significant. The negative relationship between the movement in annual stock returns and annual inflation rate is consistent with the earlier evidence on the long–run relationship between the two variables, particularly for Mauritius. The R^2 for Kenya has also improved to over 7% from 3% (see Table 6.15), which indicates that annual inflation equation explains more of annual stock returns than monthly inflation does for monthly stock return. The ECM for most countries is also significant for this relationship except in Ghana and

Zimbabwe. As for the countries where there was evidence of long–run relationship between stocks prices and annual inflation, there is only one statistically significant equation, which is that of Zimbabwe as indicated in Table 6.17 below.

Error Correction Model (ECM) for monthly stock returns and annual inflation rate: $DS_t = c + \beta DI_t + \varepsilon_{t-1}$					
Country	**c**	β	ε	R^2	F-Statistic
Ghana	0.02 (0.01)*	-0.13 (0.28)	-0.01 (0.00)	0.01	1.01
Kenya	0.01 (0.01)**	0.28 (0.22)	0.00 (0.01)	0.01	0.91
Nigeria	0.03 (0.01)*	0.12 (0.19)	0.01 (0.01)**	0.02	1.57
South Africa	0.01 (0.00)*	0.25 (0.62)	-0.02 (0.01)**	0.02	2.00
Zimbabwe	0.06 (0.01)*	0.33 (0.22)	0.02 (0.01)	0.03	2.93**
DS represents monthly stock returns, **DI** is the annual inflation rate change and **ε** the error term. Standard errors in parentheses below the coefficient (β) and constant (**c**) estimates. A single asterisk denotes significance at the 5% level and a double asterisk is at the 10% level of significance.					

Table 6.17: ECM for monthly stock returns and annual inflation rate

The coefficients for annual inflation rate changes, though positive, are statistically insignificant in all cases, thus making the nature of the short–run dynamics difficult to ascertain and confirm.

6.2.2 Johansen technique results

The other technique used to ascertain long–run relationships is that presented by Johansen and Juselius (1990), discussed in the methodology chapter. To use this method there is need to determine the lag length of the VAR, and Table 6.18 presents results of the process following Sims's (1980) likelihood ratio test (LR) and the Akaike information criterion (AIC). For the stock prices and inflation, the maximum lag length used to the VAR is 20, which Luintel and Paudyal (2006) consider to be the most general model. If a lag length is determined using LR or AIC tests, the next step is to carry out an LM test for residual serial correlation with the hypothesis of no serial correlation at specific lag order. According to Johansen (1991), the VAR residuals should be uncorrelated for reliable results. If the hypothesis is rejected at any of the lag lengths chosen using the above–mentioned criteria, then there will be need to choose a lag between these two lag lengths where the results do not reject the hypothesis of the test. If both lag lengths provide a favourable LM test result, then the criterion with the least *p*-value will be adopted. In cases where the criterion lag length choice results in the rejection of the LM test hypothesis as well as the lengths between these, then any lag from the maximum length (*k*-max=20) to a minimum length (*k*-min=10) in line with the Luintel and Paudyal (2006) procedure would be considered. A 10% level of significance will be used in the LM test to ensure consistency in the results as well as a reasonable lag length procedure.

Likelihood Ratio (LR) Statistics and Akaike Information Criterion (AIC) for Vector Autoregression (VAR) Lag Length Specification for monthly stock and inflation figures			
Country	LR: $(T\text{-}c)(\log\lvert\sum_R\rvert - \log\lvert\sum_U\rvert)$	AIC: $T \log\lvert\sum\rvert + 2N$	Lags Adopted
Botswana	2 (0.621)	2 (0.621)	17 (0.053)
Ghana	9 (0.942)	2 (0.291)	7 (0.046)
Kenya	19 (0.850)	9 (0.326)	14 (0.036)
Mauritius	1 (0.742)	1 (0.742)	10 (0.055)
Nigeria	17 (0.425)	3 (0.441)	16 (0.089)
South Africa	2 (0.746)	2 (0.746)	13 (0.074)
The *p*-values are in brackets.			

Table 6.18: Lag length specification for monthly stock and monthly inflation rate

In Table 6.18, the results of the lag length selection criteria for the VAR that incorporates stock prices and CPI index are presented with the *p*-values for the LM test in parentheses, and there is no uniformity in the VAR lag length. The LR lag lengths range from 1 to 19 lags, while the AIC is from 1 to 9 lags. The last column represents the adopted lags using the brief outlined above. In all cases the lag length chosen through the criteria show evidence of serial correlation in the VAR residuals, and adopted lags had to follow the decision rules mentioned above.

For the annual stock–inflation series, a different approach is adopted given the relationship between the current values and twelve months ones; thus the maximum lag length (*k*-max) is fixed at 11 lags instead of 20 with minimum lag length of 2. Table 6.19 presents the adopted lag lengths as well as the *p*-values for the LM test. Just like the results in Table 6.18, none of the lags chosen using the LR or the AIC result in the non-rejection of the LM test hypothesis.

Likelihood Ratio (LR) Statistics and Akaike Information Criterion (AIC) for Vector Autoregression (VAR) Lag Length Specification for annual stock and inflation figures			
Country	LR: $(T\text{-}c)(\log\lvert\sum_R\rvert - \log\lvert\sum_U\rvert)$	AIC: $T\log\lvert\sum\rvert + 2N$	Lags Adopted
Botswana	2 (0.370)	2 (0.370)	3 (0.243)
Ghana	6 (0.186)	6 (0.186)	5 (0.044)
Kenya	9 (0.195)	7 (0.910)	4 (0.009)
Mauritius	2 (0.132)	2 (0.132)	2 (0.132)
Nigeria	11 (0.470)	4 (0.540)	9 (0.054)
The *p*-values are in brackets.			

Table 6.19: Lag length specification for annual stock returns and annual inflation

The adopted lag length for Botswana and Mauritius are the only cases where a *p*-value for the LM test results in the non-rejection of the serial correlation VAR residual test, since the value is over the initially agreed significance levels. Given the existence of serial correlation in the VAR residuals, no cointegration test is to be performed for Botswana Mauritius in the ascertainment of the long–run relationship between annual inflation and annual stock returns. In the case of Ghana and Kenya, the *p*-values for the LM test for the two considered criteria resulted in the non-rejection of the serial correlation in the VAR. For this reason, the lags between these criteria and the maximum lags were then tested in line with the above–outlined decision rule; however, the results were the same. To determine the lag lengths in these cases, the lags between the minimum lag length and the maximum criterion were considered. This resulted in the adopted lag length of 5 for Ghana and 4 for Kenya.

With the above adopted VAR lag length, the Johansen technique was then executed for each country's consumer price index and the stock market price index to ascertain the long–run relationship between stocks and inflation. Table 6.20 shows the results for this test, and also indicates the cointegrating rank as well as the cointegrating vector. In Table 6.20 the indications using the maximum eigenvalue, normalised for stock prices, are that there is at least one cointegrating vector between stock market prices and inflation in Nigeria and two in South Africa. In both cases, the results show a negative and significant relationship, suggesting that a rise in the consumer price index leads to a decrease in the stock market price index over time. Except for Kenya, this negative relationship is echoed by the rest of the countries where no cointegration was established using this method.

Cointegrating rank results, normalized coefficients and VECM for stock market index and consumer price index						
Country	r = 0	r ≤ 1	Cointegrating Vectors		VECM Coefficients	
			β	c	Stock	Inflation
Botswana	11.688	2.036	-2.447 (0.397)*	5.149	-0.063 (0.028)*	0.002 (0.003)
Ghana	12.253	3.049	-1.308 (0.119)*	-0.985	-0.037 (0.014)*	0.002 (0.003)
Kenya	9.435	2.860	13.039 (5.667)*	-66.374	0.001 (0.001)	-0.001 (0.000)*
Mauritius	10.104	2.251	-1.105 (0.354)*	0.165	-0.001 (0.032)**	0.010 (0.004)
Nigeria	18.005*	2.272	-2.030 (0.174)*	0.016	-0.048 (0.017)*	0.011 (0.005)*
South Africa	17.765*	2.856*	-3.279 (0.493)*	8.432	0.002 (0.007)	0.002 (0.001)*
5% LOS	15.41	3.76				
Standard error is in parentheses below coefficient estimates. A single asterisk denotes significance at the 5% level and a double asterisk is at the 10% level of significance.						

Table 6.20: Cointegration results for monthly stock returns and monthly inflation

These results, however, contradict the findings using the Engle–Granger 2–step method performed earlier and seem to confirm the empirical findings of the late 1970s and early 1980s by researchers such as Nelson (1976), Bodie (1976), Fama and Schwart (1977), Modigliani and Cohn (1979), Gultekin (1983) and recently Ritter and Warr (2002). The possible explanation for this is that the results presented in Table 6.12 above are from an equation that looks at the effect of an increase in the current inflation rate on stocks, while the Johansen technique considers the effect of lagged values in both the independent and the dependent variable. Thus the results in Table 6.20 do not suggest that a rise in the inflation rate will result in a fall in stock prices, but merely confirm that in the long run inflation and stocks have a negative relationship.

The last two columns of Table 6.20 show the VECM results which present the error-correction coefficients for the largest eigenvalue in the VECM. As noted in Chapter Two, the speed of adjustment back into long–run equilibrium is showing. The stock prices component is negative and significant, indicating the ability of the system innovations to revert back to the long–run relationship. The positive VECM coefficient for stock prices in the South African case is worrying in that there is no evidence of the stock market series reverting back into equilibrium. However, since the positive stock coefficient in this case is not statistically significant, there is also no evidence of an exaggerated error in the next period either. The relationship between annual stock returns and the inflation rate present a different picture in that there is evidence of a long–run relationship in all the countries considered, as noted in Table 6.21 below. In Table 6.21 the three countries considered here show at least two cointegrating equations at the 5% level.

Cointegrating rank results, normalized coefficients and VECM for annual stock returns and annual inflation rate						
Country	r = 0	r ≤ 1	Cointegrating Vectors		VECM Coefficients	
			β	c	Stock	Inflation
Ghana	25.203*	6.977*	-1.771 (0.964)	0.079	-0.060 (0.017)*	0.005 (0.003)*
Kenya	15.730*	4.592*	-2.027 (0.769)*	0.137	-0.083 (0.026)*	-0.009 (1.331)**
Nigeria	17.410*	4.205*	-0.810 (0.395)*	-0.137	-0.094 (0.031)*	-0.016 (0.009)*
5% LOS	15.41	3.76				
Standard error is parentheses below coefficient estimates. A single asterisk denotes significance at the 5% level and a double asterisk is at the 10% level of significance.						

Table 6.21: Cointegration results for annual stock returns and annual inflation

The cointegrating vectors confirm a statistically negative, relationship between the two variables in Kenya and Nigeria, with Ghana negative value insignificant. All the stock components of the VECM are negative suggesting the ability to draw the system back into long–run equilibrium.

6.2.3 Impulse response

The cointegration analysis carried out above has aided the knowledge about the nature of the relationship between stock returns and inflation in the long run, while the ECM has assisted the understanding of the short–run dynamics. However, to help understand the response of stock prices to inflation innovations it is necessary to consider the impulse response function which traces the effects of one standard deviation shock on one of the innovations on current and future values of the endogenous variable (Al-Khazali and Pyun, 2004). Through the VECM developed by Johansen (1991), a shock to the inflation rate will affect its current and future movements as well as the changes in the stock market via the dynamic structure of this model. Koop *et al*. (1996) developed a non-linear impulse response for multivariate models, while Pesaran and Shin (1998) improved on this to propose the generalised impulse response analysis for an unrestricted VAR and cointegrated VAR models. This generalised system was proposed to address the shortcomings of the VAR system developed by Sims (1980). This is so because the dynamic analysis of VAR models routinely carried out using orthogonalised impulse responses, where underlying shocks to VAR are orthogonalised using Cholesky decomposition before impulses are computed, are invariant in the ordering of the variables in the VAR (Pesaran and Shin, 1998). In this regard, ordering becomes an issue whenever making analysis on the VAR system. The generalised impulse response addresses this issue since Pesaran and Shin (1998) show that for a non-diagonal error variance matrix the orthogonalised and the generalised impulse responses coincide only in the case of the impulse responses of the shocks to the first equation in the VAR. However, in this section, since only two variables are used, the ordering challenge is not much of an issue; thus the generalised system would produce the same results as the Cholesky one standard deviation shock results. Since VAR systems are difficult to define concisely owing to complex patterns of cross-equation feedback and estimated lagged coefficients, the impulse response function is considered an alternative descriptive mechanism (Al-Khazali and Pyun, 2004).

Ely and Robinson (1997) used the impulse response methodology to ascertain if share price maintain their value relative to goods prices and whether these response patterns depend on the source of the inflation shock. Figure 6.4 below shows the impulse responses of stock market prices to inflation innovations over a five–year period. The indications are that stock returns respond positively to inflation shocks over time except in Kenya, where the response is positive but dies down after four years to become negative. In Botswana, the response is negative up to a year and then becomes positive sharply, then dying down positively; the positive response is only statistically significant at the 5% level after three years. Ghana stock prices also have a negative response to inflation innovations in the first two months before the response becomes positive, then negative until the 18^{th} month, when it becomes positive with the statistical significance of the positive response only experienced after two and a half years. Apart from the positive response experienced by the Ghana stock prices between the second and the sixth months, South Africa follows a similar impulse response to inflation innovations. In these cases a positive response is experienced after two years and the statistical significance of this response is only noted after five years. Mauritius stock prices respond positively to inflation innovations from the first month to the fifth year, but none of this response is statistically significant at the 5% level.

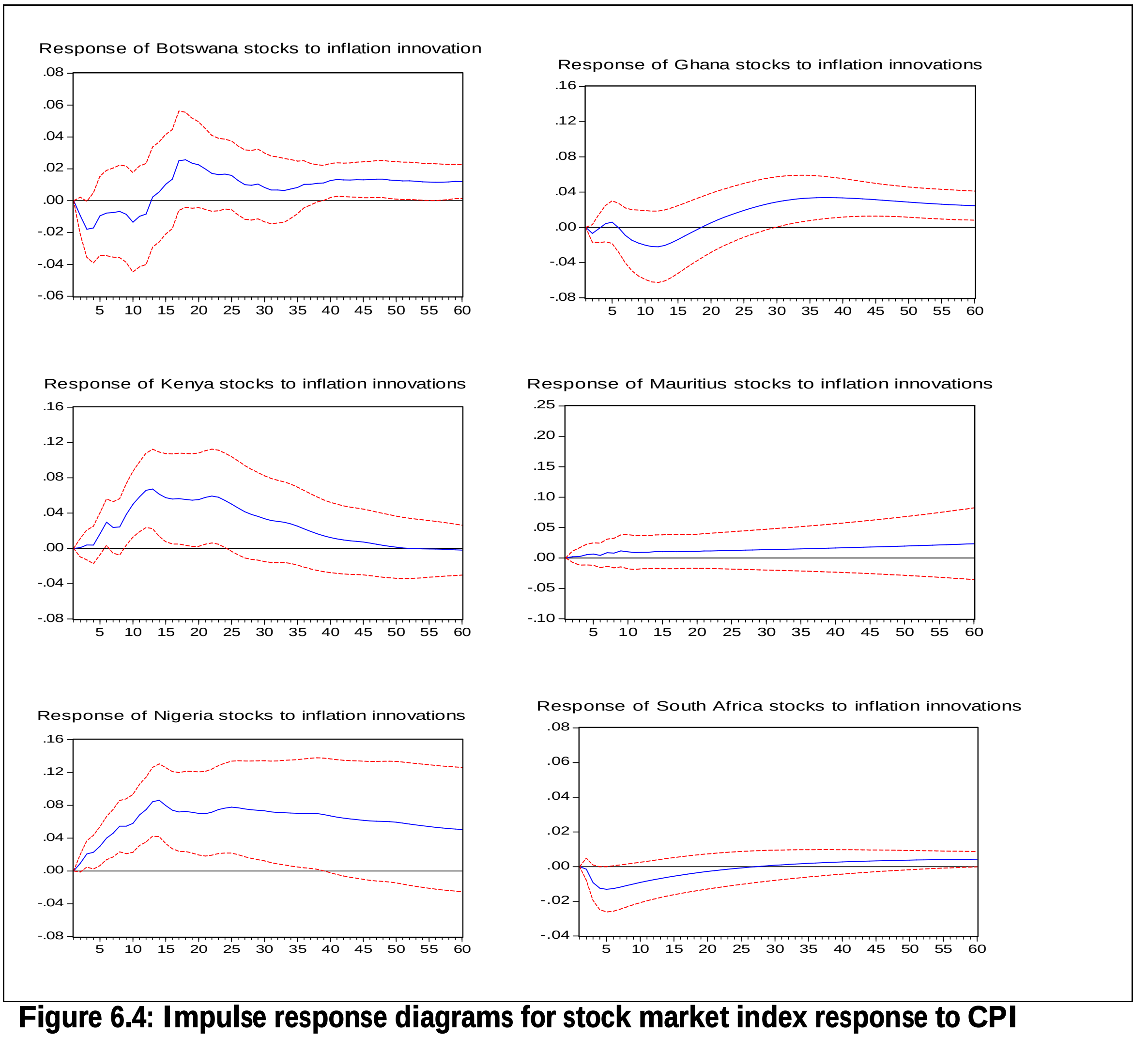

Figure 6.4: Impulse response diagrams for stock market index response to CPI

Nigerian stock prices, whose response is positive and similar to Mauritius stock prices, experience a statistically significant response from the second month to just over three years. As noted above, the only country whose stock prices' response is negative towards five years is Kenya, which starts having a positive response that becomes statistically significant after the eight month, staying so until two years. The positive response of stock prices to inflation innovations in Kenya dies down, becoming negative after four and a half years. Apart from Botswana and Ghana, the response of stock market prices to inflation innovations after one month is similar to the findings presented in Table 6.15 above, though Figure 6.4 shows statistically insignificant responses in this period for all but Nigeria.

Figure 6.5 presents the response of annual stock market returns to annual inflation rate innovations for a five–year period. The findings show that the response dies away towards the final period under consideration.

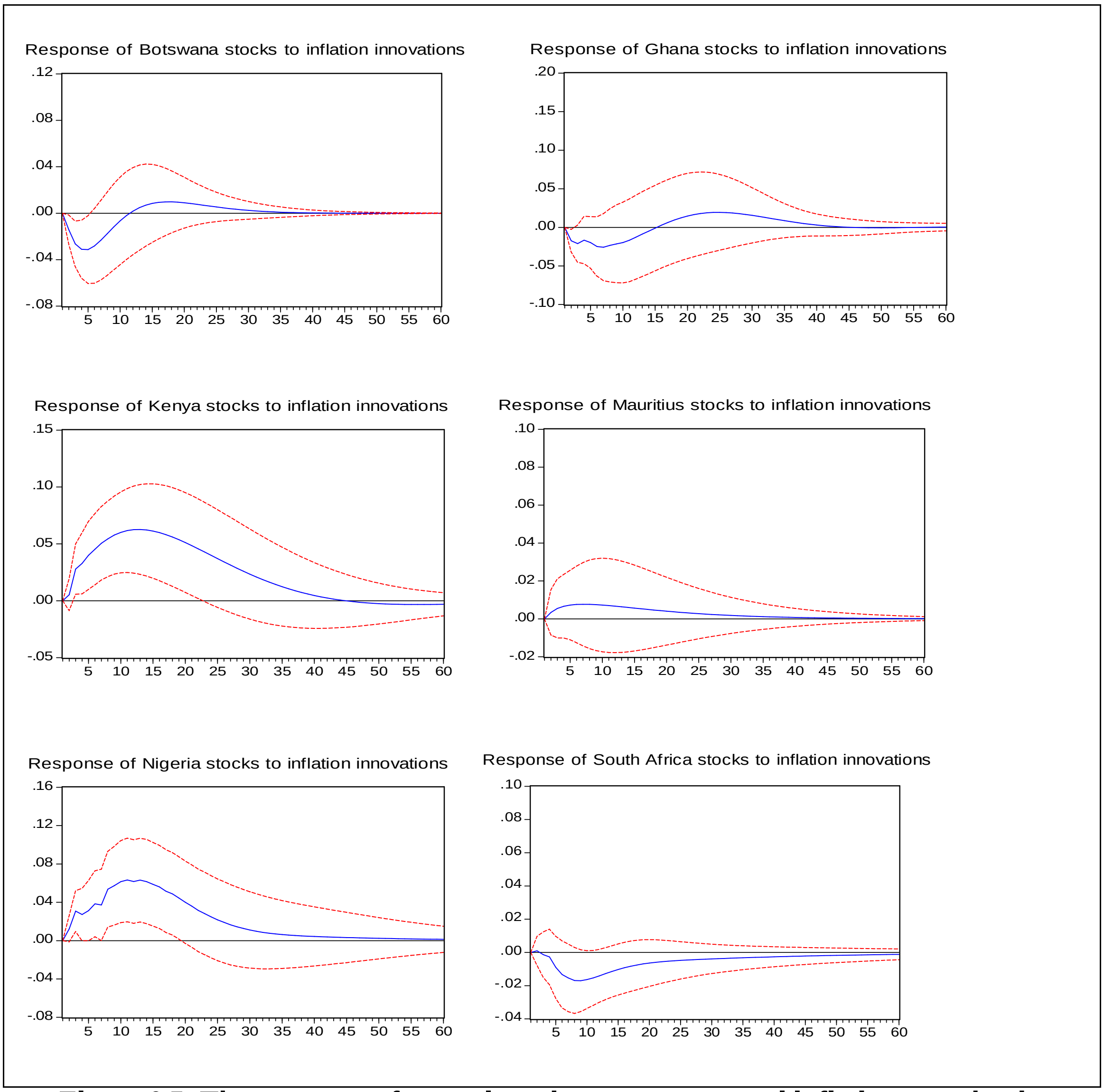

Figure 6.5: The response of annual stock returns to annual inflation rate shocks

The annual stock returns' response to annual inflation rate shocks begin positive in Nigeria and Mauritius, then dying positive towards the fifth year. For Kenya the annual stock returns show a negative response after three and a half years, having started positive to inflation innovations. The response in Kenya is also statistically significant between the third month and just before two years, while in Nigeria the response is positive between the second and the eighteenth months. The response findings in these countries are similar to those obtaining between the stock market prices and the consumer price index, as shown in Figure 6.4, and are also consistent with the ECM findings in Table 6.16. The response of South Africa stock returns is negative and dies down towards year five; none of the responses are statistically significant over the five–year period. Botswana and Ghana annual stock returns follow a similar response which starts with a transitory period of negative response, becoming positive to annual inflation rate shocks before the response dies away over time. The negative response for Botswana annual stock returns to unexpected movements in the annual inflation rate is statistically significant before six months and then becomes insignificant, following a similar response pattern with the stock market prices. In summary, Figures 6.4 and 6.5 show that unexpected movements in both the consumer price index and the annual inflation rate influence movements in the stock market prices and annual inflation rate respectively over time.

6.2.4 Variance decomposition

The techniques that have been looked at thus far examined the existence of a relationship between stock returns and inflation over a long run horizon as well as short and medium term. In this section we explore the variance decomposition of the models estimated in Tables 6.20

and 6.21 above. The variance decomposition helps determine how much of variations in stock prices are explained by inflation over a given period of time, and are constructed from a VAR with orthogonal residuals (Sims, 1980; Litterman and Weis, 1985). The ordering challenge associated with this method is not an issue here since only two variables are considered. While this method does not necessarily provide answers as to the nature of the stock–inflation relationship, it offers useful information for each country as it provides the percentage of variations in stock prices caused by inflation innovations. The lag lengths adopted in Table 6.18 are used for the VAR system in the decomposition of the variance.

Variance Decompositions for stock prices on consumer price index series						
Years	**Botswana**	**Ghana**	**Kenya**	**Mauritius**	**Nigeria**	**South Africa**
0.5	5.092	0.231	3.514	0.655	11.088	2.236
1	6.306	2.102	16.493	2.349	34.748	7.012
2	19.504	2.783	31.638	3.850	61.473	7.527
3	22.497	9.175	35.804	4.853	70.876	6.960
4	27.251	16.148	36.245	5.648	75.129	6.565
5	31.131	20.175	36.248	6.310	77.257	6.419

Table 6.22: Variance decompositions for stock prices on CPI series

In Table 6.22, the variance decomposition results are presented for the medium–term, i.e. six months, and each year until the fifth year. This approach directly addresses the contribution of inflation in forecasting the variance of stock prices, unlike cointegration, which implies that the variance decomposition in levels approximates the total variance of stocks (McMillan, 2001). The results show that after the half year 11% of stock price variations in Nigeria are explained in inflation innovations, which is a substantial percentage given that only 0.2% and 0.7% of stock variations are explained in Ghana and Mauritius respectively. After five years, over 77% of the stock market price variations are explained by the consumer price movements in Nigeria. South Africa and Mauritius results are the lowest, with variance decomposition results of just over 6%, which shows that the percentage inflation predicts variations in stock prices over five years. The situation is similar for annual stock returns, as shown in Table 6.23 below, though annual inflation predicts less variation in annual stock return than CPI does with stock prices in all countries.

Variance Decompositions for annual stock returns and annual inflation series						
Years	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
0.5	9.012	2.079	9.731	0.989	7.726	1.377
1	8.880	2.710	28.244	1.944	26.117	4.956
2	10.159	3.577	47.438	2.644	41.752	5.440
3	10.330	4.977	49.840	2.756	42.336	5.779
4	10.332	5.019	49.717	2.771	42.412	5.947
5	10.332	5.017	49.734	2.773	42.431	5.985

Table 6.23: Variance decompositions for annual stock returns and annual inflation

In conclusion, the consumer price index in Botswana, Ghana, Kenya and Nigeria predict considerable amounts of variations in stock prices at over 20%. However, the annual inflation rate only predicts annual stock returns well in Kenya and Nigeria, with figures over 42% of variations. Given these results, CPI is a good predictor of stock prices over time in Africa.

6.2.5 Structural breaks in the stocks and inflation series

The long–run relationship between two variables can be affected by the presence of structural breaks in the data, and stock–inflation relations are not exempt from this assertion. These breaks could be a result of economic regimes or a change in the factors that determine and affect innovations in variables under consideration. Therefore, if structural breaks are not taken into account when determining the existence of a long–run relationship, there is a possibility that linear methods may fail to confirm the relationship when in fact it does exist. In the context of this research, the Johansen cointegration method failed to establish a relationship between inflation and stock prices in three of the countries under consideration, and accounting for structural breaks could help determine the robustness of these results.

To identify breaks, we use the Bai and Perron (1998; 2003a, b) technique which was outlined in the Methodology chapter. Since the number of breaks required has to be specified, this section will consider only one break without indicating the span from the start of the data. The choice of one break in this context is motivated by the fact that later in this section a Granger causality test will be carried out before and after the break; hence, having more than one break point will compromise the exercise, given the number of observation in the data. Appendix 6.1 presents the diagrams showing the break points for the monthly inflation movements and the stock market monthly returns for each country. In summary, there is a downward shift in the stock returns in all countries apart from South Africa, which exhibits an upward shift in returns after the break. A similar trend is noticed for monthly inflation with all countries except Botswana projecting a downward shift in the rate. The Botswana situation presents a tightening of real stock returns with inflation on an upward shift and stocks vice versa. South Africa, on the other hand, shows potential for increased real month stock returns after the break, with the upward shift in stock returns and downward regime movement in the monthly inflation rate. Table 6.24 below presents the summary of the break points for each country.

	Botswana	**Ghana**	**Kenya**	**Mauritius**	**Nigeria**	**South Africa**
Inflation Series	Feb-05	Mar-03	Apr-04	Dec-01	Sep-95	Apr-93
Stock Series	Mar-02	Aug-04	Mar-94	Oct-04	Dec-96	Aug-04

Table 6.24: Break points for inflation and stock series

The break points provided in Table 6.24 are for the month–to–month changes in stock prices and inflation index series. The possible reasons for the structural breaks in the stock and inflation series vary from country to country as provided below, though it is important to note that these reasons are not absolute but are suggestions as to possible causes of the structural changes.

The inflation break points for Botswana and Mauritius are around the time when there was a change in the base of the consumer price index, particularly the weights used to calculate it. Between 2001 and 2002 Mauritius carried out a Household Budget Survey meant to change the base for the calculation of weights used in the inflation basket; thus the changes might have resulted in the structural shift due to inflation basket weight reallocation. The stock market structural change in Botswana coincides with a retreat in world stock markets in the post–September 11, 2001 USA tragedy.

In 2000 a new government was elected in Ghana which introduced a new monetary policy in line with the liberalisation of the economy. One of the major issues that the new government had to address was inflation, which was over 20% at the time; it made a commitment to reduce inflation to a target of 5% by 2008. In line with this projection was a series of monetary measures which included a systematic increase in interest rates through indirect means (Epstein and Heints, 2006), with a view to reducing inflation through reduced expenditure, increased savings and reduced asset prices. The presence of the break point more than two years after this policy confirms empirical evidence that interest rates do not affect inflation instantly but over time. The increase in interest rates as part of reforms in monetary and financial regulation meant stock prices had to systematically come down as investors opted for Bonds and related instruments, thus affecting the structure of the stock trend as well.

A new consumer price index was introduced in Kenya in 2003 based on the 1993/94 Urban Household Budget Survey (UHBS) with a Lasypers base of 1997. This could explain the existence of the structural break in the inflation figure. Moreover, as prior to this new inflation platform the Nairobi CPI was used as a measure of inflation, this development could have contributed to the shift in the inflation series as Kenya moved from the Nairobi CPI to a national CPI platform. In 1995, the Kenyan government also relaxed restrictions on foreign ownership of locally controlled firms when it announced its Budget in June. This meant that the aggregate limit for foreign ownership was increased to 40%, with single holding not exceeding 5%. In addition, the Exchange Control Act was repealed in December 1995, leading to an increase in the number of licensed stockbrokers. These developments within the financial sector, in particular the Nairobi Stock Exchange (NSE), could have led to the shift in the structure of the stock market.

The December 1996 break point for the Nigerian stock exchange might be attributed to the November 1996 launch of the browser's Internet System (CAPNET), which was to facilitate communication among stakeholders as part of service enhancement. On the inflation front, the food component in the consumer price index weights in Nigeria accounts for over 60%, making the country's inflation sensitive to fluctuations in food prices, particularly agricultural products. According to Okuneye (2001), the gains of the Structural Adjustment Programme in terms of reduction in food imports were lost as from 1995, when food importation took an upward turn. The jump in food importation of over 500% during the year meant a price shift associated with exchange fluctuations, hence the structural change.

In South Africa, the early 1990s heralded the end of apartheid as well as sanctions, leading to an inflow of foreign investment and the ability to purchase in competitive markets, which in turn changed the economic climate of the country. The installation of a new government brought new economic and monetary policy changes, thus possibly affecting the inflation rate movement. South Africa has been practising inflation targeting with direct controls since 2000, and the central bank uses monetary policy to police inflation in particular interest rates. Inflation was below the target in the early years of this policy, and thus a lowering of interest rates was used to induce expenditure at a time when low inflation became a worry for economic growth. The resultant systematic lowering of rates from over 12% in April 2003 to 6% in May 2005 subsequently meant a change in investment preferences to stock markets, which might explain the upward movement in stock return trend after the break point.

Figure 6.6 below shows the diagrams for each country indicating the break point in the annual inflation rate. For all the countries there was a downward shift in the annual inflation rate after the break, which might suggest African governments' efforts in arresting high inflation rate within the continent. Looking at the Botswana diagram, the annual inflation series was on a steady increase until around 1992, when it declined to below 10%, and thereafter it started fluctuating between 6% and 12% with spaced up peaks. A similar pattern exists for Kenya with a structural break visible around 1995. Apart from a peak around 1995, the Ghana annual inflation series does not show a visually convincing break point, and if methods that do not identify the break automatically were used it would be difficult to ascertain the proposed break point. Mauritius and Nigeria present visually convincing break points with small and widely spaced peaks preceding narrow high peaks after the breaks.

Figure 6.6: Diagrams showing the break point for the annual inflation rate

In the South African case, the regime after the break has high peaks with wide span in between them though after 2004 another new regime can be visually identified. As for the annual stock returns, the situation is different in that it would be difficult to confirm a break for Botswana, Ghana and Mauritius, while Kenya exhibits evidence of two break points for the stock returns.

In the Nigeria case, as shown in Figure 6.7, there are no spiky peaks before the break compared to after the break, with a steady increase noted in the earlier regime. While the movements in the South African annual stock returns series have peaks during the whole period, the break point is followed by a period of steady rise in annual returns which do not show signs of a deep fall.

Break Point diagrams for the annual stock market returns

Figure 6.7: Diagrams showing the break point for the annual stock returns

Table 6.25 shows the summary of the break points for both annual stock returns and the annual inflation rate. For Botswana there is not much difference between the break point in this table and that in Table 6.24, suggesting the break point could have been as noted in the above explanation. The breaks in South Africa and Nigeria for both the series are also close, with less than a year difference and, given that annual stock returns as well as annual inflation rate are time sensitive as they compare current and previous year figures, the explanation for a break point within a year time frame can be attributable to the justification offered above for Table 6.24.

	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
Inflation Series	Jan-05	Aug-97	Aug-94	Jun-06	Mar-96	Nov-92
Stock Series	Jul-02	Jan-05	Jan-95	Nov-02	Aug-97	Feb-04

Table 6.25: Break points for annual inflation and annual stock returns series

The same explanation can also be made for Ghana and Kenya stocks, whose break points are within a year of the points presented in Table 6.24. The annual inflation rate break for Mauritius provided above was induced by unprecedented increases in food inflation, which reached 3.9% for the month in July 2006, the highest in over five years. The increase in food inflation, which constitutes over 30% of the inflation basket, resulted in double figures for over a decade and stayed so for some months, hence the structural shift. For annual stock break points, only Mauritius provides a different break point for stock returns from what stock prices highlighted. This point could be attributed to the limitation of the approach used here, which requested only one break point, and this is thus identified by the Bai–Perron technique even when a break point does not exist or a regime switch might not have occurred.

6.2.6 Granger causality test

A Granger causality test before and after the noted breaks was then performed to establish the nature of the relationship between inflation and stock returns before and after breaks. Table 6.26 shows the causality relations between the consumer price index and stock prices for the whole period, before and after the break. The whole period causality results are for the whole sample period, while before the break represents the period from the start of the data to the first break, be it inflation or stock prices break point. After the break, Granger causality results are for the period from the last break to the end of the sample period. For cases where there is no Granger causality test statistic between the breaks in Table 6.26, the stock prices and inflation break points were within the same quarter, and thus no causality test was carried out, since the number of observations will compromise accuracy.

		Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
Whole Period	**St-Inf**	0.90	0.43	1.34	3.02**	1.83	1.13
	Inf-St	1.20	4.03*	2.32*	2.37**	5.06*	1.70
Before Break	**St-Inf**	0.21	1.38	0.78	1.43	3.07*	1.10
	Inf-St	6.08*	3.37*	1.48	1.13	0.96	2.87*
Between Breaks	**St-Inf**	0.93	75.12**	-	1.18	7.25	1.51
	Inf-St	3.58*	0.89	-	1.47	0.79	1.61
After Breaks	**St-Inf**	0.77	0.74	1.29	-	1.84**	0.48
	Inf-St	2.91	1.03	1.60**	-	2.61*	0.74

St and Inf represent stock prices and inflation respectively. A single asterisk denotes significance at the 5% level and a double asterisk is at the 10% level.

Table 6.26: Granger causality test results

The above results in Table 6.26 show that there is no causality relationship between stocks and inflation for the whole period in Botswana and South Africa. However, before the inflation break point, inflation Granger caused stock market changes in Botswana and South Africa, while no evidence of causality either way is noted between the two series after this break. This finding could point to the existence of a significant break point in the inflation series that affected the relationship entirely between the two variables, while the stock market break seem not to have changed causality relations.

The Ghana, Kenya and Nigeria cases show evidence of one way causality between inflation and stock markets over the period under consideration, with inflation Granger causing stock prices. In all the three cases, break points seem to have influenced the causality relations, pointing to the effect of structural breaks in the relationship between the two variables. While for Kenya there is one way causality for the whole period and after the inflation break point, the other two countries present different causality offerings before or after breaks. Ghana shows no Granger causality after the stock market break, while there is no evidence of inflation causing stock movements after the structural break in the inflation series. Interestingly, though, there is a shift in causality from inflation causing stock prices to vice versa after this break, and no causality either way after the stock market break. The Nigeria case is different in that stock prices Granger caused inflation before the inflation break point and a two-way causal relationship is found after the stock structural break. The results of the Mauritian causality tests are seemingly not reliable in that the test for the whole period shows a two-way causality, but no evidence of causality is found before the stock market structural break and between the break points. The inconsistency might be a product of the sensitivity of this method to lag length choice in that causality results are influenced by this choice, which is prone to inaccuracies reflected by the method used to arrive at the lag length.

The final part of this section will determine if the relationship between inflation and stock markets is any different before or after the noted break points, especially in countries where there was no evidence of a long–run relationship, using the Johansen technique. Table 6.27 presents cointegration results for Botswana, Ghana and Kenya, where the cointegration results in Table 6.20 showed no evidence that stock prices and inflation move together over time. Mauritius is the fourth country where the results in Table 6.20 rejected the existence of a cointegration relationship between inflation and stocks; however, before and after either the stock prices or inflation break point, no cointegration was found either. In Table 6.27, the results for Botswana show that there is at least one cointegration relationship between stock prices and inflation after the stock prices break point, and none before then. The relationship is negative with also a negative stock and inflation terms in the VECM, which suggests that both series have a tendency to revert back to long–term equilibrium in case of an error.

Country	r = 0	r ≤ 1	Cointegrating Vectors		VECM Coefficients	
			β	c	Stock	Inflation
Botswana	26.360*	0.305	-1.667 (0.087)*	1.247	-0.560 (0.170)*	-0.030 (0.035)*
Ghana	24.118*	0.013	0.239 (0.707)	-9.717	-0.065 (0.116)	-0.061 (0.030)*
Kenya	16.670*	2.961	2.134 (0.758)*	-16.670	-0.003 (0.005)	-0.004 (0.001)*
5% LOS	15.41	3.76				
Standard error in parentheses below coefficient estimates. A single asterisk denotes significance at the 5% level and a double asterisk 10% level of significance.						

Table 6.27: Cointegration results incorporating structural breaks

Ghana also has evidence of at least one cointegration relationship after the inflation break which could suggest that the new policies introduced by the post–2000 government resulted in the stock–inflation relations. The new monetary policies tackled inflation through indirect interest rate intervention and, since stock prices also react to interest rate movements, the new interest rates approach could have been the glue to the stock–inflation relationship. As for Kenya, the relationship confirmed in Table 6.27 is for the period before the inflation structural break. Since the regime shift coincided with the introduction of a new Kenya CPI, the results above suggest that the Nairobi CPI which was previously in use, had a long–run relationship with stock prices than stocks have with the new inflation regime.

6.2.7 Are stock–inflation relations state dependent?

In the above analysis, stock–inflation relations were established using the Engle-Granger two-step method, and the Johansen technique also confirmed this for South African and Nigeria. To establish if the impact of inflation on stock returns is state dependent, a series of conditional regressions are used in line with the approach adopted by Adam, McQueen and Wood (2004), who tested if the relationship varies across states of the economy using daily USA data. To determine the different economic states, Adam, McQueen and Wood (2004) used McQueen and Roley's (1993) state classification which compares actual levels of industrial production to a trend in industrial production. Thus high economic activity is represented by the top 25% (in terms of production) of the months and low economic activity the bottom 25%. The medium economic activity in this case equates to the 50% of the months which are between high and low economic activity. McQueen and Roley (1993), whose research looked at the effect of macroeconomic news on stocks, found that the response of stock market to economic news depends on the state of the economy. This conclusion is shared by Boyd, Jagannathan and Hu (2001) using a longer period. Adam, McQueen and Wood (2004) noted that fear of an overheating economy could result in stock market participants becoming particularly responsive to inflation news in good economic times. The effect of economic state is confirmed by Flannery and Protopapadakis (2002) as well as Barrett, Gosnell and Heuson (1997), whose research looked at the responses of Treasury security prices to macroeconomic news. Adam, McQueen and Wood (2004) concluded that stock–inflation relations are state dependent and that the strength of the relationship is stronger for large stock prices when the economy is strong and operating near capacity.

The problem with the McQueen and Roley (1993) approach, though, is that the high and low economic activities are period specific, and so might not necessarily reflect real economic growth capacity and recession. Moreover, given that agriculture plays an integral role in overall production in Africa, the seasonal tendencies of this sector will influence the industrial production levels. One way of addressing the seasonal effect of production will be to seasonally adjust the data. However, seasonally adjusting data results in data loss and could thus influence the results of this exercise. After all, with or without seasonal adjustment, if the raw data (non-adjusted data) indicates an effect of economic activity in the relationship, such results can still be used to infer state dependence.

To determine state dependence effect on stock–inflation relations, this section will use South Africa as a case study. The choice of South Africa in this case is driven by the availability of monthly industrial production data for that country, with only annual data available for the other African countries. The production data is from the International Monetary Fund and represents monthly industrial production levels. The use of one country to infer the effect of economic activity in the continent does not make the result representable. However, if annual data were to be used for the other countries, this would provide at most 20 data points, which is not enough to draw credible conclusions. The alternative solution to this annual data problem could be to subdivide the years into high, low and medium economic activity then consider all the months in the high economic activity and year as representative of same, despite monthly economic activity fluctuations. This approach would address the seasonality issue, but the importance of monthly economic activity fluctuations would render this approach too generalised to produce reliable results. In this regard, only the South African case will be examined here using the approach followed by Adam, McQueen and Wood (2004), who test for the coefficient stability across high and low economies in the following regression of stock prices on inflation. The equation below is used in the analysis:

$$R_t = \alpha_L L + \alpha_M M + \alpha_H H + \beta_L L\Pi_t + \beta_M M\Pi_t + \beta_H H\Pi_t + \varepsilon_t \qquad 6.2$$

where R is the stock market, Π is inflation, ε is the error term and t is time; while H, M and L represent high, medium and low economic activity respectively. H=1 reflects months when economic activity is high and H=0 otherwise, and similarly with L and M. The coefficients for the three economic activities are represented by α_L, α_M and α_H which form the constant for this regression. Table 6.28 below shows the β_L, β_M and β_H state-dependent coefficient results contained in Equation 6.2 with the p-value in parentheses.

	Base	**Low Economy**	**High Economy**
Observations	113	57	58
Beta Coefficients	0.713 (0.426)	-2.993 (0.023)	-1.992 (0.172)

Table 6.28: Coefficients and *p*-values for state dependence

The results show that the response of stock returns to inflation when the economy is weak is significantly negative and stronger than the response during a strong economy. A 1% positive movement of inflation in a weak economy results in a 2.99% decrease in stock returns, and this relationship is statistically significant at the 5% level. On the other hand, in a strong economy a 1% rise in the inflation rate would result in a 1.99% decrease in stock market returns. These findings are in line with that of Adam, McQueen and Wood (2004) who documented the decline of 'large stock' prices in both strong and weak economic activity when there is an unanticipated increase in the inflation rate. To determine if the response is statistically different between economic states, the Wald coefficient test is used with the hypothesis that $\beta_L = \beta_H$. The *p*-value for this test is 0.263; thus the response of stock prices to inflation movements in South Africa is not affected by the state of the economy.

6.2.8 The effect of unexpected inflation on stock–inflation relations

In this section we look at the nature of the relationship between stock market returns and unexpected inflation in Africa, and most importantly as part of a view to explore the implication of using month–end stock results when inflation is announced mid-month. To create the unexpected inflation series, the best forecasting series established earlier in Chapter 5 is used to infer inflation expectations. The advantage of using these results is that they offer realistic inflation expectations, since simple multivariate and univariate methods were used to derive the models. The models that were the best for one month out-of-sample forecasting are the only ones to be considered here, since inflation expectations for this exercise are for inflation which is announced fifteen days after the month end. The only disadvantage in using this approach is that it assumes that stock market stakeholders, in particular investors, forecast inflation homogeneously across the market which, is a lot to ask of a less sophisticated African market. In addition, the forecast period of one month might be too long, since new information within the month could render the forecast obsolete. Unlike most approaches that use other series like interest rates to infer inflation expectations, the models used here present realistic inflation expectations for each country under consideration. The following equation was used to derive the unexpected component of inflation:

$$U_t = \Pi_t - E_{t-1} \qquad 6.3$$

where U_t represents unexpected inflation, Π_t is the actual inflation rate, and E_{t-1} is the inflation expectations derived one period ago for the current period. Since the inflation forecasting model is good at determining the one month ahead expectations, the use of a lagged variable captures the current inflation expectations. The expected inflation in this case is thus arrived at by creating a fitted series from the forecast model. An alternative to using the out-of-sample forecast could have been to use the results from the in-sample forecasting, which are known to determine if the model is the best fit for the data. However, this alternative is not strong at determining future expected values, which is the expectation in this case.

To determine the relationship between unexpected inflation and stock market returns in Africa, a regression approach is used after determining if the series are stationary.

	Augmented Dickey Fuller		Phillips–Perron		KPSS
Country	**Constant**	**None**	**Constant**	**None**	**Constant**
Botswana	-10.77*	-10.65*	-10.79*	-10.66*	0.08**
Ghana	-3.61*	-3.62*	-7.42*	-7.45*	0.05**
Kenya	-7.15*	-7.15*	-10.92*	-10.93*	0.31**
Mauritius	-4.77*	-4.79*	-20.08*	-20.17*	0.34**
Nigeria	-1.57	-1.58	-8.13*	-8.15*	0.95
South Africa	-5.49*	-5.50*	-13.55*	-13.58*	0.34**

A single asterisk denotes significance at the 5% level and a double asterisk 10% level of significance.

Table 6.29: Unit root test results for unexpected inflation

The unit root test results for the unexpected inflation are presented in Table 6.29 below and, apart from the Nigeria test results, the rest exhibit stationarity. The ADF and the KPSS test for Nigeria show that the unexpected inflation series have a unit root, which is a worrying observation since the series is created from stationary series. Figure 6.8 below shows the plot of this serie,s and there is evidence of mean reversion over time.

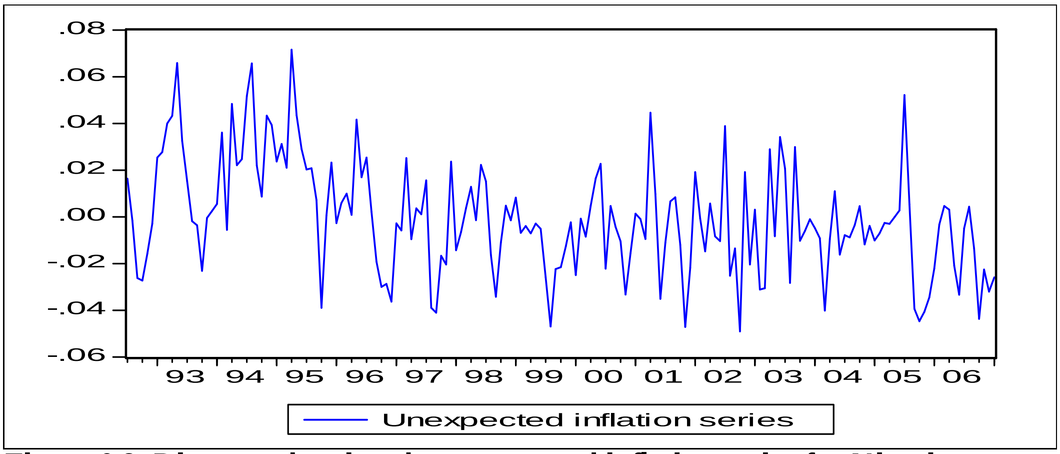

Figure 6.8: Diagram showing the unexpected inflation series for Nigeria

The series in this section is therefore considered as stationary, like the rest of the other unexpected inflation series.

Table 6.30 shows the regression results for the relationship between unexpected inflation and stock markets in Africa. On the basis of these results, unexpected inflation does not have a relationship with stock markets in Mauritius and South Africa, which would suggest that the stock market at the month end contains all the inflation expectations. On average, unexpected inflation accounts for 3% of stock market movements in Botswana, Ghana and Kenya. Positive and significant results are found in some African countries, which is a worrying finding in the face of inflation announcement dates and the use of month–end stock market figure in the ascertainment of the relationship between inflation and stocks.

Regression Analysis: $DS_t = c + \beta DU_t$						
	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
β	1.72 (0.87)**	0.89 (0.33)*	0.63 (0.26)*	-0.23 (0.66)	0.47 (0.20)*	-0.20 (0.85)
R^2	0.03	0.04	0.03	0.00	0.03	0.00
F-Statistic	3.88**	7.16*	5.95*	0.12	5.53*	0.06
DS and DU represent monthly stock returns and the unexpected inflation rate respectively. Standard errors in parentheses below coefficient estimates. A single asterisk denotes significance at the 5% level and a double asterisk at 10%.						

Table 6.30: Regression results for unexpected inflation and stock prices

The concern is rooted in the inference from the above relationship that at month-end stock markets still have not fully incorporated inflation, despite current research approaches assuming so.

6.3 Chapter summary

In this chapter the main objective has been to determine the nature of the relationship between stocks and inflation in the Sub-Saharan context. The journey towards this objective entailed subjecting stock market returns and inflation time series data to various tests with a view to determining the nature of stock–inflation relationships. Mindful of the prominence of the annual inflation rate, another approach involved the ascertainment of the relationship between annual inflation rate and monthly stock returns in a bid to establish if the prominence of the annual inflation has a bearing on stock market investor decision in the face of inflation figures. The final determination was to establish the nature of the relationship between annual stock returns and annual inflation rate. The long–run relationship in the latter case could only be determined if the two series were of the same order, and the evidence in most markets confirms this position. The unit root results for annual stock returns are puzzling, however, especially since that returns are supposed to be stationary except in markets that exhibit bubbles and structural breaks in the series. The existence of structural breaks in the data is confirmed in the later parts of this chapter, both visually and through the application of the Bai and Perron (1998; 2003a, b) technique, thus supporting the credibility of the unit root findings.

Cointegration has been used in this chapter to determine the long–run relationship between inflation and stocks, with the Engel–Granger 2–step model and the Johansen technique the basis of the analysis. Using the two–step–model, the evidence shows a positive long–run relationship between stock market prices and the monthly inflation rate for all the considered African countries. This is in line with the Fisher hypothesis and with the findings of Choudhry (2001) in similar high inflationary countries. However, for the annual stock returns and the annual inflation rate the relationship, where the coefficients are statistically significant, this is negative. To establish the short–run dynamics of these noted long–run relationships, the error correction model approach was used. This showed the tendency of the variables to bounce back into long–run equilibrium in the next period in the case of an error in the current period. This result is encouraging, as it supports the existence of a long–run relationship between stock returns and inflation.

The problem in using the Engle–Granger technique is that it lacks power in arriving at credible conclusions, and depends heavily on unit root test, thus placing the reliability of the results on the power of the unit root tests used. Moreover, this test checks the nature of the relationship for changes in the current values, ignoring the impact of lagged values of the variable, which could have an impact several periods later. The full capture of lagged values is contained in a vector autoregressive system, and the Johansen technique is useful in determining the nature of long–run dynamics in such a system. Using the Johansen method of cointegration, evidence of a long–run relationship was established in only Nigeria and South Africa, with the relationship surprisingly negative, thus contradicting the results from Engle–Granger analysis. This contradiction could be attributed to the composition of the techniques, especially that second step of the Engle–Granger method, which looks at the current values of the independent variable while the Johansen technique looks at the VAR system and lagged values. These findings are unique in that most research has shown a positive relationship when the Johansen method has been used to determine the nature of stock returns and inflation relationships. The evidence supports the empirical findings by Proxy hypothesis backers such as Geske and Roll (1983), Gultekin (1983), Vanderhoff and Vanderhoff (1986), Chang and Pinegar (1987), Kaul (1987, 1990), Lee (1992), and Lee and Ni (1996); and the following money illusion researchers: Summers (1983), Ritter and Warr (2002), Asness (2000, 2003), Campbell and Vuolteenaho (2004), and Feinman (2005). The vector error correction model (VECM) for South Africa and Nigeria exhibit worrying findings in that the inflation component is positive, reflecting the exaggeration of the error in the next period instead of a return to equilibrium.

To determine the response of stock returns to inflation innovations, the impulse response approach to time series analysis was used; this helped to ascertain the one standard deviation shock to one of the innovations on future and current values of the endogenous variable. The impulse responses in the first three years are statistically insignificant save for Nigeria, where a positive response in the first three years is observed. Towards the fifth year all countries exhibit a positive impulse response. For the annual stock returns and annual inflation rate relationship, there is evidence for a significant negative impulse response in the first six months in Botswana, and a positive impulse for Kenya and Nigeria. The impulse response results are consistent with the Engle–Granger results noted above, though this method uses a VAR system. The variance decomposition tools assisted in determining how much of the variations in the stock returns are explained by inflation innovations. After six months, over 5% of stock returns is explained by inflation innovations in Nigeria and Botswana, and the result by stock returns themselves. After five years, the variance decomposition results show that stock prices in Sub-Saharan Africa are explained between 6 and 77% by inflation innovations. The highest evidence of 77% is noted in Nigeria. The results for annual stock returns are lower for all countries, indicating that the annual inflation innovations explain less of annual stock return than monthly inflation explains monthly stock returns.

A relationship between two variables can be affected by the existence of structural breaks in the time series, which have a tendency to move the series out of equilibrium, thus affecting the long–run relationship analysis. In this chapter, only one break was sought using the technique by Bai and Perron (1998; 2003 a, b) which identifies a break in the series automatically. The identified breaks for the inflation series indicate the influence of economic policy on shifts in the series, and also the changes in the inflation basket. For Kenya, indications are that the inflation break was influenced by the change in the reporting of the inflation figures from the Nairobi consumer price index to a national price index that included evidence from other towns and the countryside. The stock price break is influenced by monetary policies, especially those relating to interest rates. Another observation is the existence of breaks around the time when the countries liberalised their economies, opening up their markets to foreign investors through the relaxation of either exchange controls or entry requirements. Another effect of these liberalisation policies was to increase the number of counters in the stock market through privatisation of large state–owned companies. Causality tests before and after structural breaks indicated that the nature of the relationship changed either side of the break points. For countries where there was no evidence of a long–run relationship using the Johansen method, the analysis either side of the break points showed support for a relationship, thus confirming the effect of structural breaks on the nature of stock returns and inflation rate relations.

Adam, McQueen and Wood (2004) showed that the nature of stock returns and inflation relations are affected by the state of the economy, be it recession or boom. To determine the effect of economic state, production figures were used to infer the state of the economy; however, there was no data in any of the countries except South Africa to carry out this exercise. The findings in South Africa show that the relationship between stock returns and inflation is negative when the economy is in either boom or recession. This evidence could be reflective of Fama's proxy hypothesis, which equates the nature of stock–inflation relations to the inferred relationship between the two variables and economic activity. Further analysis, however, fails to support the notion that the relationship between stock prices and inflation is dependent on that state of the economy, since the results are not statistically significant.

A worrying finding presented in this chapter is the statistically significant relationship between stock market returns and unexpected inflation in Botswana, Ghana, Kenya and Nigeria. This relationship implies that at month end the stock market prices might not have captured all information on the inflation rate. Since the inflation rate is not announced until after the 10th of each month in all countries, month–end figures are used on the understanding that by then stock market figures would have incorporated information about the rate of inflation. The existence of a relationship between unexpected inflation and stock market returns is an important indicator for the robustness challenges that are presented by the use of month–end inflation figures as if the announcement occurs at the end of the month. Evidence by Adam, McQueen and Wood (2004), which shows that stock market prices react to economic variable announcements and inflation in particular, indicates that results for the relationship between stock returns and inflation could be best reflected by the use of announcement date stock market prices instead of month–end data. Unfortunately, this issue was not addressed in this chapter owing to data availability constraints; thus it is an area for future research and could be the cog that reconciles the contradictions in the literature around the analysis of the stock–inflation relationships.

6.4 Conclusion

In summary, this chapter confirmed the existence of a relationship between stock returns and inflation in Africa. The nature of the relationship was confirmed as positive using the Engle–Granger 2–step method, but this was not supported by the Johansen cointegration technique, which found a negative relationship in South Africa, Nigeria and Botswana (after accounting for the existence of structural breaks). This inconsistency is rooted in the power of the methods used and the components of the variables considered by each technique. The effect of structural breaks in the relationship was also confirmed; this has the potential to affect the causality direction and therefore the nature of the relationship. Unexpected inflation is found to have a relationship with stock returns, and this raises questions about the use of month–end stock data. Since this relationship confirms that stock prices would not have captured all inflation expectations at month end, then expectations are that stock prices would move at announcement date or between month end and such announcement date. The direction of the movement will be influenced by whether the inflation rate is above or below the market expectations. Further research is required that looks at the long–run relationship using data at inflation announcement dates to increase the robustness of results that look at the relationship. The findings in this chapter also call for a set approach in ascertaining the nature of the relationship. Thus there is a need: to determine if the relationship is sought at the short or long term; to ascertain the existence of structural breaks in the data, particularly where a long–run relationship is not established; and to determine the existence of a relationship between unexpected inflation and stock returns with a view to confirming the robustness of the results.

CHAPTER SEVEN

THE IMPACT OF INFLATION ON STOCK PRICES IN SUB-SAHARAN AFRICA: A NONPARAMETRIC APPROACH

7.0 Introduction

The previous chapter looked at the relationship between inflation and stock returns on the assumption that the underlying dynamics of these series are in linear form or could easily be transformed to a linear form. The methods used in the chapter were based on the error correction mechanism following a linear path, with assumptions that the speed of adjustment is constant, thus meaning that reversion is detected through linear models. The problem with this view, however, is that it assumes that all levels of inflation shock will generally trigger a similar stock market response and therefore low or high inflation results in either a good or bad response, depending on the calculated generalised overall reaction for all data. This assumption of the linear paradigm is reflective of the utopian data analysis approach and the over–generalisation of variable relations which led to bitter rivalry between Fisher and Pearson in the 1920s. The evidence of structural breaks noted in the last chapter brings to the fore the questions about the use of orthodox linear models in inflation–stock relations in Africa, particularly with regime–switch indications. Though Fisher's linear paradigm, which has been transformed in recent years, continues to be used as a yardstick to variable relationship, analysis it is now inconsistent with empirical evidence that has shown cases of nonlinearity, especially between stocks and economic variables (McMillan, 2001b; Maghyereh, 2006). Given these concerns, that question the robustness of earlier results, this chapter explores the existence of a nonlinear relationship between inflation and stocks despite the poor efficiency assertions made by Fisher about this approach (Hardle, 1990). The expectations from the chapter are the appreciation of the reaction of stocks to different levels of inflation, thus rejecting or confirming a uniform response of the former to the movements of the latter. In addition, the chapter explores the long–run relationship between the two variables using a nonparametric technique, since the Johansen cointegration method is considered insufficient in detecting long–term relations in nonlinear cases, as it presents a misspecification problem when the true nature of the adjustment process is nonlinear and the speed of adjustment varies with the magnitude of the disequilibrium (Coakley and Fuertes, 2001).

The arguments concerning nonlinearity started with evidence of business circle asymmetries (Mitchell, 1927; Keynes, 1936; Blatt, 1980), with Neftci (1984) noting that such evidence in macroeconomics data is incompatible with linear, VAR–type data generation. Keynes (1936) in particular noted that the substitution of a downward for an upward tendency often takes place suddenly and violently, whereas there is no such sharp point when an upward is substituted for a downward tendency (Hicks, 1950; Neftci, 1984). This observation therefore calls for the separation of data to reflect different regimes, particularly if such data spans many regimes. If not separated, the effect of structural changes and regime transformation could compromise the accuracy and reliability of linear estimates. According to Neftci (1984), the question here is whether these asymmetric drops or rises invariable movements occur systematically enough to be counted as part of the probabilistic structure of the economic time series. If it is not accounted for, then the reliability of the results will be compromised unless techniques that generate asymmetric behaviour endogenously are used.

The existence of business cycles which confirmed the nonlinearity paradigm in econometric analysis then triggered a new dimension in time series research, which shifted to testing for nonlinearity (Hinich, 1982; Brock *et al*., 1987) to determine a pattern of dependence not characteristic of linear models. Brock *et al*.'s (1987) paper presented a test of dependence that can be applied to the estimated residuals of any time series model that can be transformed into a model driven by independent and identically distributed errors. This method, which can be viewed as a nonlinear analogy of the Box–Pierce Q-statistic used in the ARIMA analysis, can thus be used as a model selection tool as well as a specification test (Brock *et al*., 1987). Further support for this new dimension to time series research is noted by Hamilton (1989), who states that a variety of parameterizations for characterising nonlinear dynamics have been proposed, which produce evidence that departs from linearity as an important feature of many key macroeconomic series. In his study, which approached nonlinearity by using Goldfield and Quandt's (1973) Markov switching regression to characterise changes in the parameter of an autoregressive process, Hamilton noted the following studies which established nonlinearity: bispectral analysis of Hinich and Patterson (1985); Sichel's (1987) documentation of business cycle asymmetries; the ARCH-M model of Engle, Lilien and Robins (1987); Stock's (1987b) trim transformation; Gallant and Tauchen's (1987) semi–nonparametric approach to modelling dynamics; Quah's (1987) 'clinging' process; and Chaos models by Brocks and Sayers(1988). Testing for nonlinearity of macroeconomic data also meant there was need to develop estimation models that will be used with the data found to be nonlinear. Thus the Markov switching model (Hamilton, 1989), threshold autoregressive models (Tong, 1990), the Hansen and Seo (2002) threshold error correction model and related models were developed.

In this chapter, however, none of the above nonlinear approaches and tests will be considered. This decision is not a reflection of confidence or lack of it in these approaches, but is purely related to the availability of technical software to determine nonlinearity. To determine nonlinearity, the Nadaraya–Watson nonparametric kernel regression is used with innovations by Epanechnikov considered for this approach; this will be outlined in detail in the next section. As for the long–run relationship between inflation and stocks, the chapter uses a nonparametric cointegration technique by Beirens (1997) to ascertain nonlinear interaction. According to Abhyankar *et al*. (1997), until recently movements in stocks were taken to be stochastic, if not actually a random walk, and this assertion was unchallengeable because of the consistency with the efficient market paradigm. However, there is now broad consensus for the proposition that the return process is characterised by a pattern of nonlinear dependence. As for the relationship between inflation and stocks, this has been found to be nonlinear, theoretically (Boyd *et al*., 1996) and empirically (Barnes *et al*., 1999; Boyd *et al*., 2001; Liu *et al*., 2004; Maghyereh, 2006). Maghyereh (2006) noted that the rationale for nonlinearity is due to the existence of market frictions and transaction costs, which may prevent agents from adjusting continuously, leading to discrete adjustment processes and thereby mean–reversing the relationship. This chapter will therefore seek to ascertain the existence of nonlinearity in inflation–stock relations and to see if results from this approach will be different from the evidence contained in Chapter 6.

The chapter is organised as follows: Section 7.1 looks at data and kernel regression results while Section 7.2 considers the nonparametric cointegration results before Section 7.3 presents the conclusions of the chapter with recommendations for future research as well as investor strategies.

7.1 Data and empirical results

The empirical plot results for each country are presented here after conducting a series of nonparametric regressions in line with the Kernel specifications detailed above. The results have been subdivided into two subsections, one detailing the relationship between levels of monthly inflation and monthly stock returns. The analysis of this relationship is important to short–term investors and speculators who wish to make gains based on short time-frame movements. The other subsection looks at levels of year–to–year inflation, comparing these with annual stock returns. The year–to–year inflation considers the changes in the inflation index this year compared to last year as a percentage and is the rate of inflation mostly quoted by economists and policymakers. To ensure this rate analysis measures up to a comparable in stocks, the annual stock returns are considered here. The use of annual returns in this analysis shifts the interest of the findings from an ordinary stock investors to medium– to long–term investors whose investment strategies are rooted in the long–term benefits of chosen investment vehicles.

7.1.1 Monthly inflation and stock returns

Figure 7.1 shows the different country stock responses to inflation; none of the plots indicate any form of linearity in the relationship between inflation and stock levels. In fact, there seems to be evidence that the relationship between stocks and inflation depends on the level of inflation; thus the range of inflation levels could support limited linear reaction. The empirical evidence from the Botswana data shows a U-shaped interaction between inflation and stock levels and, apart from the outlier to the right of the diagram, higher monthly inflation figures are met with high stock returns. There is a horizontal regime around the mean inflation rate of 0.66%, with levels below this figure relating better with higher monthly stock returns than with the mean rate.

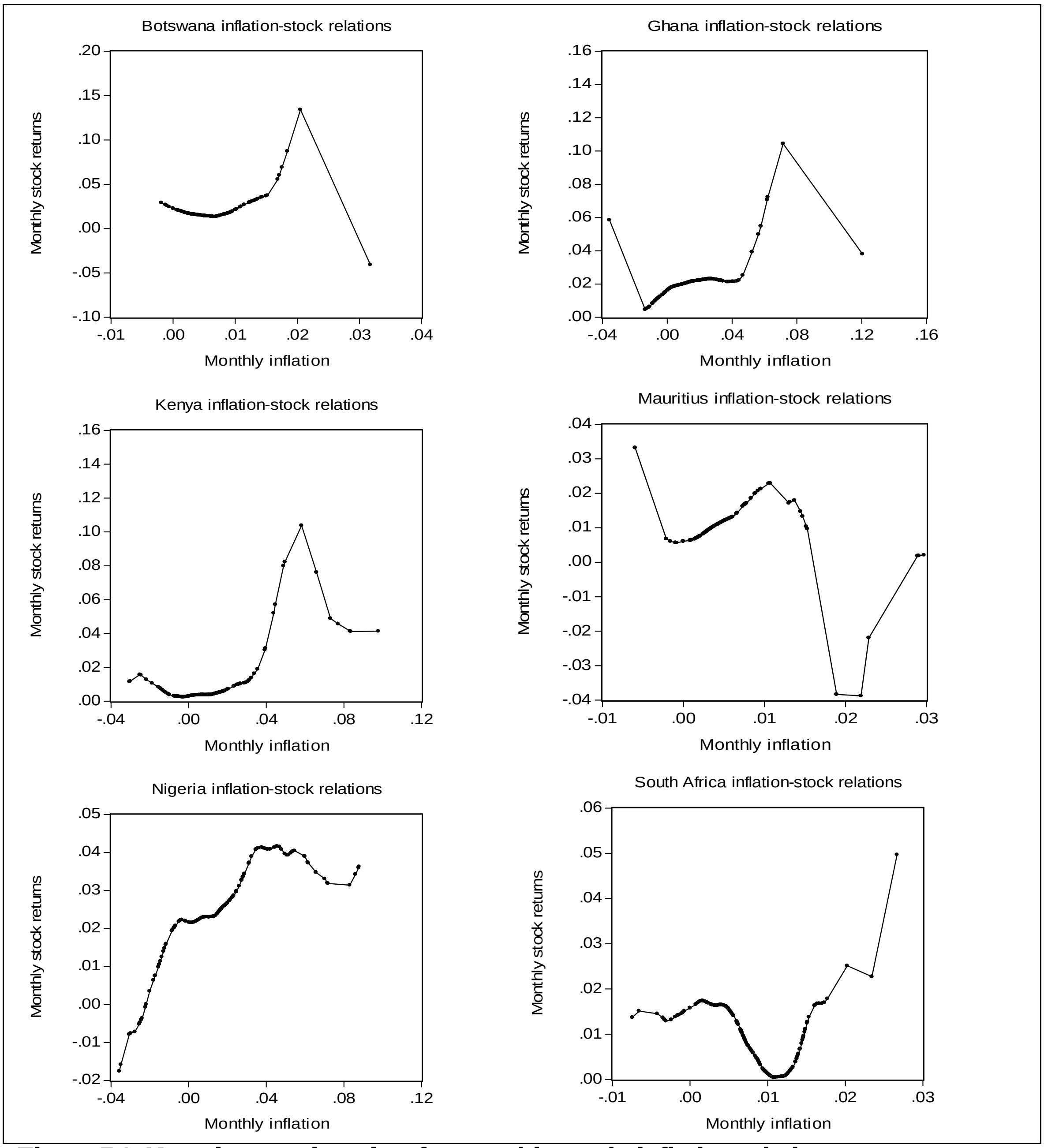

Figure 7.1: Kernel regression plots for monthly stock–inflation relations

The case of Ghana is similar to that of Botswana when one looks at higher monthly inflation levels; however, below the mean and into negative inflation, monthly stock returns approach negative levels. Around the mean inflation rate in Ghana there is a horizontal regime but no sharp increase thereof until inflation rate levels are beyond 4%. The horizontal regime around the mean inflation also occurs when one looks at the evidence from all the other countries except Mauritius, where such regime occurs below this statistic. Despite the resemblance in the evidence from other countries, there are some differences in the experiences before and after the mean inflation levels. Firstly, the Kenya experience has some semblance to the Botswana case immediately before and after the mean inflation rate, but at inflation levels beyond 6% the stock return levels start to drop until around the 8% inflation rate, after which a horizontal regime is re-established. Also, below negative 3% the return which had been increasing below the mean inflation rate begins to fall. The Kenya evidence may suggest that the same could have happened with the Botswana relationship had the data recorded larger negative values.

Secondly, the Mauritius empirical evidence, which exhibits mixed results before and after inflation mean level when compared with the above cases, has a more complex structure, with many inflation range levels attracting conflicting stock return regimes. Below the mean, the returns drop slightly before they attract a horizontal regime, then a rise in stock return levels below negative inflation rates. Also, above the 1% inflation level there is a drop in stock returns into negative values, but this is corrected after the 2% inflation rate level, where a positive slope regime is noted, underlying the complex nature of the relationship. While the initial drop before 2% could highlight market uneasiness with increased inflation rate beyond the 0.49% mean rate, the reaction above 2% cannot confirm this conclusion. However, the market could feel the increased inflation beyond this level, is unsustainable and thus expectations of a fall in the inflation level since this level is far from the norm/mean. The expectations of a fall in inflation then attract higher returns, since stock return levels close to the inflation mean are higher than what obtains around 2%. Another similar reaction after the mean is found in the Nigeria case which, however, has a horizontal regime around the mean. Negative inflation levels are met with negative stock returns in this case, and before the 4% inflation level. One could conclude that there is a generally positive relationship between stock and inflation levels which is momentarily lost between the 4% and 8% inflation levels. The South Africa case reveals another complex inflation range regime, with conflicting stock level reactions, starting with a local return climax around the mean inflation level. Immediately before and after both sides of this horizontal mean inflation level regime there is generally a drop in stock return levels and, similar to both the Nigeria and Mauritius cases, the drop lasts for a while before a rise in returns.

The analysis provided above is a detailed graph specification which ensures maximum use of the space provided within the diagram frame, and might in some cases exaggerate small changes whose overall impact on the trend is insignificant. Unfortunately, the diagrams contained in Figure 7.1 could not be drawn to a similar scale owing to the different inflation ranges and levels in each country; therefore the actual general movement contained here is specific to each country. Figure 7.2 below presents the same diagrams, but this time the stock return levels have been standardised for all the diagrams in a bid to ascertain a more general implication of inflation levels to stock return in the considered countries. Again, this approach has its own disadvantages in that it assumes homogeneity in the acceptance of different return levels; also, the countries with fewer return jumps will be disadvantaged in the analysis. Despite these concerns, the diagrams provide an interesting dimension to the analysis. If the odd out of line changes are ignored, the diagrams for South Africa and Nigeria show a positive linear interaction between inflation and stock levels.

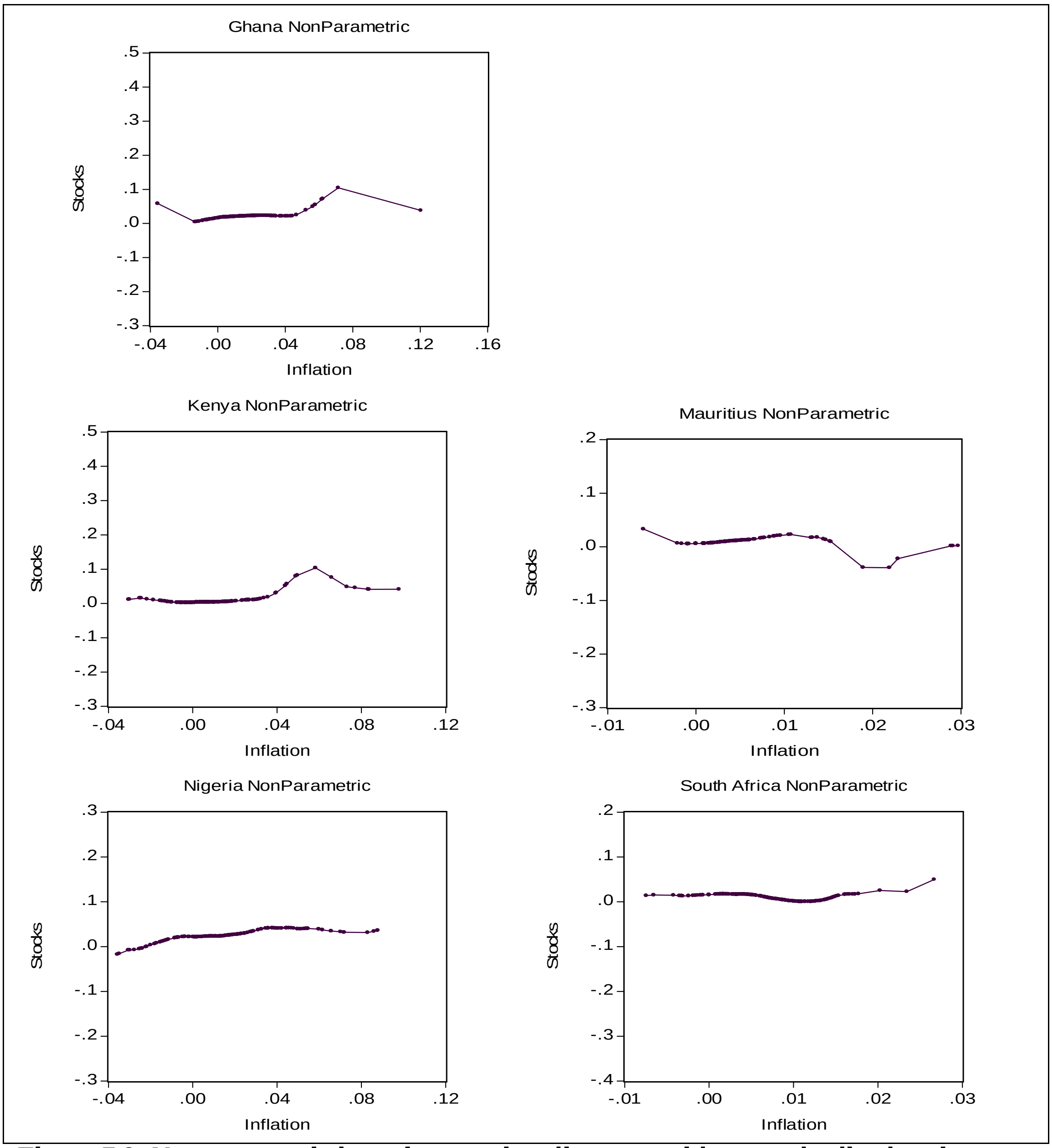

Figure 7.2: Nonparametric kernel regression diagrams with a standardised scale

This finding could explain why there was confirmation of a linear long–run relationship in the previous chapter. The diagrams for the other four countries are not too dissimilar to what obtains in Figure 7.1 and the explanations thereof.

7.1.2 Year–to–year inflation and annual stock returns

This section looks at the annual inflation–stock relations, with Figure 7.3 presenting the results of the Kernel regression based on the Nadaraya–Watson specification, with the optimal kernel based on the Epanechnikov (1969) kernel described in the methodology chapter. The results show different annual stock return responses to levels of the inflation rate. Apart from the Nigerian and Kenya cases, there is no evidence from these results that assists an analysis of how annual stock returns would react to negative year–to–year inflation rate. Despite this, further inferences can be drawn from the South Africa and Ghana diagrams.

An inflation rate over 11% in Botswana attracts higher annual stock returns, but the rate of increase slows down beyond the 13% annual inflation rate. Concerns about stock return being a hedge against inflation or getting positive real annual stock returns may therefore start to worry investors as inflation approaches the hyper stage. Between 5% and 11% inflation rate levels, there is no consistent evidence as to which levels stock return would reach. Mauritius follows a slightly similar trend to that obtaining with Botswana, because levels of inflation beyond 7% are met with higher annual stock returns, but the increase in the returns slow beyond the 11% inflation level. A horizontal regime is attained around the 5.8% mean inflation rate, and this attracts a positive 10% annual stock return in the Mauritius case. Beyond this mean annual inflation rate and between the 7% and 8% inflation rates, the levels of stock return fall to a negative, possibly demonstrating the lack of confidence in the market beyond an industry–accepted inflation mean as explained earlier.

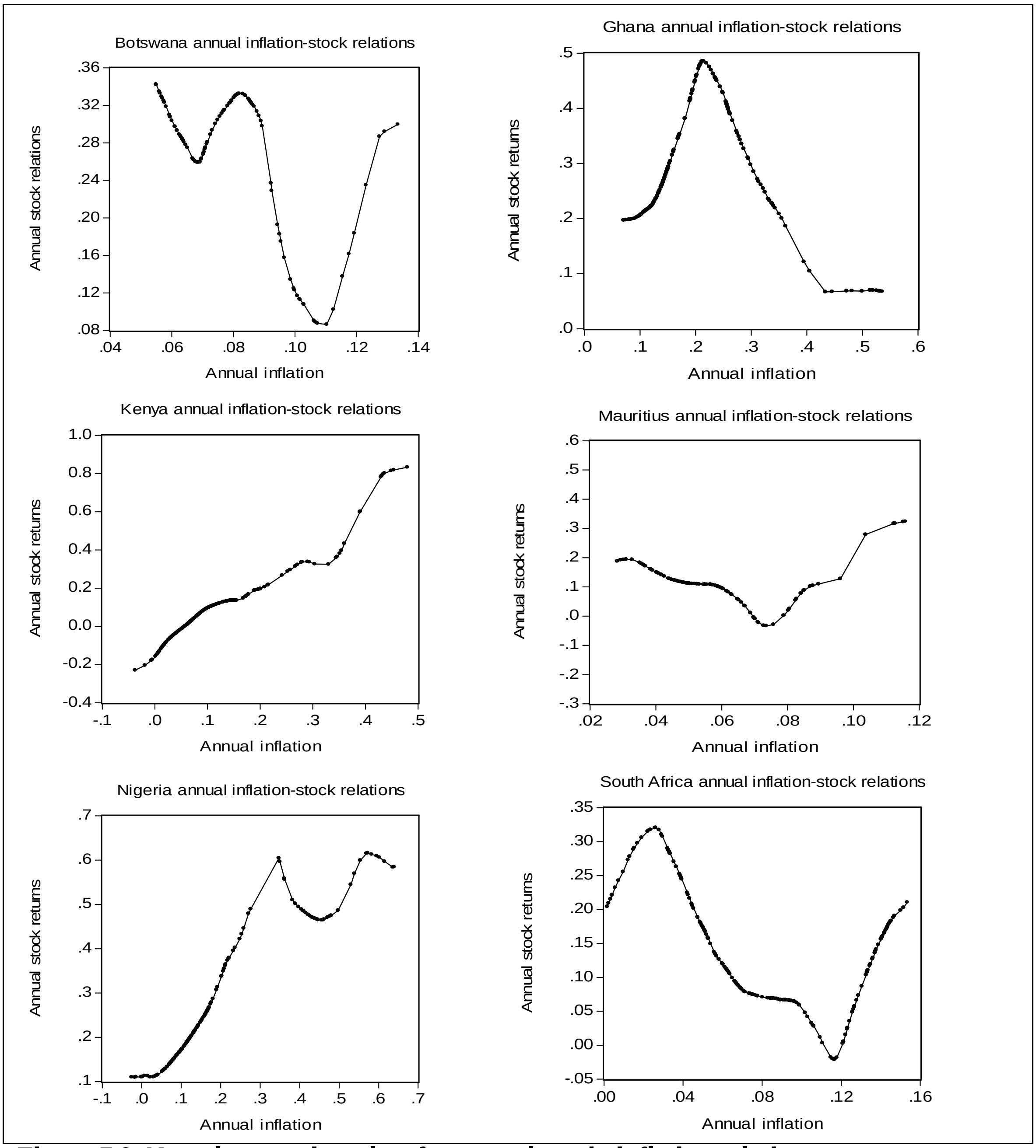

Figure 7.3: Kernel regression plots for annual stock–inflation relations

This evidence is also reflected in the Botswana results, where inflation levels beyond the mean annual inflation of 8% attracted a sharp fall in annual stock return, which fall reached a near zero return. The Ghana evidence presents a headache for long–term investors when inflation goes beyond a 45% level. This concern is rooted in the confirmation that, on average, inflation beyond the mean level of 20% attracts decreased annual stock return levels, and after 45% content returns are attained in the face of high inflation rates. This observation points to the earlier submission on eroded real stock returns, but in this case there is more certainty that negative annual stock returns obtain in Ghana when inflation reaches and stays at hyper levels. Interestingly, though, the above mean annual stock returns of 28% in Ghana are reached when inflation levels are as high as between 15% and 25%, which range is at the foot of the hyper inflation level and indicates a 3–13% real stock return. The South Africa case presents evidence similar to that of Mauritius and Botswana save for the lower level inflation, which in this case attracts lower stock returns. Below a 2% inflation rate there is evidence that the annual stock returns in South Africa begin to fall. Similarities, with that of Botswana, are the horizontal regime around the mean annual inflation, which is 8% for South Africa. Beyond this level there is a sharp fall in stock returns to negative returns at 11.5–12% annual inflation levels.

The Kenya inflation–stock return level relations are more linear than the rest, with mean level inflation rate attracting a horizontal regime beyond which high levels of inflation draw high annual stock returns. Another horizontal regime obtains at the foot of hyper inflation between 25% and 35% inflation levels and, unlike the Ghana case, when inflation is hyper higher levels of annual stock returns are experienced in Kenya. When the inflation level is below 5% in Kenya it becomes more likely that annual stock return levels will be negative. The final case to be reviewed here is Nigeria, where a mean annual inflation rate of 21% does not attract a horizontal annual stock return regime. Inflation below a 5% level results in stock returns that approach the zero level. When the inflation level reaches hyper stage, there is a sharp turn and fall in stock return level response but this creates a U-shape between 35% and 55% inflation levels, after which increased hyper inflation results in decreased annual stock return levels.

The above evidence dismisses any notion that there is a linear relationship between the annual inflation rate and stock returns, since levels of inflation are met with inconsistent levels of stock returns. In fact, an increase or decrease in the inflation level does not result in a consistent response in stock returns, but stock return reactions are sensitive to particular country–specific inflation levels or ranges and could therefore signify some form of threshold effect and, indeed, nonlinearity in the relationships.

7.2 Nonparametric cointegration results

Now that the Kernel regressions have confirmed the existence of nonlinearity in stock–inflation relations, the next step is to determine if this is in the long run. This subsection therefore presents the results of the nonparametric following the Bierens (1997) technique. The Bierens method, which was described in detail in the methodology chapter, is ideal for detecting cointegration in nonlinear variables. Having confirmed a long–run relationship between stocks and inflation in the case of South Africa and Nigeria using Johansen's cointegration method, this subsection pays particular interest to the results in countries where such linear long–run interaction was rejected. All the countries will be considered here for the nonparametric tests, even where the Johansen technique confirmed cointegration.

The subsection considers three sets of series in the analysis: first, the data for the whole of the sample period; second, the series before the first structural break; and third, the series after the last break. The first break point is determined by the series which had the first structural break between stocks and inflation, while the last considers the other break point. The main problem with using these two set of series is that the number of observations become so low that carrying out cointegration analysis compromises the robustness of the results. However, since there are no guidelines relating to what constitutes long enough a series to perform cointegration, the classical 30 minimum observation will be applied for the nonparametric cointegration. These subsets, however, omit the data between the two break points because of limited observations to carry meaningful analysis in most countries. The rationale behind taking two subsets before and after the breaks is rooted in the belief that a regime change could have been the result of some underlying influences which had discouraged or discourages the confirmation of a long–run relationship before or after the break respectively.

For the whole dataset, the Bierens approach employs two statistics to determine cointegrating rank r, which were defined earlier in the methodology chapter: the $\lambda_{\min}$ and $g_m(r_0)$. Table 7.1 below presents the results. The Null hypothesis for $r = 0$ is rejected in Botswana, Ghana and Mauritius on the strength of the $\lambda_{\min}$ statistic values. The $\lambda_{\min}$ statistic is, however, not able to reject the Null hypothesis for $r = 0$ in the analysis of the relationship in South Africa, Nigeria and Kenya. These results indicate that there is at most one cointegrating vector between stock prices and inflation where $r = 0$ was rejected. The empirical evidence from Ghana, however, is at the 10% level, while Botswana and Mauritius statistics are significant at the 5% level. The $g_m(r_0)$ column further confirms these results with the highlighted figures, which are the smallest within the three figure columns, indicating the cointegrating ranks $r_0 = 0,1,2$. Where there is at most one cointegrating rank, the highlighted figure corresponds to $r_0 = 1$ and this obtains even in the Ghana case where the $g_m(r_0)$ statistic was significant at the 10% level.

Country	**λ_{min} r = 0 / r = 1 r = 1 / r = 2**	**$g_m(r_0)$ r_0 = 0, 1, 2**	**β'**	**H_O: β' = (1 - 1) λ_{max}**
Botswana	0.00003* 0.58331	3.10E+05 **1.676E-01** 1.01E+03	(1 0.079)	3.19**
Ghana	0.00259** 0.15760	2.45E+03 **6.19E+02** 5.78E+05	(1 0.275)	34.15
Kenya	0.09570 0.63442	**1.24E+01** 8.32E+03 1.39E+08		
Mauritius	0.00005* 0.34857	1.84E+11 **7.89E-07** 1.70E-03	(1 0.010)	2.24*
Nigeria	1.28099 1.08528	**3.87E+01** 7.59E+02 3.09E+07		
South Africa	0.01382 0.33298	**4.06E+02** 1.27E+03 8.03E+06		
A single asterisk (*) denotes significance at the 5% level and a double (**) is at the 10% level.				

Table 7.1: Bierens nonparametric cointegration test results for the whole sample

Interestingly, the Johansen method had rejected cointegrating rank in the three counties where the Bierens technique has confirmed the existence of long–run stock–inflation relations. These findings are contrary to current literature views, which indicate that the Bierens method complements Johansen's technique by establishing nonparametric cointegration in nonlinear combinations rather than conflicting with it. Bierens' (1997a), who used a linear Error

Correction Model when carrying out Monte Carlo simulations, showed similar results from both methods (Coakley and Fuertes, 2001) and these were further confirmed by Kanas (1998). These results are not unique, however, to this research because Coakley and Fuertes (2001) also report a discrepancy between the findings from the Bierens and Johansen cointegrating techniques. They attribute these conflicting results to the misspecification problem in the standard linear cointegrating framework which are unable to detect linearity when the adjustment process is nonlinear and the adjustment speed varies with the magnitude of the disequilibrium.

The $\lambda_{\max}$ statistic, whose values are in the last column of Table 7.1, help to ascertain if the cointegrating vector $\beta' = (1 - 1)$ could be rejected or not through imposing a rank of 1 and testing the resultant linear restriction. The trace test results show that the linear restrictions in the cointegrating system were able to reject the Null hypothesis at the 5% level for Mauritius and at 10% for Botswana, implying that the $\beta' = (1 - 1)$ cointegrating vector is a vector that can span the cointegrating space (Davradakis, 2005). The null cannot be rejected in the Ghana case at both 5% and 10% significance levels; thus there is no evidence of a long-run nonlinear relationship between stocks and inflation in this case.

Table 7.2 shows the results for the data series before any of the breaks. The results are interesting especially those confirming nonparametric contegration on this segment in all countries considered except Ghana. The Nigeria lambda-min statistic is significant at the 10% level, while for Botswana, Kenya, Mauritius and South Africa it is significant at the 5% level. Again, $g_m(r_0)$ confirms these findings, with the lowest figure corresponding to $r_0 = 1$.

Country	λ_{min} **r = 0 / r = 1** **r = 1 / r = 2**	**$g_m(r_0)$** **r_0 = 0, 1, 2**	$\beta^{/}$	H_O: $\beta^{/}$ = (1 -1) λ_{max}
Botswana	0.00008* 2.13577	1.19E+07 **2.24E-04**	(1 0.0310)	6.15
Ghana	1.08889 1.55116	1.23E+01 **7.06E-01** 1.29E+04 6.80E+08		
Kenya	0.01069* 0.97202	3.52E+02 **7.51E+00** 1.77E+04	(1 -0.0960)	9.25
Mauritius	0.00005 0.0774*	1.07E+07 **8.11E-02** 2.52E+00	(1 -0.0554)	4.70
Nigeria	0.02039** 0.60313	7.84E+05 **8.76E-03** 7.97E+00	(1 0.0261)	5.01
South Africa	0.00000* 0.42024	5.60E+08 **5.54E-05** 5.36E-02	(1 0.0537)	2.89
A single asterisk (*) denotes significance at the 5% level and a double (**) at the 10% level.				

Table 7.2: Bierens nonparametric cointegration test for the sample before the breaks

These findings imply that stocks and inflation had a nonparametric long run relationship before the break points. The only problem with these results, as indicated above, is the lack of robustness given the number of observations considered. Table 7.3 shows the number of observations for each country using the break points presented in the previous chapter.

	Botswana	**Ghana**	**Kenya**	**Mauritius**	**Nigeria**	**South Africa**
Whole sample	134	195	205	134	187	240
Before 1st break	76	149	51	73	51	87
After 2nd break	24	30	34	27	122	30

Table 7.3: The number of observations for each country

Kenya and Nigeria, with 51 observations for the period before the break, are the main concern, but so are Mauritius, Botswana and South Africa with fewer than 100 observations. Bierens proved anything above 100 to be adequate for this test when he made simulations, and thus confirmed that the lambda-min test might exhibit a low power for small samples compared to Johansen's lambda-max test (Davradakis, 2004). This explanation falls short, however, when the Ghana evidence is considered, especially since the observations here are above 100 and constitute the majority of the whole sample period which found a nonlinear long-run relationship.

For the sample period after the break, only two cases are considered whose data series have more than 30 observations, in line with the classic acceptable number of observations. There is confirmation of a long–run relationship between stocks and inflation in Kenya, while the Nigerian experience shows no evidence of nonparametric cointegration. Lambda-max also shows that after the last break in Kenya there is evidence of a nonlinear interaction between the variables.

Bierens nonparametric cointegration test for the sample after the breaks				
Country	λ_{min} **r = 0 / r = 1** **r = 1 / r = 2**	**$g_m(r_0)$** **r_0 = 0, 1, 2**	$\beta^{/}$	H_O: $\beta^{/}$ = (1 - 1) λ_{max}
Kenya	0.01322* 0.07498	3.88E+09 **5.00E-05** 3.06E-04	(1 0.4918)	1.08
Nigeria	0.01585 1.48133	**1.39E+03** 4.79E+00 1.54E+05	(1 0.0042)	12.07
A single asterisk (*) denotes significance at the 5% level and a double (**) at the 10% level.				

Table 7.4: Bierens nonparametric cointegration test for the sample after the breaks

The number of observations in the Kenya case could explain the distortions between the findings in Tables 7.1, 7.2 and 7.4, especially since the rest of the observations were left out in the last two analyses. Moreover, the distortion could be explained by Hubrich, Lutkepohl and Saikkonen (2001), whose review of cointegration tests found the Bierens test to have little power in typical sample sizes (Cushman, 2003).

7.3 Conclusions

The main objective in this chapter was to ascertain if the relationship between stocks and inflation is nonlinear, in a bid to determine the robustness of the findings of the last chapter. The inability of the Johansen technique to confirm a long–run relationship in most countries except South Africa and Nigeria prompts investigation into the nature of the data–generating processes of the variables in these countries. This investigation is based on the fact that the Johansen method, which promotes the linear paradigm, has been proved not to produce credible results where the data–generating process of variables involved is nonlinear. In this context, the first part of the empirical analysis sought to establish the linearity of the stock–inflation relationship through the Kernel regression procedure and using the Nadaraya–Watson approach. The findings from this process confirm nonlinearity in the four countries where the Johansen methodology failed to establish a long–run relationship between stocks and inflation.

The Nigeria and South Africa cases, which had favourable linear cointegrating results, looked nonlinear when the initial nonparametric analysis was carried out, but failed to produce conclusive evidence when the robustness of the findings was put to test; thus they cannot be considered nonlinear with confidence. While the linear outcomes provide consistent results in the interaction of the variables, the Kernel process offered interesting observations on the nature of the reaction between the variables. In particular, there is a horizontal regime around the mean inflation rate; thus stock return levels just before or after such statistics tend to be constant. This finding implies market homogeneity in return expectation and achievement on a particular range of inflation levels, which undermines the contribution of other factors to stock movements unless one assumes that these factors affect both variables simultaneously. The other finding of note is the conflicting reaction of month–to–month and year–to–year, especially beyond the inflation mean value. For the month-to-month cases, stock returns tend to increase just after the horizontal mean regime, while it decreases in the year–to–year case. The rationale for this is that increases in monthly inflation prompt a reactive central government intervention through a decrease in interest rates, which in turn results in short-term investors dropping a bond investment strategy for one dominated by stocks. On the other hand, annual stock returns are driven by long–term government strategies rather than reactive policies, and the fact that one month's returns are compared to the previous year's suggests a staged reaction to policy changes. The above submission is further supported by the evidence that further increases in year–on–year inflation levels towards maximum figures attract high annual stock returns. Deflation results in low stock returns in general, with two countries showing increased returns. The contradiction is caused by the lack of more negative data to provide a more conclusive interpretation, but where the figures are negative the above interpretation involving stocks, interest rates and inflation could justify the levels of return. It is not surprising, though, that deflation occurred in Botswana and Mauritius, where government policies tend to be more proactive; thus their reaction to negative inflation is to look at broader long–term inflation strategies thereby ignoring a quick–fix short–term strategy.

Establishing nonlinearity in stock–inflation relations implies that the use of the Johansen technique in determining long–run dynamics would not produce reliable findings; thus an appropriate nonparametric cointegration was used. Evidence in Botswana, Ghana and Mauritius confirmed nonparametric cointegration. Interestingly, the results from the linear cointegrating methodology had failed to substantiate the long–run stock–inflation relations. Furthermore, there is confirmation that the Botswana and Ghana stock–inflation long–run relations over this sample period are, in fact, nonlinear, which result complements the submission from the Kernel regressions. The rationale to these findings and the existence of a nonlinear relationship is rooted in the presence of market friction and transaction costs (Davradakis, 2004; Maghyereh, 2006).

However, these findings failed to back-up Bierens' (1997) Monte Carlo simulation findings that his technique does not replace the Johansen method but complements it where nonlinearity is established, because no nonparametric long–run relationship could be supported in South Africa and Nigeria. These are the two countries where the linear cointegration had found real stock return adjustments, as noted in the previous chapter. This contradiction is not new; recent research has also reflected these results and attributed them to low power challenges of Bierens' technique, especially where there is a small sample size.

To determine the sensitivity of stock–inflation relations to break point and regime changes within the nonparametric framework, the data was subdivided, with tests carried out before the first break and after the second break. A long–run relationship could not be confirmed in only one country when data before the break was taken into consideration. Given earlier conclusions, these results provide a new dimension in the analysis in that the linearity of the data is limited to the full sample period, and segmenting this presents pockets of nonlinearity which could be determined by the fundamental variable drivers. Though the robustness of these results can be challenged, given the sample size, they still complement earlier findings which confirmed the sensitivity of the long–run relationship to structural breaks and regime shifts.

The recommendations from this analysis indicate the need for investors and policymakers to understand the interaction between inflation and stocks in their country. Such analysis should initially be centred on the linearity of the variable interaction to equip these groups of people with appropriate tools to further understand the long–run relationship. Using either linear or nonparametric approaches without this understanding will compromise the reliability of their results and, where forecasting is to be carried out, spurious results may be achieved. From an investor's viewpoint, the results help shape short–and medium–term investment strategies in the face of forecasted inflation levels, thus providing a platform for above–average returns. Further research also needs to be carried out to ascertain the reasons for the differences in results produced through using either the Bierens technique or the Johansen method, especially when the variables are linear. Finally, the nonlinear interaction between stocks and inflation needs to be explored in the face of new robust econometric techniques.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.0 Conclusions

This chapter concludes the thesis by summarising the findings and discussion areas for further research. Evidence in this thesis provides grounds for the acceptance of the thesis hypothesis that there is a relationship between inflation and stock returns in Sub-Saharan Africa. In line with fulfilling the objectives of this research, the following are the main contributions to current literature: first, the study provides evidence of the nature of stock–inflation relations in the African context. Second, in light of the different issues that can influence the nature of the relationship between stock returns and inflation, this thesis proposes steps that form a checklist for reliable and credible findings. The production of a checklist is influenced by the impact of the following factors in the relationship of the variables: existence of structural breaks, linearity of the relationship, the length of data considered in the analysis, and the use of month-end stock market price data to arrive at findings. Third, for the first time, the thesis provides evidence that official inflation rates in Africa are not accurate, given the presence of hidden inflation. Fourth, when forecasting inflation in Africa, multivariate models that incorporate lagged values of the inflation rate are better than univariate models. Further details on the main thesis motivation, its hypothesis development and insights are summarised in Section 8.1, while Section 8.2 looks at the research implications of the thesis findings and how African countries could benefit from the research findings. Section 8.3 describes further research areas that could be considered beyond this thesis.

8.1 Research findings

This thesis started by exploring the hypothesis that stock market returns have a long–run relationship with the inflation rate in Sub-Saharan Africa. The journey towards answering the thesis hypothesis started with a comprehensive search of the literature in stock–inflation relations, and this showed that there are three main theories to explain the nature of the relationship. The initial theory sought to justify the whole essence of investment, that it ought to be protected against inflation lest real investment returns are eroded over time; hence the expectation for a positive relationship. However, this seemingly plausible justification failed empirical tests that showed a negative relationship between stock returns and inflation. Many explanations have been offered to date, but two still stand out: the proxy hypothesis and the inflation illusion hypothesis. The proxy hypothesis attributes the negative relationship to an inferred association between economic activity and both stock returns and inflation. The relationship between economic activity and stock returns is considered positive, while inflation and economic activity were empirically shown to be negative. These two opposite relations are thus the justification for the negative relationship, with a direct association ruled out by the proxy hypothesis.

The other explanation for the negative stock–inflation relations is offered by the inflation illusion hypothesis which states that the negative relationship is due to the failure by investors to understand the effect of inflation on nominal dividend growth; rates thus they extrapolate historical nominal growth rates during the period of inflation. Another interesting discovery from the review of the literature showed that inflation can be induced by a variety of different shocks since it is a product of a reactive and proactive government policy, and these have distorted the credibility of the above theories on stock–inflation relations. Furthermore, these theories have been affected by the existence of different results in time, geographic and economic settings. In harmony with the above justification of the thesis hypothesis, indications from the review are that different economic regimes and structural changes are pivotal in explaining the nature of the relationship; hence it will be sensitive to the period considered in the analysis and the economic regime of a particular country. The review also showed that literature on the relationship in the African context has been limited. This study therefore provides an insight into the relationship in settings not studied before, those that are dominated by predominantly young and small stock markets.

To empirically answer the thesis hypothesis, cointegration was used to determine the long–run relationship between inflation and stock returns, with the Engel–Granger 2–step model and the Johansen technique forming the basis of the analysis. Using the 2–step model, the evidence shows a positive long–run relationship between stock market returns and inflation for all the African markets studied. Despite these plausible results that support the Fisher hypothesis, the Engle–Granger technique only checks the nature of the relationship for changes in the current values, ignoring the impact of lagged values of the variable, which values could have an impact several periods later. The full capture of lagged values is contained in a vector autoregressive (VAR) system, and the Johansen technique is useful in determining the nature of long–run dynamics in such a system.

Using the Johansen cointegration methodology, evidence in Africa also supports the hypothesis for a relationship between stock returns and inflation, particularly in the South African and Nigerian markets. However, an interesting finding in this study is the fact that stock markets and inflation experience different regimes that are influenced by local and international conditions. Thus, indications are that treating the relationship without accounting for these regimes has the tendency to distort results. When structural breaks in the data were accounted for, the evidence for a long–run relationship, using the Johansen technique in Botswana, Ghana and Kenya, was confirmed. To further support the effects of structural breaks on the nature of stock–inflation relations, Granger causality tests before and after the break showed a change in the direction of causality indicating that the relationship varies over time and, depending on the period tested, could reflect different results in the short–run, a fact also noted by Anari and Kolari (2001). These results add to the current literature and debate by providing the rationale for the differences in findings between short–run and long–term findings.

The evidence of the existence of different regimes in the data raised questions about the linearity of the data, and the credibility of the results if linear methods are used when the data–generating process of variables involved is nonlinear. This thesis then examined the linearity of the relationship between stock returns and inflation using the Kernel regression procedure as well as the Nadaraya–Watson approach. The results confirm nonlinearity in the four countries where the Johansen methodology failed to establish a long–run relationship between stock returns and inflation. These findings could explain why the Johansen technique failed to establish a long–run stock–inflation relationship, since the method is more reliable when the data generating process is linear. When an appropriate nonparametric cointegration was used to establish a long–run relationship between stock returns and inflation, the evidence confirmed this relationship in Botswana, Ghana and Mauritius, these being the countries where the linear cointegrating methodology had failed to substantiate it. The rationale for these findings and the existence of a nonlinear relationship is rooted in the presence of market friction and transaction costs (Davradakis, 2004; Maghyereh, 2006). The nonlinear result further adds to the current debate on the relationship between stock returns and inflation in that where a relationship cannot be confirmed using linear methods, linearity of the data generating process should be checked, and nonlinear long–run techniques used to verify the existence of a relationship.

A worrying finding in the inflation–stock relationship is the statistically significant relationship between stock market prices and unexpected inflation in Botswana, Ghana, Kenya and Nigeria. This relationship implies that, at month end, stock market prices might not have captured all information on the inflation rate. Since the inflation rate is not announced until the after the tenth of each month in all countries, using month–end figures is on the understanding that, by then, stock market figures would have incorporated information about the rate of inflation. The existence of a relationship between stock prices and unexpected inflation is an important indicator for the robustness problem that are presented by the use of month–end stock market figures as if the inflation rate announcement occurred on that date. Evidence by Adam, McQueen and Wood (2004) that stock market prices react to economic variable announcements, in particular to inflation announcements, indicates that results for the relationship could be best reflected by the use of announcement date stock prices data rather than month–end data.

To further support the thesis aim that sought to prove the research hypothesis as well as answer research questions, several objectives were considered, some of which have been fulfilled in the conclusions presented above. Another objective was to ascertain the accuracy of inflation figures in Africa, given that household surveys, which provide the basis for inflation baskets are carried out more than five years apart. The research found enough evidence that announced official inflation figures are understated owing to the existence of hidden inflation. Thus the findings question the accuracy of the figures in Kenya, Mauritius and Zimbabwe. In particular, the statistically higher increases in food inflation, which constitutes the largest component of the inflation basket, is worrying, especially since most countries in the continent only change their weights after five years, and in some cases over ten years. Furthermore, the results showed that annual inflation in Zimbabwe was understated by over 35% by June 2007; thus the need for the re-calculation of weights in Zimbabwe cannot be over emphasised. The findings on the accuracy of inflation in the continent are new, from the hidden–inflation angle of unveiling unofficial inflation, and they also support evidence already established by the repressed inflation approach to unofficial inflation carried out in Zimbabwe in 2006 by Munoz (2006). Another finding established from the empirical work in fulfilling the thesis objective to test the accuracy of African inflation figures, is the significant positive relationship between changes in poverty and the food weights within a consumer basket. This result reinforces the need for countries to carry out consumer consumption surveys more often, when people's living standards, as measured by the consumer price index, are falling.

Another objective of the research was to determine the appropriate tools for forecasting inflation in Africa, since one of the reasons for wanting knowledge about short– and long–term inflation–stock relations is to ensure market positioning in the case of pending inflation surge or dip. Univariate and multivariate forecasting methods were considered for the inflation prediction as well as its relationship with economic variables. Using different techniques showed that bivariate and multivariate forecasting models are better predictors of inflation in Africa, and innovations that include past values of the inflation rate seem to improve the forecast results in the short, medium and long term as well as in and out of sample. There is enough evidence to show that imported inflation has useful information about changes in the inflation rate in most Sub-Saharan African countries. These results are not surprising because Sub-Saharan African economies are young and therefore depend on imports to aid production. Moreover, these countries import fuel, thus leaving them at the mercy of volatile oil price movements. These results point to the fact that most African countries would find it difficult to control inflation when there is a surge in the phenomenon in the rest of the world, but since causality with the interest rate was established, monetary policy could be useful in regulating and ensuring inflation levels do not go out of control. The findings are also supported by the results which demonstrated that the exchange rate has useful information about changes in the inflation rate. Contrary to the monetarist view that inflation is predominantly caused by monetary elements, especially money supply, evidence in African inflation does not show that this element has useful information about inflation. These findings indicate tight monetary policy restrictions, in particular relating to money supply, and this is not surprising because in the 1990s most of the countries underwent International Monetary Fund economic reforms that sought to tightened government expenditure.

8.2 Research implications

The findings on the relationship between stock returns and inflation in this thesis have wide implications for investors in the African market, as well as for researchers who are keen to establish a consistent theoretical framework for this relationship. Four main points are considered vital: first, there is a need to determine if the analysis being carried out is short or long term. Second, the research will have to establish the existence of structural breaks within the data and account for economic regimes before carrying out any analysis, lest the result produced may not be robust. Third, the significance of the relationship between unexpected inflation and stock market prices has to be established to ascertain if the use of month–end stock market figures would compromise the accuracy of the results. Finally, the linearity of the variables ought to be examined before a method to analysise the relationship is chosen, given that some linear techniques are not reliable when the data–generating process is nonlinear. If the above steps are carried out, the expectations are that the results of the analysis between the relationship of any two time series are robust and the resultant conclusions reliable.

An analysis of the African stock markets in this thesis showed that the countries that had a broad approach to economic reform experienced significant increases in stock market activity. A broad approach included privatisation of state companies as well as the liberalisation of the stock market, which entailed removing or reducing entry and ownership restrictions, thus broadening the market for participants. Policymakers in Africa are encouraged to remove exchange controls and make further stock market reforms to ensure free entry into the market, which entry will inject more capital into the country and improve the balance of payments.

This thesis has also provided evidence for the existence of hidden inflation in Africa, thus placing doubt on the accuracy of this economic element within the continent. The need for accurate inflation figures is multidimensional.First, businesses project future growth using the figures, and inaccuracy compromises both viability and prosperity of the private sector.

Second, governments end up producing inadequate policies to tackle economic challenges and thus potentially fail within the economic plane or continuously review their policies when targets are not met. Third, workers use the rate to negotiate salary increases to ensure real salary increments that are not eroded by inflation over time. In light of this existence of unofficial inflation, African governments can eliminate the hidden inflation part of unofficial inflation by having regular household consumption surveys, thus changing their inflation baskets every three years at the most for single–figure inflation rates. For countries with double figures, household surveys are encouraged every two years, and annually when poverty is increasing. If household surveys are too expensive, then weight adjustments that are biased towards food inflation are recommended, and these can be done by tracking poverty levels.

Interest rates, imported inflation and exchange rates have useful information about movements in the African inflation rate. The influence of imported inflation makes it difficult to implement an effective inflation–targeting regime, since it is difficult to regulate because it is beyond the control of any one state. In Afric,a though, imported inflation is a result of net importer status as well as low raw material diversity; hence a policy that addresses these would help reduce the impact of this factor on the inflation rate. Policy intentions that tackle increased manufacture of processed production inputs and machinery assembly could help arrest the effects of imported inflation which is difficult to control. Prudent exchange rate management could also assist the impact of imported inflation, as an appreciation of the local currency makes imports cheaper. Interest rates are a good tool to use within the continent to regulate the inflation rate, as well as to predict it, given that the interest rate has useful information about inflation. Another finding relates to the general forecasting of the inflation rate, since a multivariate model that incorporates inflation lags is a better predictor of the inflation rate than univariate and bivariate models.

8.3 Areas for future research

This thesis has explored current literature and theory on stock–inflation relations, and has recommended a set of steps to be considered for analysis that can be applied to future research that seeks to determine a relationship between two time series. It would be interesting to put this set of steps in more advanced markets to ascertain if they could answer the inconsistent nature of the empirical relationship between stock market prices and inflation. Moreover, in this research, the presence of structural breaks has influenced the nature of the relationship between the two variables, and nonparametric cointegration models were used to confirm the presence of a nonlinear relationship. However, nonlinear threshold models could also be considered to substantiate future findings, something not done because it is a wide area requiring a different research scope. Another issue related to the aforementioned set of empirical steps is the determination of what could be considered as short-term and long-term within time series analysis, particularly two variable relationship analysis. The current rule of thumb is that a period beyond fifteen years for monthly data is considered long–run analysis, but a more precise methodology would strengthen the proposed set of empirical steps.

Recent research has considered the relationship between unexpected inflation and stock market returns as well as the impact of the inflation announcement date to stock prices. In both cases, the results have raised questions about using month–end stock prices data which seems not to have incorporated all the inflation information. A time series analysis in advanced markets for the long–run relationship at inflation announcement date would provide a useful comparison with current month-end results.

Hidden inflation in Africa was noted in the countries where data for this research was available, but an analysis of a wider set of countries in the continent would help ascertain if this is a problem throughout the continent. In addition, other emerging markets could be investigated with a view to identifying the presence of hidden inflation. Other forms of unofficial inflation, particularly repressed inflation, considered by Munoz (2006) in Zimbabwe, could also be investigated in other African countries. Since the presence of unofficial inflation questions the accuracy of announced inflation rates, the expectation from the aforementioned future research is that the evidence will encourage these countries to change their inflation determination policies. Another area of further investigation in Africa could be to determine if multivariate models are better inflation predictors than the Phillips Curve. In this research, the Phillips Curve could not be considered because of the unavailability of data to carry out the analysis in the continent.

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Appendix 4.1: Inflation measurement and calculation

While there has been controversy surrounding the causes of inflation as will be shown later, there is considerable agreement on what it is. However, to understand its causes, how it is measured and calculated there is need to define the phenomenon, which is generally considered to be an increase in the price of goods and services over time. Beardshaw (1992) adds purchasing power of money to this definition and notes that if there is a rise in the general level of prices, such that the value of money declines then there is inflation. In this regard when the price of goods and services rise the purchasing power of money falls, hence Griffiths and Wall (2001) state that the rate of inflation measures the change in the purchasing power of the money. When the purchasing power of money rises, thus the value of money increases or there is a fall in the general level of prices for goods and services, this phenomenon is termed deflation and is the opposite of inflation.

Parkin, Powell and Matthews (1997) who define inflation as a process in which the price level is rising and money is losing value note that there are two features to the definition of inflation, the first being that it is a monetary phenomenon thus it is the value of money that is changing not the price level of one particular commodity and second it is an ongoing process, not a one-shot affair. Alexander (2001) adds another dimension to this definition by saying the inflation rate measures the percentage change in cost-of-living at various points in time. The definition that equates inflation with the cost of living however is put to test when inflation is measured using the Harmonised Index of Consumer Prices (HICP) which Wynne and Rodriguez-Palenzuela (2004) state is not a cost of living index due to the way it is calculated and that it is not a measure of the change in minimum cost of achieving the same standard of living. The consumer price index (CPI) also uses a base year consumer basket and inflation is then calculated based on the changes in the prices of the commodities. The base year basket is based on household surveys and in Africa these surveys are not done annually as in the case of the United Kingdom but are carried out every five or more years. Given this length between inflation basket weights change the basket looses touch with consumer expenditure patterns and subsequently the true meaning of cost of living.

In addition to the above definitions another interesting issue on the subject of inflation is the different measures that exist and the consensus that it can be measured in different ways. Each measure will thus result in a different inflation rate and this can impact on the effect it will have on the stock market. More so, an insight into inflation measurements provides useful information that could be helpful in determining the existence of hidden inflation an issue under review in this chapter. Most of the submissions in this section will follow the work done by Beardshow (1992) and Griffiths and Wall (2001) unless otherwise referenced herein. Inflation levels are normally measured through movements in their index and an index in this context is a method of expressing the change of a number of variables through the movement of one number with another static one called a base. The United Kingdom has in the last part of the twentieth century used firstly the retail price index (RPI) and later RPI excluding mortgage interest payments (RPIX) however from December 2003 this was changed to the Harmonised Index of Consumer Prices (HICP) which is used by its European Union counterparts. Reflecting the new roles as the main UK domestic measure of inflation for macro-economic purpose the National Statistician decided that the UK HICP would be known as the Consumer Price Index (CPI). CPI differs from RPIX in the particular households it represents, the range of goods and services included and the way the index is constructed and these will be explored fully later in this section. Most African countries use CPI as a measure of official inflation though they produce other forms of measurements to help industry satisfactorily project the future. Currently Zimbabwe produces figures for both CPI and the producer's price index though it uses the former as a measure of inflation in the country and produces the later quarterly and yearly. The producer price index measures the changes in the selling price of output from domestic producers.

Inflation measures the change from period to period in the cost of a representative 'basket' of goods and services bought by a typical household. The changes from this base as a measure of inflation to other forms revealed above is precipitated by the challenges that are associated with the use of this form of inflation rate calculation such as time factor, high rates of inflation, quality changes, taxes and benefits, minorities and political implications. Since inflation indices have a base year, which acts as a reference point for either increases or decreases in the inflation rate, the time between the base year and year of calculation can be wide. Thus, time lapse becomes a concern in that society expenditure patterns change, their tastes and interests on commodities could be different, and though this is well reflected in the weights, the challenge is that comparison of prices could be difficult when interpreting the meaning of the index changes. The quality change challenges noted in the list above relates to the service and goods provision which have changed over years and an example to this is television sets which were black and white in the 1970s and are now different but this is not reflected in the index calculations. The way the housing costs, especially mortgages interest, are treated in the consumer price indices makes it an unreliable indicator of the underlying inflationary trend since only a fraction of the housing stock in many economies is mortgaged making mortgage interest an unrepresentative measure. Given this mortgage interest argument some countries like South Africa produce two types of inflation measures one without mortgage interest payments and another with the interest.

The other measure of inflation is Harmonised Index of Consumer Prices (HICP), which has been used predominantly by the European countries as a comparison tool to ensure control, and to also ensure that admission adherence rules are kept in check. This measure is different from the RPI previously produced in the UK in terms of calculation and coverage. The UK RPI uses arithmetic mean, whereas the HICP uses the geometric mean. Another difference relates to the basket of goods and services used in the computations of the two indices with only a 87% similarity between them. The consumers' expenditure deflator (CED) is also another measure of inflation which is arrived at by comparing the national account estimates of total consumers' expenditure at current prices with those re-valued at constant prices. Thus CED is a product of the national account and covers the personal expenditure of the whole population. Other deflator measures of inflation include the government expenditure deflator and the GDP deflator, and the later seeks to measure movements in the prices of the entire basket of goods and services produced within a country and can be regarded as the most comprehensive price index. One the other hand, the GDP deflator is more comprehensive and arguably more accurate but its main challenge is that it is less up-to-date compared to other indicators and is liable to greater revision. In 1979, the UK government introduced the taxes and prices index (TPI) which sought to counter the view that the RPI did not give an accurate view of the purchasing power because of government reduction of direct taxes. The taxes and pricing index (TPI) is arrived at by averaging changes in taxes and changes in the prices of goods and services. The wholesale price index measures the rate of inflation at the wholesale stage of the retail chain and it has two parts, the first giving the input prices (prices of raw material and fuel) as they enter the factory and the second gives the output prices of goods as they leave the factory. The two indices are used to give an indication of the future trends in retail prices. Despite the existence of all these forms of inflation measures this paper looks at the CPI, which is predominately used in African countries considered herein.

Appendix 4.2: Calculating an inflation Index

The measurements of inflation presented above have their own methods of calculation, which are not entirely different, but their particular emphasis makes for the uniqueness of each measurement. Beardshow (1992) indicates that there are three main questions that must be answered in the construction of an inflation index thus; who the index is relevant to, what is to be included and how the weights are to be allocated to different commodities in the index.

According to Diewert (2002) there are four approaches to the construction of price index numbers and these are, the fixed-basket approach, the test or axiomatic approach, the stochastic approach and the economic approach. The fixed basket approach entails keeping the basket constant either at the reference or current date and then comparing prices of goods and services in both periods. For the Laspeyres pricing index the basket of goods is at the initial reference year for which the current year is being compared with, and the comparison here is to see how much the similarly weighted basket has changed in price from the initial year to date. The HICP concept is thus built on this foundation and though countries can update these weights "…. each year for large changes in expenditure patterns," (Wynne and Rodriguez-Palenzuela, 2004 pg 82), Knipe (2006) confirms that the United Kingdom makes surveys every December for weight changes in January for HICP calculations. The other index associated with the basket approach is the Paasche price index which uses a current basket to see changes in prices, thus the comparison is to see how much the current basket cost in the price reference year compared to current prices. Diewert (2002) proves that the Paasche price index will normally be significantly below the Laspeyres and as such the Fisher ideal price index, which involves averaging the two indices, is favoured. The Walsh price index considers an average basket quantify weights for the reference and the date of interest then applying the prices at these different dates. The challenge with these approaches is that some current goods might not have a price at both the reference point and the current year, given the change in consumer tastes. An example of this is the ipod, memory stick and other technological items, which might not have been in existence at the reference year or the floppy discs, which are no longer sold widely. In addition to this challenge the issue of quality also comes in, a television set or radio at the reference year might be different from that of the current year due to quality differences and how to account for this objectively without bias and criticism could be hard. Despite these shortcomings, Diewert (2002) considers the Fisher ideal index and the Walsh price index as the best for the fixed basket approach.

The other approach to index construction theory is the test or axiomatic approach, which according to Wynne and Rodriguez-Palenzuela (2004), involves running a series of tests and hence seeks an index formula that satisfies a number of tests. Diewert (2002), who explains these tests in detail, concludes that the Fisher ideal index is the best for this approach. The tests, which are beyond the scope of this research, include the time reversal test, invariance to proportional changes in current quantities test, commensurability test, proportionality in current prices test, inverse in proportionality in base period prices test, monotonicity in current and base period prices tests, and the consistency in aggregate test. The Stochastic approach involves the use of central tendency principles to determine which index type is the best and again Diewert (2002) finds the Tornqvist Theil price index, which he defines as the expected value of the distribution of the logarithmic price ratios, the most appropriate for this approach to numbers theory. Finally, the economic approach is rooted to what Wynne and Rodriguez-Palenzuela (2004) describe as neoclassical theory of consumer behaviour with the price index considered as the change in the cost of attaining some reference level of utility between the two periods. Diewert (2002) says the Tornqvist Theil index, the Fisher ideal price index and the Walsh price index can all be regarded as equally desirable for this approach given that each has its own strengths on the economic approach tests. The above section on the approaches to index number theory show how varied the calculation of inflation indices is and that it depends on the approach that is used by an individual country or economic region. Knipe (2006) notes that CPI on a month-to-month basis are a Laspeyres type price index since they reflect changes in prices, not ongoing variations in consumer purchasing patterns.

The first step to be considered in the calculation of an inflation index is the selection of items which are deemed to represent the shopping basket of the population. Knipe (2006) states that in principle shopping basket should be calculated with reference to all consumer goods and services purchased by households and prices measured in every shopping outlet that supplies them. This is a big task, which might be unachievable in the face of time and resource constraints since weights are done annually in developed countries like the UK and more than five years between in most African countries while prices are sought monthly. To counter this challenge representative samples are taken and for Mauritius 370 outlets are considered throughout the country in different regions while in the UK, Knipe (2006) says 650 representative goods and service are collected, in 150 different areas bring a total of 120 000 multiple quotations collected monthly. As noted above the challenge with this approach is how to deal with a product that is no longer on the shelves or products, which are seasonal, that Knipe (2006) notes that comparables will have to be taken or else a price adjustment will take place. After the selected items have been collected using statistical methods the goods and services will then have to be classified and weighted to differentiate their over proportion to a household's expenditure as reflected in the annual surveys data. Wynne and Rodriguez-Palenzuela (2004) says the HICP classifies goods and services using the Classification of individual consumption by purpose (COICOP), which was criticised by Triplett (2001) because it is not rooted in economic theory.

The second stage in deriving the consumer price index involves collecting the price data (Griffiths and Wall, 2001) and this happens on specific days of the month, which is between the 12th and 18th of each month in Mauritius. The individual prices derived from either geometric or arithmetic mean are then multiplied by the weights to arrive at an index value and this can then be compared with other months or years to appreciate the actual movement of the consumer prices with the reference year or base year important in this instance. If the index value today is say Y and that of last year is X then the annual inflation rate will be given by:

$$[(Y - X)X^{-1}] \times 100\% \qquad \text{A4.2}$$

This method can also be repeated for month-to-month inflation rate by using last month index value and the current month to determine the rate.

Appendix 5.1: Unit root test results

5.1.1 Unit root test at levels

EXCHANGE RATE - UNIT ROOT TESTS AT LEVELS						
	Augumented Dickey Fuller		Phillips-Perron		KPSS	
Country	Constant	Trend & C	Constant	Trend & C	Constant	Trend & C
Botswana	-0.80	-1.79	-0.54	-1.69	1.85	0.25
Ghana	-1.19	-1.48	-1.61	-0.22	1.93	0.25
Kenya	-2.56	-0.85	-1.98	-1.20	1.65	0.42
Mauritius	-0.43	-2.34	-0.42	-2.35	1.90	0.15*
Nigeria	-1.32	-1.80	-1.31	-1.81	1.50	0.16*
South Africa	-1.23	-1.06	-1.22	-1.24	1.77	0.23
Zimbabwe	-1.93	-3.38	2.78	0.16	1.70	0.40
Critical Values						
1%	-3.46	-4.00	-3.46	-4.00	0.74	0.22
5%	-2.87	-3.43	-2.87	-3.43	0.46	0.15
10%	-2.57	-3.14	-2.57	-3.14	0.35	0.12
The unit root tests results for the exchange rate, the asterisk (*) represents cases where the Null is rejected at 1% level of significance.						

MONEY SUPPLY - UNIT ROOT TESTS AT LEVELS						
	Augumented Dickey Fuller		Phillips-Perron		KPSS	
Country	Constant	Trend & C	Constant	Trend & C	Constant	Trend & C
Botswana	-0.67098	-2.50418	-1.59200	-3.56979**	1.94743	0.15240**
Mauritius	-3.89013*	-3.63556**	-5.41551*	-4.48828*	1.93184	0.46863
South Africa	-0.12786	-2.43484	-0.11863	-1.68747	1.93981	0.17146**
Zimbabwe	-1.05228	-2.78227	-1.31108	-3.75684**	1.66454	0.27917
Critical Values						
1%	-3.46	-4.00	-3.46	-4.00	0.74	0.22
5%	-2.87	-3.43	-2.87	-3.43	0.46	0.15
10%	-2.57	-3.14	-2.57	-3.14	0.35	0.12
The unit root tests results for money supply, the asterisk (*) represents cases where the Null is rejected at 1% level of significance, and double asterisk (**) represents where the Null is rejected at 5% level of significance.						

INTEREST RATES - UNIT ROOT TESTS AT LEVELS						
	Augumented Dickey Fuller		Phillips-Perron		KPSS	
Country	**Constant**	**Trend & C**	**Constant**	**Trend & C**	**Constant**	**Trend & C**
Ghana	0.16386	0.12534	-1.01335	-1.19588	0.44300***	0.41185
Kenya	-1.89414	-2.63643	-1.85736	-2.55850	0.91955	0.29007
Mauritius	-2.45313	-2.99450	-1.62969	-1.96843	1.19182	0.20084
Nigeria	-1.06638	-1.49534	-2.32237	-2.85763	0.44291***	0.16312**
South Africa	-1.89169	-3.08605	-1.63912	-2.69066	0.91015	0.23036
Zimbabwe	-1.92859	-3.37802***	-1.71803	-2.84268	1.47452	0.12444***
Critical Values						
1%	-3.46	-4.00	-3.46	-4.00	0.74	0.22
5%	-2.87	-3.43	-2.87	-3.43	0.46	0.15
10%	-2.57	-3.14	-2.57	-3.14	0.35	0.12

The unit root tests results for the interest rates, the triple asterisk (***) represents cases where the Null is rejected at 10% level of significance, double asterisk (**) represents where the Null is rejected at 5% and one asterisk (*) at 1% level of significance.

5.1.2 Differenced Series

EXCHANGE RATE - UNIT ROOT TESTS FIRST DIFFERENCE					
	Augumented Dickey Fuller		Phillips-Perron		KPSS
Country	**Constant**	**None**	**Constant**	**None**	**Constant**
Botswana	-7.80*	-7.29*	-15.15*	-15.12*	0.10***
Ghana	-3.41**	-2.44	-9.92*	-10.16*	0.33***
Kenya	-4.15*	-3.92**	-11.21*	-11.26*	0.30***
Mauritius	-15.79*	-15.75*	-15.78*	-15.75*	0.05***
Nigeria	-13.90*	-13.90*	-13.90*	-13.90*	0.11***
South Africa	-15.20*	-15.23*	-15.24*	-15.26*	0.17***
Zimbabwe	-14.89*	-15.36*	-14.89*	-15.37*	0.85
Critical Values					
1%	-3.46	-4.00	-3.46	-4.00	0.74
5%	-2.87	-3.43	-2.87	-3.43	0.46
10%	-2.57	-3.14	-2.57	-3.14	0.35

The unit root tests results for exchange rate, the asterisk (*) represents cases where the Null is rejected at 1% level of significance, double asterisk (**) represents where the Null is rejected at 5% level of significance and the triple asterisk (***)at the 10% level.

MONEY SUPPLY - UNIT ROOT TESTS FIRST DIFFERENCE					
	Augumented Dickey Fuller		Phillips-Perron		KPSS
Country	**Constant**	**None**	**Constant**	**None**	**Constant**
Botswana	-6.22442*	-3.92548**	-20.20622*	-20.37807*	0.18558***
Mauritius	-4.27726*	-1.78252	-14.54409*	-15.41254*	1.24197
South Africa	-16.66777*	-16.63275*	-16.83598*	-16.80821*	0.22149***
Critical Values					
1%	-3.46	-4.00	-3.46	-4.00	0.74
5%	-2.87	-3.43	-2.87	-3.43	0.46
10%	-2.57	-3.14	-2.57	-3.14	0.35

The unit root tests results for money supply, the asterisk (*) represents cases where the Null is rejected at 1% level of significance, double asterisk (**) represents where the Null is rejected at 5% level of significance and the triple asterisk (***)at the 10% level.

INTEREST RATES - UNIT ROOT TESTS FIRST DIFFERENCE					
	Augumented Dickey Fuller		Phillips-Perron		KPSS
Country	**Constant**	**None**	**Constant**	**None**	**Constant**
Botswana					
Ghana	-6.84666*	-6.85294*	-10.41536*	-10.50141*	0.26735***
Kenya	-12.09905*	-12.10011*	-12.46090*	-12.45920*	0.07113***
Mauritius	-2.35049	-2.32350	-18.53018*	-18.39852*	0.10280***
Nigeria	-10.34475*	-10.34246*	-10.34475*	-10.32772*	0.07911***
South Africa	-8.89739*	-8.98025*	-9.00020*	-8.91790*	0.17924***
Zimbabwe	-9.32022*	-9.30213*	-9.42040*	-9.40284*	0.03798***
Critical Values					
1%	-3.46	-4.00	-3.46	-4.00	0.74
5%	-2.87	-3.43	-2.87	-3.43	0.46
10%	-2.57	-3.14	-2.57	-3.14	0.35

The unit root tests results for interest rates, the asterisk (*) represents cases where the Null is rejected at 1% level of significance, double asterisk (**) represents where the Null is rejected at 5% level of significance and the triple asterisk (***)at the 10% level.

Appendix 5.2: Diagnostic Tests for ARIMA univariate models

To check if there is serial correlation left in the residuals of the ARIMA models a Ljung-Box test is performed on the above models. Thus the test is done to determine if the residuals are random or there is linear dependency of the residuals in the model. The correlogram could be checked to determine this but this is not so conclusive hence the Q-statistics were checked against critical values at 5% for different degrees of freedom using the following hypothesis;

H_0: Residuals are random

H_1: Residuals are not random

DF	$\chi^2_{(0.05)}$	Q-statistics											
		Botswana		Ghana	Kenya		Mauritius		Nigeria		South Africa	Zimbabwe	
		A	S	S	A	S	A	S	A	S		A	S
1	3.8	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0
2	6.0	0.0	0.3	0.3	0.0	0.4	0.0	0.5	0.0	1.4	0.0	0.0	0.1
3	7.8	0.1	2.0	0.8	0.0	2.2	0.0	0.8	0.0	1.6	0.7	0.1	0.1
4	9.5	0.6	2.7	0.9	0.0	5.3	0.5	1.7	0.2	1.6	1.3	0.1	1.0
5	11.1	0.9	4.9	1.1	0.0	5.5	1.6	2.6	0.5	3.8	2.2	0.1	1.3
6	12.6	0.9	4.9	1.2	0.1	10.1	1.6	3.8	0.7	4.1	4.0	0.1	1.3
7	14.1	0.9	5.4	1.4	0.4	10.1	3.9	4.3	1.1	4.1	5.6	1.5	2.6
8	15.5	1.3	5.4	1.7	0.5	12.1	4.1	4.7	1.7	4.5	5.8	1.6	2.9
9	16.9	1.6	5.6	2.9	0.6	13.0	4.5	8.2	2.1	4.8	5.9	1.6	3.5
10	18.3	2.2	7.4	3.3	1.2	14.5	6.6	10.4	2.8	5.4	7.3	6.6	14.8
11	19.7	3.4	9.8	4.9	3.1	15.9	6.8	10.7	3.0	6.1	8.4	10.6	14.9
12	21.0	11.4	20.1	5.4	4.7	18.7	6.9	11.1	3.2	7.7	27.7*	11.3	16.1
13	22.4	13.3	21.3	7.7	4.9	18.7	11.0	15.5	5.9	10.3	29.7*	11.5	18.2
14	23.7	13.9	21.4	7.7	5.5	19.7	12.7	17.0	6.3	10.3	29.7*	15.5	18.3
15	25.0	13.9	21.4	7.9	9.0	21.2	12.8	17.2	6.5	10.4	30.0*	16.3	18.5

'A' represents the results of the AIC (Alkaike) models and 'S' represents the results of the BIC (Schwarz) models. The figure with asterisk (*) are above the critical values and the hypothesis is this case is rejected.

Ljung-Box test result

The Table above shows the results of this test and most of the values of the Q-statistic are below the critical values at different degrees of freedom at 5% LOS, which means the null hypothesis is not rejected. This implies that the residuals of all the models are random and the influences to the models have been picked. The only results where the hypothesis is rejected at 5% LOS are those obtained from the South Africa ARIMA model from 12 to 15 degrees of freedom, these however pass at 10% LOS.

The other test for the ARIMA models is the Breusch-Godfrey LM test, which tests whether or not the error terms are auto-correlated thus related to each other. This is to examine the relationship of error terms with several of its lagged values at the same time. The hypothesis for this test is:

H_o: No residual autocorrelation

H_1: There is residual autocorrelation

The next Table presents the results of this test as well and most of the calculated values of the different country models are less than the critical value of 5.99 at 5% level of significant with 2 degrees of freedom except Ghana (Akaike), Kenya (Schwarz), Mauritius (Schwarz), and South Africa.

	Botswana		Ghana		Kenya		Mauritius		Nigeria		South Africa	Zimbabwe	
	A	S	A	S	A	S	A	S	A	S		A	S
$Obs*R^2$	0.03	0.71	18.89	1.08	0.10	8.95	0.42	8.76	2.07	1.33	14.90	0.17	1.76

‘A’ represents the results of the AIC (Alkaike) models and ‘S’ represents the results of the BIC (Schwarz) models.

Breusch-Godfrey LM test results

The null hypothesis in this case is not rejected and we conclude that the residuals of the ARIMA models are not auto-correlated. The null hypothesis is not rejected at 5% LOS for

Ghana Akaike information criteria ARIMA after 11 degrees of freedom, Kenya's Schwarz ARIMA after 4 degrees of freedom, Mauritius' Schwarz ARIMA model after 4 degrees of freedom, and South African ARIMA model after 8 degrees of freedom. Despite rejecting the Breusch-Godfrey LM test the above models was taken to the next step to see how their forecast results compare with other models to be considered later.

Appendix 5.3: Univariate models forecast results

5.3.1 Actual forecast results

MAURITIUS UNIVARIATE FORECASTING RESULTS							
Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
Out of Sample Forecasts	3 Months	ARIMA-S	0.005071	0.004837	303.0309	0.357161	0.909825
		ARIMA-K	0.004845	0.004723	304.6839	0.343647	0.950232
		GARCH	0.003461	0.003312	169.0762*	0.372142	0.00506*
		GARCH-AK	0.002716*	0.002078*	187.2662	0.23994*	0.498268
		GARCH-AS	0.0028	0.002228	192.4267	0.25097	0.410879
		AR(1)	0.004397	0.004212	287.5015	0.392237	0.232851
	6 Months	ARIMA-S	0.008692	0.007519	203.2883	0.420429*	0.008034*
		ARIMA-K	0.008709	0.007676	208.6107	0.421618	0.009108
		GARCH	0.009612	0.007048	116.5871*	0.587853	0.260863
		GARCH-AK	0.008256*	0.005687*	120.2679	0.456922	0.175658
		GARCH-AS	0.008301	0.005792	122.8765	0.46234	0.184789
		AR(1)	0.009127	0.007271	180.8907	0.507218	0.130011
	12 Months	ARIMA-S	0.007291	0.006381	354.7243	0.41728	0.000755
		ARIMA-K	0.007257	0.006343	334.3255	0.415702	0.000422*
		GARCH	0.007802	0.006116	237.1685*	0.549647	0.13748
		GARCH-AK	0.00664*	0.004782*	345.6791	0.406249	0.026497
		GARCH-AS	0.006718	0.00484	367.3594	0.405913*	0.016485
		AR(1)	0.007488	0.006228	322.9752	0.476948	0.035122
In-Sample Forecasts	3 Months	ARIMA-S	0.012049	0.007419*	36.96525*	0.554942	0.287501*
		ARIMA-K	0.012972	0.008944	37.34229	0.643465	0.383711
		GARCH	0.012485	0.008412	47.52836	0.634656	0.453985
		GARCH-AK	0.011929	0.007931	42.8514	0.586705	0.425354
		GARCH-AS	0.01207	0.007975	42.33346	0.59816	0.431467
		AR(1)	0.011619*	0.007473	38.4703	0.553661*	0.373379
	6 Months	ARIMA-S	0.008972	0.006199	115.8518	0.498602*	0.001924
		ARIMA-K	0.009846	0.007092	146.5522	0.535226	0.000029*
		GARCH	0.009204	0.005592	88.19755*	0.602011	0.093893
		GARCH-AK	0.00898	0.005467*	92.22618	0.557712	0.051296
		GARCH-AS	0.009041	0.00547	91.63472	0.564558	0.054819
		AR(1)	0.008861*	0.005724	107.8363	0.534026	0.029297
	12 Months	ARIMA-S	0.006736	0.004474	111.1224	0.451023*	0.033139
		ARIMA-K	0.006894	0.00439	111.6831	0.4705	0.021863
		GARCH	0.006698	0.003815*	106.5372*	0.541358	0.01346
		GARCH-AK	0.006467*	0.004204	144.9306	0.467299	0.010507
		GARCH-AS	0.006478	0.00428	149.8259	0.46394	0.01477
		AR(1)	0.006677	0.004361	149.1392	0.486315	0.00757*
The figures with asterisk (*) are have the best models in each forecast period using a particular forecast determination criterion.							

NIGERIA UNIVARIATE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ARIMA-S	-0.0367	-0.6637	-0.7875	0.1099	0.0755	-1.3025
		ARIMA-K	1.0178	-0.4864	1.1251	0.9405	0.9601	3.5571
		AR(1)	-0.9812	1.1502	-0.3376	-1.0504	-1.0356	-2.2546*
	6 Months	ARIMA-S	-0.9391	-0.5945	-0.4327	-0.1134	-1.0999	-3.1796*
		ARIMA-K	1.0514	1.1545	-0.7108	1.0519	0.2455	2.7926
		AR(1)	-0.1123	-0.5601	1.1435	-0.9385	0.8544	0.3870
	12 Months	ARIMA-S	-0.6427	-0.3873	-0.0911	-0.0984	-0.5301	-1.7496
		ARIMA-K	-0.5095	-0.7484	-0.9513	1.0456	-0.6234	-1.7870*
		AR(1)	1.1521	1.1357	1.0424	-0.9472	1.1534	3.5366
In-Sample Forecasts	**3 Months**	ARIMA-S	0.1862	0.1228	-0.0265	0.9085	0.0550	1.2460
		ARIMA-K	-1.0800	-1.0557	-0.9865	-1.0715	-1.0263	-5.2201*
		AR(1)	0.8938	0.9329	1.0130	0.1630	0.9714	3.9741
	6 Months	ARIMA-S	-0.0533	0.1738	1.0975	0.8797	0.2016	2.2993
		ARIMA-K	1.0256	0.9017	-0.8597	0.2079	-1.0854	0.1900
		AR(1)	-0.9723	-1.0755	-0.2378	-1.0876	0.8838	-2.4893*
	12 Months	ARIMA-S	0.8650	0.8752	-0.5154	-0.1424	-0.3408	0.7416
		ARIMA-K	0.2300	0.2147	-0.6372	1.0636	-0.7850	0.0860
		AR(1)	-1.0950	-1.0899	1.1526	-0.9212	1.1259	-0.8276*

The figures with asterisk (*) are have the best models in each forecast period using a particular forecast determination criterion.

ZIMBABWE UNIVARIATE FORECASTING RESULTS							
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**
Out of Sample Forecasts	3 Months	ARIMA-S	0.078967	0.061272	83.7011	0.750197	0.131443
		ARIMA-K	0.098864	0.077892	199.2573	0.84061	0.353151
		GARCH	0.09216	0.071503	100.519	0.998881	0.139891
		GARCH-AK	0.119533	0.11539	43.59013*	0.293356*	0.931875
		GARCH-AS	0.07619*	0.060743*	90.27922	0.70153	0.114871*
		AR(1)	0.085909	0.06561	82.94201	0.87187	0.133621
	6 Months	ARIMA-S	0.070473	0.053311	93.4016*	0.807348	0.001945
		ARIMA-K	0.08015	0.065749	228.8611	0.764217	0.1608
		GARCH	0.07799	0.0583	100.7082	0.998052	0.005967
		GARCH-AK	0.101225	0.088433	35.49682	0.270317*	0.763234
		GARCH-AS	0.068863*	0.052901*	95.24466	0.76814	0.000557*
		AR(1)	0.074722	0.055718	93.7775	0.90475	0.003292
	12 Months	ARIMA-S	0.093458	0.072613	96.69522	0.907541	0.027105
		ARIMA-K	0.095686	0.076522	202.9202	0.805987	0.08614
		GARCH	0.096424	0.075138	99.50798	0.998592	0.030823
		GARCH-AK	0.128464	0.11445	47.49065*	0.340351*	0.65902
		GARCH-AS	0.092859*	0.072411*	97.62232	0.887348	0.024879*
		AR(1)	0.094943	0.073662	99.87793	0.952368	0.027141
In-Sample Forecasts	3 Months	ARIMA-S	0.027048	0.023664	80.38623	0.622729	0.334311
		ARIMA-K	0.079771	0.076897	310.6214	0.946012	0.321432
		GARCH	0.033125	0.030445	99.7158	0.9934	0.111343*
		GARCH-AK	0.037908	0.02618	13.43338*	0.117661*	0.380102
		GARCH-AS	0.031676	0.028815	94.47829	0.883743	0.157885
		AR(1)	0.02333*	0.019111*	77.51918	0.438187	0.671038
	6 Months	ARIMA-S	0.066058	0.055126	77.97522	0.352407	0.058295
		ARIMA-K	0.118515	0.108953	328.1413	0.38027	0.282882
		GARCH	0.124637	0.090263	99.81305	0.998316	0.075878
		GARCH-AK	0.052935	0.045363	28.47875	0.16605*	0.237263
		GARCH-AS	0.065459*	0.05606	84.85897	0.32851	0.012922*
		AR(1)	0.071838	0.051989*	66.37433*	0.401538	0.109328
	12 Months	ARIMA-S	0.066058*	0.055126*	77.97522	0.352407*	0.058295
		ARIMA-K	0.141785	0.114084	372.627	0.655404	0.21154
		GARCH	0.105687	0.069885	100.1581	0.998493	0.001047*
		GARCH-AK	0.127839	0.105946	58.6554*	0.541008	0.686819
		GARCH-AS	0.105573	0.069189	96.47466	0.883979	0.004126
		AR(1)	0.104945	0.06834	93.68061	0.877302	0.002051

The figures with asterisk (*) are have the best models in each forecast period using a particular forecast determination criterion.

5.3.2 Z-Score normalised results

BOTSWANA UNIVARIATE FORECASTING RESULTS RANKING								
Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP	Total
Out of Sample Forecasts	3 Months	ARIMA-S	-0.811	-0.601	-0.528	-0.998	0.906	-2.032
		ARIMA-K	1.117	1.154	1.153	1.002	0.168	4.595
		AR(1)	-0.307	-0.553	-0.626	-0.005	-1.073	-2.564*
	6 Months	ARIMA-S	0.470	1.154	0.467	0.473	0.525	3.089
		ARIMA-K	0.679	-0.546	0.681	0.675	0.628	2.118
		AR(1)	-1.148	-0.608	-1.148	-1.149	-1.153	-5.207*
	12 Months	ARIMA-S	0.460	0.443	0.463	0.466	0.527	2.360
		ARIMA-K	0.687	0.702	0.685	0.682	0.626	3.381
		AR(1)	-1.147	-1.145	-1.148	-1.148	-1.153	-5.741*
In-Sample Forecasts	3 Months	ARIMA-S	-0.102	0.623	1.137	-0.170	-0.479	1.009
		ARIMA-K	-0.945	-1.153	-0.394	-0.904	-0.671	-4.067*
		AR(1)	1.047	0.531	-0.743	1.074	1.149	3.058
	6 Months	ARIMA-S	1.133	1.070	0.993	1.145	0.346	4.686
		ARIMA-K	-0.761	-0.911	-1.007	-0.704	0.781	-2.602*
		AR(1)	-0.372	-0.158	0.014	-0.441	-1.127	-2.085
	12 Months	ARIMA-S	0.872	0.742	-1.012	0.842	0.709	2.153
		ARIMA-K	0.220	0.395	0.025	0.263	0.435	1.338
		AR(1)	-1.092	-1.137	0.987	-1.105	-1.144	-3.491*
The z-score total figures with asterisk (*) are have the best models in each forecast period.								

SOUTH AFRICA UNIVARIATE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ARIMA	-0.7071	-0.7071	-0.7071	-0.7071	-0.7071	-3.5355*
		AR(1)	0.7071	0.7071	0.7071	0.7071	0.7071	3.5355
	6 Months	ARIMA	0.7071	0.7071	-0.7071	0.7071	0.7071	2.1213
		AR(1)	-0.7071	-0.7071	0.7071	-0.7071	-0.7071	-2.1213*
	12 Months	ARIMA	0.7071	0.7071	-0.7071	0.7071	0.7071	2.1213
		AR(1)	-0.7071	-0.7071	0.7071	-0.7071	-0.7071	-2.1213*
In-Sample Forecasts	**3 Months**	ARIMA	-0.7071	-0.7071	-0.7071	-0.7071	-0.7071	-3.5355*
		AR(1)	0.7071	0.7071	0.7071	0.7071	0.7071	3.5355
	6 Months	ARIMA	-0.7071	-0.7071	-0.7071	-0.7071	-0.7071	-3.5355*
		AR(1)	0.7071	0.7071	0.7071	0.7071	0.7071	3.5355
	12 Months	ARIMA	0.7071	0.7071	-0.7071	0.7071	0.7071	2.1213
		AR(1)	-0.7071	-0.7071	0.7071	-0.7071	-0.7071	-2.1213*
The z-score total figures with asterisk (*) are have the best models in each forecast period.								

GHANA UNIVARIATE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ARIMA-S	-0.4024	-0.3930	-0.3866	-0.3612	-0.1534	-1.6966
		ARIMA-K	-0.7361	-0.7438	-0.7490	-0.7692	-0.9144	-3.9125*
		AR(1)	1.1385	1.1368	1.1356	1.1304	1.0678	5.6092
	6 Months	ARIMA-S	-0.4594	-0.5034	-0.4310	-0.4480	-0.3593	-2.2011
		ARIMA-K	-0.6877	-0.6482	-0.7123	-0.6977	-0.7707	-3.5166*
		AR(1)	1.1472	1.1517	1.1432	1.1457	1.1300	5.7177
	12 Months	ARIMA-S	-0.5361	-0.5377	-0.4878	-0.5454	-0.3305	-2.4376
		ARIMA-K	-0.6176	-0.6161	-0.6625	-0.6087	-0.7929	-3.2978*
		AR(1)	1.1537	1.1538	1.1503	1.1541	1.1234	5.7354
In-Sample Forecasts	**3 Months**	ARIMA-S	-0.2268	-0.2226	-0.2245	-0.1691	0.0788	-0.7640
		ARIMA-K	-0.8671	-0.8700	-0.8687	-0.9047	-1.0371	-4.5476*
		AR(1)	1.0939	1.0925	1.0932	1.0738	0.9582	5.3116
	6 Months	ARIMA-S	-0.2468	-0.4190	-0.3308	-0.2097	0.1435	-1.0628
		ARIMA-K	-0.8535	-0.7223	-0.7927	-0.8785	-1.0640	-4.3110*
		AR(1)	1.1003	1.1413	1.1235	1.0882	0.9205	5.3739
	12 Months	ARIMA-S	-0.2601	-0.1093	-0.0947	-0.4730	-0.2632	-1.2004
		ARIMA-K	-0.8442	-0.9409	-0.9493	-0.6757	-0.8421	-4.2522*
		AR(1)	1.1044	1.0502	1.0440	1.1488	1.1053	5.4525
The z-score total figures with asterisk (*) are have the best models in each forecast period.								

MAURITIUS UNIVARIATE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ARIMA-S	1.1537	1.0427	0.9744	0.4825	1.0961	4.7494
		ARIMA-K	0.9345	0.9493	1.0002	0.2731	1.2045	4.3615
		GARCH	-0.4081	-0.2074	-1.1184	0.7146	-1.3308	-2.3501
		GARCH-AK	-1.1307	-1.2190	-0.8342	-1.3334	-0.0078	-4.5252*
		GARCH-AS	-1.0492	-1.0960	-0.7536	-1.1626	-0.2422	-4.3037
		AR(1)	0.4999	0.5304	0.7317	1.0259	-0.7198	2.0681
	6 Months	ARIMA-S	-0.1762	0.7862	1.0214	-0.8779	-1.1808	-0.4272
		ARIMA-K	-0.1432	0.9659	1.1435	-0.8591	-1.1702	-0.0631
		GARCH	1.6081	0.2470	-0.9671	1.7639	1.3061	3.9581
		GARCH-AK	-1.0217	-1.3108	-0.8827	-0.3020	0.4680	-3.0492*
		GARCH-AS	-0.9345	-1.1906	-0.8228	-0.2165	0.5578	-2.6066
		AR(1)	0.6675	0.5023	0.5077	0.4916	0.0190	2.1881
	12 Months	ARIMA-S	0.2047	0.7909	0.5933	-0.4857	-0.6864	0.4168
		ARIMA-K	0.1288	0.7407	0.1562	-0.5131	-0.6929	-0.1803
		GARCH	1.3457	0.4412	-1.9260	1.8097	1.9668	3.6373
		GARCH-AK	-1.2490	-1.3192	0.3995	-0.6770	-0.1869	-3.0325*
		GARCH-AS	-1.0748	-1.2426	0.8641	-0.6828	-0.3812	-2.5173
		AR(1)	0.6446	0.5890	-0.0871	0.5490	-0.0195	1.6760
In-Sample Forecasts	**3 Months**	ARIMA-S	-0.2914	-1.0473	-0.9646	-1.0543	-1.7586	-5.1163*
		ARIMA-K	1.6528	1.5854	-0.8725	1.2603	-0.1482	3.4777
		GARCH	0.6270	0.6670	1.6150	1.0300	1.0281	4.9670
		GARCH-AK	-0.5441	-0.1634	0.4728	-0.2238	0.5488	0.0903
		GARCH-AS	-0.2471	-0.0875	0.3464	0.0757	0.6511	0.7386
		AR(1)	-1.1971	-0.9541	-0.5971	-1.0878	-0.3212	-4.1573
	6 Months	ARIMA-S	-0.4981	0.4343	0.3975	-1.4362	-1.0235	-2.1259*
		ARIMA-K	1.9385	1.8444	1.7841	-0.3860	-1.0764	4.1046
		GARCH	0.1487	-0.5243	-0.8514	1.5289	1.5470	1.8489
		GARCH-AK	-0.4758	-0.7217	-0.6695	0.2587	0.3564	-1.2518
		GARCH-AS	-0.3057	-0.7169	-0.6962	0.4550	0.4549	-0.8090
		AR(1)	-0.8076	-0.3158	0.0355	-0.4204	-0.2584	-1.7667
	12 Months	ARIMA-S	0.4769	0.9394	-0.8430	-0.9048	1.7474	1.4159
		ARIMA-K	1.4470	0.5807	-0.8163	-0.2982	0.5352	1.4484
		GARCH	0.2436	-1.8745	-1.0607	1.9089	-0.3682	-1.1510
		GARCH-AK	-1.1748	-0.2135	0.7626	-0.3979	-0.6856	-1.7093*
		GARCH-AS	-1.1073	0.1110	0.9950	-0.5025	-0.2274	-0.7311
		AR(1)	0.1146	0.4569	0.9624	0.1944	-1.0014	0.7270
The z-score total figures with asterisk (*) are have the best models in each forecast period.								

ZIMBABWE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ARIMA-S	-0.8164	-0.6844	-0.3125	0.0307	-0.5261	-2.3087
		ARIMA-K	0.4360	0.1206	1.8963	0.4025	0.1626	3.0181
		GARCH	0.0140	-0.1889	0.0090	1.0535	-0.4999	0.3878
		GARCH-AK	1.7369	1.9370	-1.0791	-1.8483	1.9605	2.7070
		GARCH-AS	-0.9912	-0.7101	-0.1867	-0.1695	-0.5776	-2.6351*
		AR(1)	-0.3794	-0.4743	-0.3270	0.5311	-0.5194	-1.1690
	6 Months	ARIMA-S	-0.7177	-0.6690	-0.2267	0.2185	-0.5064	-1.9014
		ARIMA-K	0.1061	0.2463	1.8891	0.0478	0.0159	2.3052
		GARCH	-0.0778	-0.3019	-0.1126	0.9730	-0.4932	-0.0124
		GARCH-AK	1.9001	1.9157	-1.1311	-1.9065	1.9967	2.7749
		GARCH-AS	-0.8547	-0.6992	-0.1979	0.0633	-0.5110	-2.1995*
		AR(1)	-0.3560	-0.4919	-0.2208	0.6039	-0.5020	-0.9668
	12 Months	ARIMA-S	-0.4941	-0.4944	-0.2087	0.3816	-0.4542	-1.2697
		ARIMA-K	-0.3333	-0.2583	1.8712	-0.0388	-0.2219	1.0189
		GARCH	-0.2801	-0.3419	-0.1536	0.7585	-0.4395	-0.4565
		GARCH-AK	2.0317	2.0321	-1.1721	-1.9665	2.0325	2.9578
		GARCH-AS	-0.5373	-0.5066	-0.1905	0.2980	-0.4629	-1.3993*
		AR(1)	-0.3869	-0.4310	-0.1463	0.5672	-0.4540	-0.8511
In-Sample Forecasts	**3 Months**	ARIMA-S	-0.5685	-0.4939	-0.3174	-0.1290	0.0250	-1.4838
		ARIMA-K	1.9800	2.0049	1.9444	0.8141	-0.0400	6.7036
		GARCH	-0.2748	-0.1756	-0.1275	0.9524	-1.1002	-0.7256
		GARCH-AK	-0.0436	-0.3758	-0.9751	-1.6025	0.2561	-2.7409*
		GARCH-AS	-0.3448	-0.2521	-0.1789	0.6325	-0.8653	-1.0087
		AR(1)	-0.7483	-0.7076	-0.3455	-0.6674	1.7243	-0.7446
	6 Months	ARIMA-S	-0.5654	-0.5034	-0.3376	-0.2977	-0.6657	-2.3698
		ARIMA-K	1.1607	1.6079	1.9894	-0.2006	1.4362	5.9936
		GARCH	1.3622	0.8749	-0.1345	1.9527	-0.5012	3.5541
		GARCH-AK	-0.9972	-0.8863	-0.7981	-0.9470	1.0092	-2.6193
		GARCH-AS	-0.5851	-0.4667	-0.2736	-0.3810	-1.0904	-2.7968*
		AR(1)	-0.3752	-0.6264	-0.4456	-0.1265	-0.1881	-1.7618
	12 Months	ARIMA-S	-1.6548	-1.0678	-0.4675	-1.4917	-0.3788	-5.0608*
		ARIMA-K	1.2875	1.4203	2.0240	-0.2557	0.1884	4.6643
		GARCH	-0.1150	-0.4449	-0.2799	1.1437	-0.5907	-0.2868
		GARCH-AK	0.7456	1.0768	-0.6308	-0.7224	1.9473	2.4166
		GARCH-AS	-0.1195	-0.4743	-0.3111	0.6766	-0.5793	-0.8075
		AR(1)	-0.1439	-0.5101	-0.3347	0.6494	-0.5870	-0.9262
The z-score total figures with asterisk (*) are have the best models in each forecast period.								

Appendix 5.4: Cointegration test results

5.4.1 Engle-Granger 2-Step Cointegration Method

UNIT ROOT TESTS FOR RESIDUALS-CPI & INTEREST RATE								
	Augumented Dickey Fuller			Phillips-Perron			KPSS	
Country	A	T&C	None	A	T&C	None	A	T&C
Ghana	-4.79*	-4.98*	-4.80*	-9.87*	-10.16*	-9.88*	0.32***	0.09***
Kenya	-7.26*	-6.42*	-7.28*	-12.61*	-12.66*	-12.64*	0.46**	0.14**
Mauritius	-7.81*	-7.96*	-7.82*	-14.82*	-14.83*	-14.84*	0.30***	0.05***
Nigeria	-2.62***	-10.18*	-2.64*	-9.79*	-11.01*	-9.81*	1.03	0.23
South Africa	-4.59*	-12.48*	-4.60*	-10.30*	-12.55*	-10.32*	1.62	0.11***
Critical Values								
1%	-3.46	-4.00	-2.57	-3.46	-4.00	-2.57	0.74	0.22
5%	-2.87	-3.43	-1.94	-2.87	-3.43	-1.94	0.46	0.15
10%	-2.57	-3.14	-1.62	-2.57	-3.14	-1.62	0.35	0.12

Unit root tests results for the residual series of the inflation and interest rates regression. The triple asterisk (***) representing situations where the Null is rejected at 10% level of significance, double asterisk (**) represents where the Null is rejected at 5% and one asterisk (*) at 1% level of significance. 'A' stands for constant, 'T&C' trend and constant and 'None' without trend or constant.

UNIT ROOT TESTS FOR RESIDUALS-CPI & MONEY SUPPLY								
	Augumented Dickey Fuller			Phillips-Perron			KPSS	
Country	A	T&C	None	A	T&C	None	A	T&C
Botswana	-5.90*	-13.76*	-5.92*	-14.39*	-14.55*	-14.41*	0.70*	0.13**
Mauritius	-7.73*	-7.87*	-7.75*	-14.82*	-14.85*	-14.84*	0.29***	0.05***
South Africa	-5.28*	-7.01*	-5.29*	-8.64*	-10.77*	-8.65*	1.52	0.08***
Critical Values								
1%	-3.46	-4.00	-2.57	-3.46	-4.00	-2.57	0.74	0.22
5%	-2.87	-3.43	-1.94	-2.87	-3.43	-1.94	0.46	0.15
10%	-2.57	-3.14	-1.62	-2.57	-3.14	-1.62	0.35	0.12

Unit root tests results for the residual series of the inflation and money supply regression. The triple asterisk (***) representing situations where the Null is rejected at 10% level of significance, double asterisk (**) represents where the Null is rejected at 5% and one asterisk (*) at 1% level of significance. 'A' stands for constant, 'T&C' trend and constant and 'None' without trend or constant.

UNIT ROOT TESTS FOR RESIDUALS-CPI & ALL VARIABLES								
	Augumented Dickey Fuller			Phillips-Perron			KPSS	
Country	**A**	**T&C**	**None**	**A**	**T&C**	**None**	**A**	**T&C**
Botswana	-13.62*	-13.76*	-13.65*	-14.32*	-14.37*	-14.34*	0.31***	0.13***
Ghana	-5.19*	-5.26*	-5.20*	-9.98*	-10.12*	-9.99*	0.21***	0.08***
Kenya	-6.50*	-6.76*	-6.52*	-12.75*	-12.87*	-12.78*	0.47*	0.15**
Mauritius	-7.92*	-7.98*	-7.93*	-14.95*	-14.94*	-14.98*	0.17***	0.04***
Nigeria	-2.60**	-10.06*	-2.61*	-9.46*	-10.92*	-9.48*	1.02	0.24
South Africa	-4.48*	-8.12*	-4.49*	-10.63*	-12.89*	-10.65*	1.63	0.10***
Critical Values								
1%	-3.46	-4.00	-2.57	-3.46	-4.00	-2.57	0.74	0.22
5%	-2.87	-3.43	-1.94	-2.87	-3.43	-1.94	0.46	0.15
10%	-2.57	-3.14	-1.62	-2.57	-3.14	-1.62	0.35	0.12

Unit root tests results for the residual series of the inflation and all variables regression. The triple asterisk (***) representing situations where the Null is rejected at 10% level of significance, double asterisk (**) represents where the Null is rejected at 5% and one asterisk (*) at 1% level of significance. ‘A’ stands for constant, ‘T&C’ trend and constant and ‘None’ without trend or constant.

5.4.2 Results for the Johansen Cointegration Method

Ghana Results

Likelihood Ratio Tests For Cointegrating Rank for inflation				
Hypothesised Rank (r)	Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value
r=0*	0.141137	53.89924	47.21*	54.46
r≤1	0.033595	17.99283	29.68	35.65
r≤2	0.023843	9.928127	15.41	20.04
r≤3	0.017777	4.23306	3.76	6.65
The test results indicate one cointegrating equation at 5% level of significance no evidence of cointegration at 1% LOS.				

Kenya Results

Likelihood Ratio Tests For Cointegrating Rank for inflation				
Hypothesised Rank (r)	Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value
r=0	0.095309	42.8592	47.21	54.46
r≤1	0.057007	19.42136	29.68	35.65
r≤2	0.019477	5.686277	15.41	20.04
r≤3	0.00462	1.083616	3.76	6.65
The test results indicate no cointegrating equation at both 5% and 1% level of significance.				

Mauritius Results

Likelihood Ratio Tests For Cointegrating Rank for inflation				
Hypothesised Rank (r)	Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value
r=0**	0.157037	82.43614	68.52*	76.07*
r≤1	0.093811	42.46142	47.21	54.46
r≤2	0.039452	19.4108	29.68	35.65
r≤3	0.029085	9.991966	15.41	20.04
r≤4	0.013098	3.085255	3.76	6.65
The test results indicate no cointegrating equation at both 5% and 1% level of significance.				

Nigeria Results

Likelihood Ratio Tests For Cointegrating Rank for inflation				
Hypothesised Rank (r)	Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value
r=0**	0.187273	57.47201	47.21*	54.46*
r≤1	0.078766	20.14729	29.68	35.65
r≤2	0.029437	5.379931	15.41	20.04
r≤3	9.03E-06	0.001626	3.76	6.65
The test results indicate no cointegrating equation at both 5% and 1% level of significance.				

Appendix 5.5: Multicollinearity test results

Ghana Multicollinearity Test				
	Inflation	Exchange Rate	Interest Rate	Trading Partner
Inflation	1.00000	0.17803	0.24853	0.16565
Exchange Rate	0.17803	1.00000	0.23251	0.14847
Interest Rate	0.24853	0.23251	1.00000	-0.02828
Trading Partner	0.16565	0.14847	-0.02828	1.00000

Kenya Multicollinearity Test				
	Inflation	Exchange Rate	Interest Rate	Trading Partner
Inflation	1.00000	0.12342	0.05579	-0.03073
Exchange Rate	0.12342	1.00000	0.31249	0.09852
Interest Rate	0.05579	0.31249	1.00000	0.02097
Trading Partner	-0.03073	0.09852	0.02097	1.00000

Mauritius Multicollinearity Test					
	Inflation	Exchange Rate	Interest Rate	Money Supply	Trading Partner
Inflation	1.00000	-0.01248	0.08127	0.00038	0.07447
Exchange Rate	-0.01248	1.00000	0.00379	-0.05991	-0.12541
Interest Rate	0.08127	0.00379	1.00000	-0.09232	0.11450
Money Supply	0.00038	-0.05991	-0.09232	1.00000	0.11114
Trading Partner	0.07447	-0.12541	0.11450	0.11114	1.00000

Nigeria Multicollinearity Test				
	Inflation	Exchange Rate	Interest Rate	Trading Partner
Inflation	1.00000	0.06287	-0.05127	0.06148
Exchange Rate	0.06287	1.00000	0.04301	-0.01019
Interest Rate	-0.05127	0.04301	1.00000	-0.11297
Trading Partner	0.06148	-0.01019	-0.11297	1.00000

South Africa Multicollinearity Test					
	Inflation	Exchange Rate	Interest Rate	Money Supply	World inflation
Inflation	1.00000	-0.03116	0.36643	0.06463	0.30551
Exchange Rate	-0.03116	1.00000	0.15421	-0.02774	-0.13689
Interest Rate	0.36643	0.15421	1.00000	0.14478	0.04717
Money Supply	0.06463	-0.02774	0.14478	1.00000	-0.12084
World inflation	0.30551	-0.13689	0.04717	-0.12084	1.00000

Appendix 5.6: Diagnostic Tests for ECM

As noted in the main text having obtained the ECM the noble next step is to carry out diagnosis tests to check if the models pass the normality test. The following diagnostic tests were conducted at 5% significance level:

- The LM Test (Breusch-Godfrey test) which tests whether or not the residuals are auto correlated thus related to each other and to ascertain autocorrelation the correlogram of residuals can be looked at though this is too subjective thus the LM test comes handy. Our wish was that the residuals should not be auto correlated though even if they are at this juncture we proceed and do more diagnosis tests.
- The Normality Test (Jarque-Bera test) which tests if the residuals are normally distributed or not and this can be done by either looking at the Histogram or taking the Jarque-Bera statistic and comparing this with the critical values at a particular level of significance which is 5% in this case.
- Misspecification test (Ramsey's-RESET test) which tests for potential mis-specification of the model thus, if some main explanatory variables have been omitted from the model.
- The heteroskedasticity test (White's general test) which is to check if the errors do have a constant variance or not and the expectation is that the variance of the errors are constant hence oskedastic.

5.6.1 The LM test (Breusch-Godfrey test)

As noted above the test is to determine if the residuals are auto-correlated and thus the Null and the alternative hypothesis are:

H_0: Residuals are not auto-correlated

H_1: Residuals are auto-correlated

Table below presents the results of this test and the figures in asterisk indicate where the Null hypothesis was rejected for the alternative at 5% level of significance.

Lagged variables	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
CPI & Exchange rate	0.5520	1.8454	0.2545	1.5390	1.5697	3.4687
CPI & Interest rate	X	0.2952	0.5088	1.8074	2.4137	0.6162
CPI & Money Supply	0.5129	X	X	3.42561	X	0.9356
CPI & Trading Partner	1.9907	8.8397*	0.1230	1.3768	2.4820	0.0975
Exchange rate	6.5676*	10.3873*	4.9903	19.5851*	11.6001*	17.8783*
Interest Rate	X	11.4587*	11.5554*	17.8532*	6.3214*	8.8808*
Money supply	4.1670	X	X	13.206*	X	11.7616
Trading Partner CPI	4.4227	2.0769	14.5275	16.7437*	13.2140*	27.4068
All variables	0.1281	1.2943	1.2101	2.0149	2.2151	1.0062

'X' indicates cases where the data was not available thus no test was conducted while asterisk on results denotes cases where the Null Hypothesis is rejected. 'All variables' section of the table refers to innovations that include all the variables and their significant lags.

Breusch-Godfrey LM test results to check if residuals are auto-correlated

The calculated and observed value for the Kenya CPI and Exchange rate lagged ECM is 0.2545, which is below the critical value of 5.99 for 5% level of significant at 2 degrees of freedom. Most of the models involving the lagged exchange rate except for Kenya result in the rejection of the null hypothesis at 5% LOS which suggests that the model with only this lagged variable is mis-specified on the strength of this test. Surprisingly thought the model involving this variable and lagged inflation is correctly specified for all the countries since their observed values are less than the critical value of 5% LOS thus the Null Hypothesis is not rejected and the residuals are not auto correlated. This observation is also noted for most of the innovations in Mauritius which do not have lagged values of the inflation rate.

5.6.2 The normality test (Jarque-Bera test)

This test is to determine if the residuals are normally distributed or not and this can be done by looking at the histogram or computing the Jarque-Bera (JB) statistic. The hypothesis for this test is:

H_0: Residuals are normal

H_1: Residuals are not normal

If the histogram is bell shaped one can conclude that the residuals follow a normal distribution but this process is not conclusive to reject the Null Hypothesis because some shapes will be bell shaped with a peak and decaying tails on both sides of the peak with gaps in between. The table below presents the calculated Jarque-Bera statistics, which can be compared with the critical value of 5.99 for 5% level of significant at two degrees of freedom.

Lagged variables	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
CPI & Exchange rate	150.2400	4798.4840	305.4741	124.7577	2.4729*	71.1905
CPI & Interest rate	X	3724.5860	335.3130	131.8035	0.4246*	38.3583
CPI & Money Supply	444.5484	X	X	108.3133	X	58.9998
CPI & Trading Partner	381.7685	3936.3370	188.0683	113.3911	0.4837*	67.4458
Exchange rate	100.4348	4434.7730	448.3230	227.0277	2.7770*	47.7018
Interest Rate	X	3277.6670	401.9210	230.6245	0.3813*	32.0112
Money supply	158.5688	X	X	135.8391	X	33.7924
Trading Partner CPI	165.8821	3421.5190	348.7591	168.5637	2.1292*	31.1753
All variables	68.4153	4698.8130	216.4305	102.2279	0.2859*	46.4225

‘X’ indicates cases where the data was not available thus no test was conducted while asterisk on results denotes cases where the Null Hypothesis can not be rejected and the residuals in this case are normal. ‘All variables’ section of the table refers to innovations that include all the variables and their significant lags.

Jarque-Bera normality test results to check if residuals are normal

The South African lagged interest rate ECM has a JB statistic of 38.3683 which is above the critical value of 5.99 noted above and thus the null hypothesis is rejected and we conclude that the residual for the model do not follow a normal distribution. The same can not be said for all the models prepared except for Nigeria whose calculated JB statistic are below 5.99, thus the Null Hypothesis can not be rejected in this case.

5.6.3 Misspecification test (Ramsey's-RESET test)

The test is to determine if the model is mis-specified with the following Null and Alternative Hypothesis.

H_0: The model is correctly specified

H_1: The model is mis-specified

The results in table below show the likelihood ratio values which are compared with the critical value of 5.99 for 5% level of significant at two degree of freedom. The values below this value indicated that the Null hypothesis is not rejected and the models are thus correctly specified.

Lagged variables	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
CPI & Exchange rate	2.3658	0.0063	1.3736	13.7362*	0.6698	0.0273
CPI & Interest rate	X	0.0327	1.2657	19.1969*	3.3561	0.1872
CPI & Money Supply	0.4783	X	X	16.4658*	X	0.1653
CPI & Trading Partner	3.1645	0.0020	0.7558	13.7329*	2.2924	0.8155
Exchange rate	0.0988	11.0510*	1.7010	0.2204	2.5658	4.0310
Interest Rate	X	17.3263*	0.0470	0.0444	3.7937	2.9689
Money supply	0.0487	X	X	7.8591*	X	2.7161
Trading Partner CPI	0.3611	2.5930	4.0674	1.1268	1.2863	9.2748*
All variables	5.9364	0.9370	7.2372*	19.9804*	3.5426	2.7038

'X' indicates cases where the data was not available thus no test was conducted while asterisk on results denotes cases where the Null Hypothesis is rejected. 'All variables' section of the table refers to innovations that include all the variables and their significant lags.

Ramsey's-RESET test results to check if residuals are mis-specified

The values obtained for the Mauritian models with lagged inflation and another variables are above 5.99 hence the Null hypothesis cannot be rejected, thus these innovations are considered mis-specified. The rejection of the Null Hypothesis for this stability test also means that the relationship between the variables is not linear hence the linear ECM models prepared here might not appropriately explain the relationship thus a non-linear model might be ideal.

5.6.4 The heteroskedasticity test (White's general test)

The last diagnostic test to be performed on the ECM is the White's test which checks if the errors of the model have constant variance or not and if the errors possess constant variance, they are said to be homoskedastic which is our expectation. The hypothesis for the White's test given below and is based on heteroscedasticity which is the opposite of the expectation homoskedasticity.

H_o: There is no heteroscedasticity

H_1: There is heteroscedasticity

The table below presents the Observed R-squared values for White's general test for heteroscedasticity and the values above the critical value of 5.99 for the chi-square distribution with two degrees of freedom at 5% level of significance mean the null hypothesis is not rejected.

Error Correction Model Test - Heteroskedasticity test (White's general test)						
Lagged variables	Botswana	Ghana	Kenya	Mauritius	Nigeria	South Africa
CPI & Exchange rate	97.4566	10.5354	101.5736	139.2106	24.1164	34.9975
CPI & Interest rate	X	27.4080	67.3723	148.7712	41.4054	47.0069
CPI & Money Supply	41.1635	X	X	150.7436	X	48.7039
CPI & Trading Partner	40.9787	15.4363	97.1786	147.1079	58.4134	27.4068
Exchange rate	45.6235	20.0384	10.7976	15.7463	1.3512*	26.4398
Interest Rate	X	35.2624	7.9784	17.5369	17.4212	29.2815
Money supply	11.1957	X	X	44.3750	X	32.4147
Trading Partner CPI	56.1218	28.5305	13.4388	43.1203	5.4589*	38.1324
All variables	192.1448	28.1794	191.6604	177.3250	158.6047	74.1358
'X' indicates cases where the data was not available thus no test was conducted while asterisk on results denotes cases where the Null Hypothesis is not rejected. 'All variables' section of the table refers to innovations that include all the variables and their significant lags.						

White's general heteroskedasticity test results for the error correction model

The observed R-squared value for Nigeria's exchange rate and Trading partner CPI's lagged models are below 5.99 critical value and thus the hypothesis is not rejected for these models. In this case the innovations exhibit heteroscedasticity which means the errors for these models do not have a constant variance as per the assumptions of the normal regression.

Appendix 5.7: One month forecast results for multivariate innovations

BOTSWANA ONE MONTH FORECASTING RESULTS				
Type of forecast	Forecast Period	Model	RMSE	MAPE
Out of Sample Forecasts	One Month Ahead	Exchange Rate	0.000772	8.749591
		Exchange Rate & Inflation	0.000778	8.823128
		Money Supply	0.000413	4.677212
		Money Supply & Inflation	0.000353*	4.00332*
		Trade Partner Inflation	0.000737	8.349733
		Trade Partner & Inflation	0.000724	8.211733
		Multivariate	0.000927	10.50954
In-Sample Forecasts	One Month	Exchange Rate	0.003981	26.17506
		Exchange Rate & Inflation	0.002096*	13.78322*
		Money Supply	0.007453	49.00798
		Money Supply & Inflation	0.005916	38.9021
		Trade Partner Inflation	0.008752	57.54689
		Trade Partner & Inflation	0.006879	45.23151
		Multivariate	0.002143	14.09325
The results with asterisks (*) are the best for each forecast measure.				

GHANA ONE MONTH FORECASTING RESULTS				
Type of forecast	Forecast Period	Model	RMSE	MAPE
Out of Sample Forecasts	One Month Ahead	Exchange Rate	0.005659	213.881
		Exchange Rate & Inflation	0.005989	208.2073
		Interest Rates	0.005963	224.7833
		Interest Rate & Inflation	0.004465*	155.2226*
		Trade Partner Inflation	0.011484	399.2538
		Trade Partner & Inflation	0.011286	392.3438
		Multivariate	0.009139	317.7048
In-Sample Forecasts	One Month	Exchange Rate	0.004188	77.81007
		Exchange Rate & Inflation	0.004331	80.46741
		Interest Rates	0.003665	68.0957
		Interest Rate & Inflation	0.001916	35.60657
		Trade Partner Inflation	0.004866	90.41182
		Trade Partner & Inflation	0.004108	76.31991
		Multivariate	0.000503*	9.33882*
The results with asterisks (*) are the best for each forecast measure.				

KENYA ONE MONTH FORECASTING RESULTS				
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAPE**
Out of Sample Forecasts	**One Month Ahead**	Exchange Rate	0.027742	77.29715
		Exchange Rate & Inflation	0.022121	61.63621
		Interest Rates	0.0159*	44.30289*
		Interest Rate & Inflation	0.018412	51.30026
		Trade Partner Inflation	0.024136	67.25031
		Trade Partner & Inflation	0.028615	79.73037
		Multivariate	0.033917	94.5032
In-Sample Forecasts	**One Month**	Exchange Rate	0.056694	89.12811
		Exchange Rate & Inflation	0.050354	79.16188
		Interest Rates	0.054178	85.17372
		Interest Rate & Inflation	0.05067	79.65777
		Trade Partner Inflation	0.045595	71.67955
		Trade Partner & Inflation	0.036458	57.31518
		Multivariate	0.03603*	56.64323*
The results with asterisks (*) are the best for each forecast measure.				

MAURITIUS ONE MONTH FORECASTING RESULTS				
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAPE**
Out of Sample Forecasts	**One Month Ahead**	Exchange Rate	0.007025	760.5474
		Exchange Rate & Inflation	0.005832	631.3813
		Interest Rates	0.003804	411.8649
		Interest Rate & Inflation	0.002212	239.4657
		Money Supply	0.00487	527.2622
		Money Supply & Inflation	0.006086	658.9451
		Trade Partner Inflation	0.004535	490.9291
		Trade Partner & Inflation	0.004122	446.2748
		Multivariate	0.000727*	78.73895*
In-Sample Forecasts	**One Month**	Exchange Rate	0.019247	75.4527
		Exchange Rate & Inflation	0.018478	72.43646
		Interest Rates	0.014574	57.13352
		Interest Rate & Inflation	0.013541*	53.08141*
		Money Supply	0.019571	76.72206
		Money Supply & Inflation	0.019135	75.01097
		Trade Partner Inflation	0.021607	84.7024
		Trade Partner & Inflation	0.020629	80.87044
		Multivariate	0.015365	60.23177
The results with asterisks (*) are the best for each forecast measure.				

SA ONE MONTH FORECASTING RESULTS				
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAPE**
Out of Sample Forecasts	**One Month Ahead**	Exchange Rate	0.002001	112.5774
		Exchange Rate & Inflation	0.0000169*	0.950058*
		Interest Rates	0.002783	156.5623
		Interest Rate & Inflation	0.000401	22.57323
		Money Supply	0.003789	213.169
		Money Supply & Inflation	0.002099	118.0804
		Trade Partner Inflation	0.007299	410.5915
		Trade Partner & Inflation	0.006167	346.9257
		Multivariate	0.003309	186.1412
In-Sample Forecasts	**One Month**	Exchange Rate	0.001633	49.72911
		Exchange Rate & Inflation	0.001348	41.0521
		Interest Rates	0.000839	25.55927
		Interest Rate & Inflation	0.000401	22.57323
		Money Supply	0.001128	34.36885
		Money Supply & Inflation	0.001834	55.85962
		Trade Partner Inflation	0.0000939*	2.859838*
		Trade Partner & Inflation	0.000372	11.34089
		Multivariate	0.0007	21.31427
The results with asterisks (*) are the best for each forecast measure.				

Appendix 5.8: More than one month forecast results:

5.8.1 Actual forecast results

The diagrams follow in the next page. On these diagrams the figures with asterisk (*) have the best models in each forecast period using a particular forecast determination criterion. MS above represents money supply; ER, exchange rate; CPI is the inflation rate; TP is the country main trading partner inflation

BOTSWANA FORECASTING RESULTS							
Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
Out of Sample Forecasts	3 Months	ER	0.00283	0.00209	24.12085	0.17093	0.30946
		ER & CPI	0.00243	0.00214	24.32158	0.13622	0.01249*
		MS	0.00063*	0.00051*	5.61502*	0.03571*	0.13800
		MS & CPI	0.00174	0.00118	13.70962	0.09157	0.46431
		TPCPI	0.00190	0.00172	19.25506	0.11844	0.81795
		TP & CPI	0.00120	0.00112	12.71311	0.06716	0.00035
		Multivariate	0.00428	0.00307	35.51934	0.26175	0.31396
	6 Months	ER	0.00332	0.00282	54.24748	0.21849	0.08818
		ER & CPI	0.00384	0.00342	68.24895	0.23455	0.33223
		MS	0.00235	0.00183	40.50706	0.15258	0.38379
		MS & CPI	0.00366	0.00300	62.96964	0.21546	0.67014
		TPCPI	0.00201	0.00173	32.61676	0.14517	0.00372*
		TP & CPI	0.00190*	0.00164*	33.65133*	0.12554*	0.33225
		Multivariate	0.00397	0.00320	58.10020	0.26486	0.01371
	12 Months	ER	0.00323	0.00291	59.87978	0.22979	0.27528
		ER & CPI	0.00381	0.00339	71.42913	0.25610	0.42216
		MS	0.00259	0.00216	48.56826	0.18314	0.56266
		MS & CPI	0.00351	0.00303	65.49707	0.22938	0.74675
		TPCPI	0.00232	0.00206	43.20215	0.17495	0.20199*
		TP & CPI	0.00211*	0.00178*	37.88508*	0.15240*	0.50990
		Multivariate	0.00378	0.00323	64.81804	0.27091	0.13870
In-Sample Forecasts	3 Months	ER	0.00324	0.00288	29.58702	0.15325	0.00499*
		ER & CPI	0.00336	0.00302	37.08191	0.14607	0.38992
		MS	0.00448	0.00328	27.04370	0.23303	0.14220
		MS & CPI	0.00379	0.00340	32.76413	0.18440	0.00665
		TPCPI	0.00511	0.00355	27.50832	0.29528	0.48139
		TP & CPI	0.00399	0.00291	23.66206	0.21102	0.24007
		Multivariate	0.00153*	0.00129*	12.07097*	0.07324*	0.03231
	6 Months	ER	0.00550	0.00440	33.42679	0.24929	0.23468
		ER & CPI	0.00462*	0.00399	32.66687	0.19942*	0.11472*
		MS	0.00557	0.00429	29.87173	0.26355	0.39322
		MS & CPI	0.00493	0.00396	28.56857	0.22600	0.32869
		TPCPI	0.00644	0.00515	36.20509	0.32999	0.63899
		TP & CPI	0.00585	0.00468	32.91505	0.29142	0.61551
		Multivariate	0.00479	0.00358	24.77221	0.22584	0.55922
	12 Months	ER	0.00460*	0.00373	44.60739	0.23254*	0.06778*
		ER & CPI	0.00469	0.00373*	42.32572	0.23975	0.23975
		MS	0.00476	0.00395	47.70919	0.25001	0.13533
		MS & CPI	0.00500	0.00420	47.67441	0.27028	0.21778
		TPCPI	0.00521	0.00422	41.12493*	0.29670	0.38804
		TP & CPI	0.00537	0.00436	40.62341	0.31056	0.43018
		Multivariate	0.00502	0.00418	49.23368	0.26989	0.26467

GHANA FORECASTING RESULTS							
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**
Out of Sample Forecasts	**3 Months**	ER	0.00462*	0.00382*	143.27790*	0.35493*	0.64535
		ER & CPI	0.00686	0.00672	209.02240	0.42293	0.95902
		IR	0.00505	0.00473	159.75510	0.39868	0.40238*
		IR & CPI	0.00491	0.00441	156.19390	0.35739	0.80387
		TPCPI	0.00797	0.00654	240.47780	0.50129	0.60557
		TP & CPI	0.01380	0.01365	412.93850	0.59578	0.97818
		Multivariate	0.00762	0.00694	243.35170	0.46870	0.83026
	6 Months	ER	0.00382*	0.00323*	81.66065*	0.18864*	0.11453
		ER & CPI	0.00492	0.00379	108.19160	0.21695	0.59389
		IR	0.00431	0.00374	90.51818	0.21019	0.09216
		IR & CPI	0.00407	0.00351	87.84356	0.20635	0.04807
		TPCPI	0.00578	0.00414	126.69290	0.26829	0.20255
		TP & CPI	0.01069	0.00979	229.62610	0.37301	0.83962
		Multivariate	0.00741	0.00701	148.70870	0.38776	0.00008*
	12 Months	ER	0.00335*	0.00294*	56.69153*	0.16845*	0.34465
		ER & CPI	0.00750	0.00638	108.62210	0.30587	0.72264
		IR	0.00548	0.00506	83.75810	0.24838	0.49385
		IR & CPI	0.00967	0.00774	117.07070	0.37867	0.44195
		TPCPI	0.00461	0.00344	79.77532	0.22440	0.31261
		TP & CPI	0.01396	0.01291	211.96520	0.44848	0.85463
		Multivariate	0.00630	0.00572	101.18430	0.31529	0.06650*
In-Sample Forecasts	**3 Months**	ER	0.00383	0.00377	58.58602	0.21316	0.96672
		ER & CPI	0.00666	0.00601	99.32044	0.32891	0.81372
		IR	0.00403	0.00399	60.28185	0.22038	0.98304
		IR & CPI	0.00780	0.00742	118.01700	0.36071	0.90301
		TPCPI	0.00629	0.00611	91.88648	0.30777	0.94380
		TP & CPI	0.00746	0.00655	109.67040	0.35735	0.77203*
		Multivariate	0.00379*	0.00323*	52.81091*	0.21661*	0.72868
	6 Months	ER	0.00280	0.00228	32.88019	0.13704	0.39453
		ER & CPI	0.00322	0.00287	37.88645	0.17306	0.00051*
		IR	0.00297	0.00250	34.63576	0.14449	0.39490
		IR & CPI	0.00408	0.00360	48.28998	0.21026	0.02407
		TPCPI	0.00556	0.00496	62.50037	0.23514	0.70883
		TP & CPI	0.00779	0.00615	91.15072	0.31177	0.62418
		Multivariate	0.00247*	0.00231*	28.61987*	0.13458*	0.01455
	12 Months	ER	0.00542	0.00402*	38.97752*	0.21551	0.01588*
		ER & CPI	0.00929	0.00804	67.83162	0.55355	0.74996
		IR	0.00523*	0.00416	44.75526	0.19493*	0.16448
		IR & CPI	0.00709	0.00610	67.95910	0.26568	0.11667
		TPCPI	0.00689	0.00598	61.75186	0.25538	0.13568
		TP & CPI	0.01236	0.01072	115.63780	0.42041	0.07260
		Multivariate	0.00676	0.00503	46.81350	0.28271	0.00383

KENYA FORECASTING RESULTS							
Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
Out of Sample Forecasts	3 Months	ER	0.02069	0.01700	83.83778*	0.66281	0.00824
		ER & CPI	0.02019	0.01822	108.90230	0.55188	0.02953
		IR	0.01516*	0.01376*	84.10342	0.40640*	0.04337
		IR & CPI	0.02299	0.02149	148.52670	0.54218	0.16079
		TPCPI	0.02086	0.01797	99.82258	0.62405	0.00006*
		TP & CPI	0.02489	0.02127	117.39690	0.68937	0.00777
		Multivariate	0.02401	0.02199	124.25940	0.86768	0.09733
	6 Months	ER	0.01923	0.01683	165.46720	0.74446	0.14784
		ER & CPI	0.01911	0.01774	219.52360	0.63873	0.29436
		IR	0.01645*	0.01502*	154.11880*	0.55500*	0.34906
		IR & CPI	0.02231	0.02109	271.27690	0.64640	0.44926
		TPCPI	0.01959	0.01790	210.95330	0.70310	0.20355
		TP & CPI	0.02492	0.02229	394.17320	0.71960	0.26168
		Multivariate	0.02210	0.01999	349.42150	0.72746	0.05652*
	12 Months	ER	0.01568	0.01348	113.57460	0.64923	0.00761
		ER & CPI	0.01487	0.01269	134.98770	0.53125	0.00853
		IR	0.01247*	0.01014*	92.09785*	0.43798*	0.03197
		IR & CPI	0.01616	0.01272	148.63420	0.51192	0.10877
		TPCPI	0.01608	0.01351	137.58540	0.57160	0.00029*
		TP & CPI	0.01985	0.01564	232.30370	0.59575	0.01903
		Multivariate	0.02109	0.01717	229.37450	0.65142	0.03120
In-Sample Forecasts	3 Months	ER	0.03482	0.02757	80.32291	0.78797	0.62706
		ER & CPI	0.03442	0.02754	79.27727	0.76355	0.63996
		IR	0.03251*	0.02424*	62.53707	0.65125	0.45036
		IR & CPI	0.03427	0.02556	62.14151*	0.74020	0.55647
		TPCPI	0.02856	0.02324	93.65841	0.46804	0.14915*
		TP & CPI	0.02515	0.02150	81.14917	0.42354*	0.26451
		Multivariate	0.02558	0.02199	75.27346	0.44851	0.41205
	6 Months	ER	0.02494	0.01631	219.72050	0.75531	0.24532
		ER & CPI	0.02496	0.01596	189.43330	0.76406	0.34117
		IR	0.02401	0.01653	372.63110	0.61910*	0.07326*
		IR & CPI	0.02424	0.01518	217.87270	0.66428	0.13573
		TPCPI	0.02052	0.01416	197.02460	0.46344	0.02097
		TP & CPI	0.01823*	0.01329	170.22900	0.41712	0.09738
		Multivariate	0.01830	0.01203*	108.82240*	0.44846	0.24961
	12 Months	ER	0.01860	0.01109	321.78130	0.69389	0.11226
		ER & CPI	0.01838	0.01088	317.52490	0.66414	0.10386
		IR	0.01865	0.01334	681.81340	0.54890	0.00163
		IR & CPI	0.01821	0.01273	636.10340	0.54842	0.00011*
		TPCPI	0.01672	0.01242	493.25940	0.47555	0.00217
		TP & CPI	0.01406*	0.01073	448.06790	0.39556*	0.00253
		Multivariate	0.01432	0.01041*	294.40270*	0.43310	0.01948

MAURITIUS OUT OF SAMPLE FORECASTING RESULTS							
Type of forecast	Period	Model	RMSE	MAE	MAPE	TIC	BP
Out of Sample Forecasts	3 Months	ER	0.00525	0.00502	345.58140	0.44015	0.28090
		ER & CPI	0.00436	0.00415	289.31550	0.32259	0.90335
		IR	0.00327	0.00324	201.48490	0.31177	0.18583
		IR & CPI	0.00226	0.00223	120.71310	0.18299	0.97597
		MS	0.00467	0.00466	274.82450	0.42464	0.15866
		MS & CPI	0.00407	0.00346	281.56020	0.32049	0.72279
		TPCPI	0.00390	0.00380	222.97380	0.39031	0.05493*
		TP & CPI	0.00263	0.00227	180.67400	0.22202	0.74136
		Multivariate	0.00114*	0.00097*	39.71712*	0.09984*	0.38748
	6 Months	ER	0.00889	0.00745	208.96540	0.47797	0.09517
		ER & CPI	0.00885	0.00746	194.39910	0.44644*	0.03763*
		IR	0.00902	0.00706	145.08040	0.50719	0.15109
		IR & CPI	0.00919	0.00692	118.52040	0.47472	0.07848
		MS	0.00990	0.00790	182.92490	0.54534	0.11290
		MS & CPI	0.01015	0.00791	197.47460	0.53309	0.06462
		TPCPI	0.00883*	0.00688	144.16610	0.50962	0.20358
		TP & CPI	0.00897	0.00668	135.32780	0.48652	0.12893
		Multivariate	0.00952	0.00660*	79.65175*	0.51091	0.14815
	12 Months	ER	0.00735	0.00628	382.46090	0.44634	0.00857
		ER & CPI	0.00701	0.00544	413.98150	0.39519*	0.00182
		IR	0.00756	0.00620	311.73860	0.46626	0.01830
		IR & CPI	0.00738	0.00552	375.79500	0.41925	0.00000*
		MS	0.00798	0.00649	307.06170	0.50991	0.04306
		MS & CPI	0.00783	0.00596	376.40460	0.46306	0.00759
		TPCPI	0.00726	0.00596	277.82130*	0.47714	0.06968
		TP & CPI	0.00683*	0.00487*	280.84200	0.42097	0.04039
		Multivariate	0.00731	0.00500	286.32310	0.44064	0.03440

MAURITIUS IN-SAMPLE FORECASTING RESULTS							
Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
In-Sample Forecasts	3 Months	ER	0.01115	0.00711	36.60172	0.51716	0.34403
		ER & CPI	0.01122	0.00736	39.01302	0.53454	0.40587
		IR	0.00847	0.00563*	32.44331	0.35855	0.32061
		IR & CPI	0.00829*	0.00578	35.81087	0.35177*	0.36650
		MS	0.01131	0.00690	32.39998	0.51439	0.29578*
		MS & CPI	0.01109	0.00674	31.74373*	0.51627	0.36973
		TPCPI	0.01256	0.00809	40.84413	0.62761	0.41462
		TP & CPI	0.01261	0.00841	45.78614	0.64060	0.44500
		Multivariate	0.00956	0.00686	44.18185	0.43913	0.51447
	6 Months	ER	0.00851	0.00543	102.28710	0.50864	0.02690
		ER & CPI	0.00805	0.00474	74.29359	0.49163	0.05606
		IR	0.00637	0.00429	72.48281	0.35567	0.02074*
		IR & CPI	0.00612*	0.00405	71.72001	0.34357*	0.02375
		MS	0.00852	0.00478	80.66384	0.51421	0.04176
		MS & CPI	0.00807	0.00463	71.01420	0.49142	0.06804
		TPCPI	0.00922	0.00538	82.12487	0.59830	0.08639
		TP & CPI	0.00894	0.00486	59.69484	0.59092	0.12172
		Multivariate	0.00675	0.00402*	57.28671*	0.41099	0.12295
	12 Months	ER	0.00649	0.00429	150.68700	0.46582	0.01422
		ER & CPI	0.00648	0.00438	158.77030	0.45719	0.02168
		IR	0.00545	0.00389	129.76790	0.36119	0.05350
		IR & CPI	0.00543	0.00402	145.84470	0.35054*	0.10659
		MS	0.00623	0.00337	103.12700	0.47155	0.00022
		MS & CPI	0.00614	0.00370	123.46860	0.45497	0.00018
		TPCPI	0.00676	0.00383	110.48170	0.54053	0.00966
		TP & CPI	0.00674	0.00381	108.21470	0.54187	0.01356
		Multivariate	0.00510*	0.00297*	80.00011*	0.36968	0.00000*

NIGERIA FORECASTING RESULTS							
Type of forecast	**Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**
Out of Sample Forecasts	**3 Months**	ER	0.01592	0.01366*	116.97990	0.37438	0.00322
		ER & CPI	0.02216	0.01828	88.44137*	0.89369	0.68080
		IR	0.03558	0.03374	290.83440	0.44891	0.89922
		IR & CPI	0.04086	0.03595	326.90370	0.48964	0.77413
		TPCPI	0.01766	0.01452	130.64470	0.39959	0.00080*
		TP & CPI	0.01455*	0.01436	121.93130	0.34188*	0.08526
		Multivariate	0.02868	0.02685	239.18070	0.39751	0.87635
	6 Months	ER	0.01515	0.01323	363.04590	0.46522	0.15377
		ER & CPI	0.01720	0.01305	249.21640*	0.82023	0.09254
		IR	0.02770	0.02311	484.55470	0.47020	0.50928
		IR & CPI	0.03731	0.03280	1253.42100	0.56835	0.77322
		TPCPI	0.02103	0.01864	730.94900	0.54843	0.30576
		TP & CPI	0.01271*	0.01224*	448.03340	0.40154*	0.00063*
		Multivariate	0.02783	0.02653	1156.69000	0.48105	0.49806
	12 Months	ER	0.01472	0.01286	386.05940	0.50606	0.22042
		ER & CPI	0.01504	0.01188	311.34820*	0.69713	0.00074*
		IR	0.03204	0.02483	574.65970	0.64260	0.08561
		IR & CPI	0.03675	0.03219	1144.57200	0.66520	0.34282
		TPCPI	0.01792	0.01606	609.99170	0.55736	0.28540
		TP & CPI	0.01205*	0.01090*	425.68220	0.44598*	0.00142
		Multivariate	0.03607	0.03191	1288.51300	0.68166	0.04230
In-Sample Forecasts	**3 Months**	ER	0.01364	0.01161	116.05010	0.88073	0.72484
		ER & CPI	0.02030	0.01820	198.81250	0.89707	0.80355
		IR	0.01105	0.00918	91.84765*	0.88191	0.47181
		IR & CPI	0.02249	0.02079	233.48400	0.89995	0.85387
		TPCPI	0.01653	0.01349	132.59440	0.91676	0.65683
		TP & CPI	0.01370	0.01325	158.49610	0.98586	0.23698*
		Multivariate	0.00907*	0.00835*	105.57560	0.52771*	0.84814
	6 Months	ER	0.01839	0.01575	130.25270	0.64106	0.73350
		ER & CPI	0.02654	0.02378	238.10350	0.79747	0.80281
		IR	0.01686*	0.01492*	121.04240*	0.57509	0.70150
		IR & CPI	0.03227	0.03034	312.87500	0.79566	0.88406
		TPCPI	0.01968	0.01664	135.18830	0.65105	0.71040
		TP & CPI	0.02950	0.02671	291.12200	0.68177	0.15774*
		Multivariate	0.01751	0.01690	175.75900	0.57267*	0.93085
	12 Months	ER	0.01853	0.01533	204.57560	0.50128	0.09001
		ER & CPI	0.01996	0.01600	216.91880	0.52649	0.17810
		IR	0.01865	0.01667	192.90480	0.49950	0.04749
		IR & CPI	0.02155	0.01817	176.16090*	0.55998	0.11651
		TPCPI	0.01944	0.01630	208.31630	0.50943	0.09459
		TP & CPI	0.13248	0.10846	1259.96800	0.87323	0.00450*
		Multivariate	0.01588*	0.01468*	182.08320	0.41373*	0.11164

SOUTH AFRICA OUT OF SAMPLE FORECASTING RESULTS							
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**
Out of Sample Forecasts	**3 Months**	ER	0.00155	0.00135	188.03180	0.27405	0.74897
		ER & CPI	0.00037*	0.00025*	13.79243*	0.08688*	0.44499
		IR	0.00271	0.00234	367.75420	0.42959	0.55503
		IR & CPI	0.00129	0.00099	190.29570	0.25826	0.30780
		MS	0.00326	0.00268	419.24240	0.46689	0.67386
		MS & CPI	0.00144	0.00125	151.34930	0.26706	0.50364
		TPCPI	0.00557	0.00523	638.28990	0.64276	0.38737*
		TP & CPI	0.00617	0.00589	810.45700	0.60758	0.91347
		Multivariate	0.00199	0.00154	112.86670	0.31909	0.59855
	6 Months	ER	0.00156	0.00141	103.43970	0.14516	0.00175*
		ER & CPI	0.00234	0.00173	27.58938*	0.25372	0.54943
		IR	0.00219	0.00184	192.86660	0.18758	0.12980
		IR & CPI	0.00236	0.00203	115.16070	0.24744	0.24976
		MS	0.00237	0.00168	213.89420	0.19827	0.25891
		MS & CPI	0.00210	0.00189	91.90175	0.21008	0.12772
		TPCPI	0.00472	0.00428	340.32640	0.35105	0.15469
		TP & CPI	0.00445	0.00358	413.37980	0.32276	0.51106
		Multivariate	0.00146*	0.00102*	59.73775	0.12351*	0.23630
	12 Months	ER	0.00182*	0.00156*	74.28687	0.16110*	0.18263
		ER & CPI	0.00248	0.00200	38.92984*	0.24543	0.06489
		IR	0.00300	0.00241	135.96940	0.24316	0.34545
		IR & CPI	0.00305	0.00270	98.30443	0.27146	0.03047*
		MS	0.00263	0.00215	139.68590	0.21164	0.53274
		MS & CPI	0.00205	0.00182	68.62851	0.18748	0.03682
		TPCPI	0.00370	0.00297	189.75650	0.29484	0.15751
		TP & CPI	0.00466	0.00399	257.66550	0.32593	0.66221
		Multivariate	0.00324	0.00251	77.11497	0.24898	0.47262

SOUTH AFRICA IN-SAMPLE FORECASTING RESULTS							
Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP
In-Sample Forecasts	3 Months	ER	0.00309	0.00266	153.58540	0.38805	0.73963
		ER & CPI	0.00391	0.00328	180.78930	0.45298	0.59321
		IR	0.00333	0.00270	162.84980	0.41352	0.65437
		IR & CPI	0.00426	0.00347	198.88650	0.47285	0.66156
		MS	0.00302	0.00255	149.48490	0.38395	0.71626
		MS & CPI	0.00359	0.00299	167.67080	0.42535	0.69306
		TPCPI	0.00209	0.00133	93.53627	0.32387	0.26124
		TP & CPI	0.00135*	0.00111*	54.09401*	0.26208*	0.03601*
		Multivariate	0.00282	0.00200	131.88800	0.39568	0.33389
	6 Months	ER	0.00264*	0.00217	107.11500	0.29271*	0.67910
		ER & CPI	0.00316	0.00225	111.16410	0.34170	0.45487*
		IR	0.00307	0.00244	121.30330	0.32884	0.63365
		IR & CPI	0.00362	0.00274	139.12080	0.37566	0.52226
		MS	0.00266	0.00213*	106.69270	0.29612	0.64165
		MS & CPI	0.00319	0.00238	123.14330	0.34307	0.55459
		TPCPI	0.00296	0.00236	97.67122*	0.31257	0.56438
		TP & CPI	0.00443	0.00410	170.92110	0.40096	0.86023
		Multivariate	0.00357	0.00288	136.09880	0.36042	0.63347
	12 Months	ER	0.00271	0.00231	206.84350	0.31677	0.28916
		ER & CPI	0.00281	0.00210	182.45720	0.31698	0.25894
		IR	0.00274	0.00225	184.41400	0.31126	0.34499
		IR & CPI	0.00228*	0.00176*	99.94991	0.30489	0.00001*
		MS	0.00270	0.00220	221.10350	0.30887	0.38208
		MS & CPI	0.00263	0.00203	167.27360	0.30213	0.30620
		TPCPI	0.00287	0.00230	118.55080	0.31053	0.32261
		TP & CPI	0.00368	0.00335	208.06460	0.37802	0.32861
		Multivariate	0.00242	0.00180	98.35543*	0.28338*	0.15012

5.8.2 Z-Score normalised results

Diagrams are on the next page. On these diagrams the z-score total figures with asterisk (*) are have the best models in each forecast period. MS above represents money supply; IR represents interest rates; ER, exchange rate; CPI is the inflation rate; TP is the country main trading partner inflation.

BOTSWANA FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ER	0.578	0.476	0.491	0.603	0.055	2.202
		ER & CPI	0.242	0.530	0.511	0.137	-0.980	0.440
		MS	-1.272	-1.403	-1.402	-1.210	-0.543	-5.829*
		MS & CPI	-0.340	-0.600	-0.574	-0.461	0.594	-1.381
		TPCPI	-0.204	0.033	-0.007	-0.101	1.827	1.549
		TP & CPI	-0.794	-0.680	-0.676	-0.788	-1.023	-3.961
		Multivariate	1.790	1.643	1.657	1.820	0.070	6.980
	6 Months	ER	0.350	0.394	0.292	0.471	-0.714	0.792
		ER & CPI	0.934	1.185	1.264	0.777	0.297	4.456
		MS	-0.733	-0.911	-0.663	-0.786	0.510	-2.582
		MS & CPI	0.730	0.628	0.897	0.413	1.696	4.364
		TPCPI	-1.115	-1.039	-1.210	-0.927	-1.064	-5.355
		TP & CPI	-1.240	-1.155	-1.139	-1.301	0.297	-4.538*
		Multivariate	1.075	0.897	0.559	1.354	-1.022	2.863
	12 Months	ER	0.249	0.412	0.314	0.361	-0.613	0.722
		ER & CPI	1.076	1.151	1.223	0.955	0.064	4.468
		MS	-0.648	-0.769	-0.577	-0.692	0.713	-1.973
		MS & CPI	0.653	0.598	0.756	0.352	1.562	3.920
		TPCPI	-1.035	-0.923	-0.999	-0.878	-0.951	-4.786
		TP & CPI	-1.335	-1.373	-1.418	-1.387	0.469	-5.044*
		Multivariate	1.040	0.905	0.702	1.289	-1.244	2.693
In-Sample Forecasts	**3 Months**	ER	-0.354	-0.028	0.314	-0.450	-0.937	-1.455
		ER & CPI	-0.247	0.154	1.261	-0.552	1.063	1.679
		MS	0.734	0.499	-0.007	0.675	-0.224	1.675
		MS & CPI	0.131	0.653	0.715	-0.011	-0.929	0.560
		TPCPI	1.295	0.849	0.051	1.553	1.538	5.286
		TP & CPI	0.309	0.013	-0.435	0.364	0.284	0.536
		Multivariate	-1.867	-2.140	-1.899	-1.579	-0.795	-8.281*
	6 Months	ER	0.182	0.214	0.590	-0.130	-0.884	-0.028
		ER & CPI	-1.187	-0.582	0.388	-1.253	-1.482	-4.115*
		MS	0.290	-0.003	-0.354	0.191	-0.094	0.030
		MS & CPI	-0.699	-0.643	-0.700	-0.655	-0.416	-3.111
		TPCPI	1.622	1.656	1.328	1.687	1.130	7.422
		TP & CPI	0.713	0.741	0.454	0.818	1.013	3.739
		Multivariate	-0.921	-1.383	-1.708	-0.658	0.733	-3.937
	12 Months	ER	-1.235	-1.286	-0.043	-1.195	-1.410	-5.169*
		ER & CPI	-0.924	-1.290	-0.695	-0.946	-0.073	-3.927
		MS	-0.676	-0.394	0.844	-0.591	-0.884	-1.702
		MS & CPI	0.177	0.573	0.834	0.110	-0.243	1.450
		TPCPI	0.917	0.671	-1.038	1.024	1.081	2.654
		TP & CPI	1.494	1.224	-1.181	1.503	1.408	4.447
		Multivariate	0.248	0.502	1.279	0.096	0.121	2.246

GHANA FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	3 Months	ER	-0.828	-0.865	-0.864	-1.016	-0.488	-4.061
		ER & CPI	-0.127	0.009	-0.157	-0.230	1.026	0.522
		IR	-0.695	-0.591	-0.687	-0.510	-1.660	-4.144*
		IR & CPI	-0.736	-0.688	-0.725	-0.988	0.277	-2.860
		TPCPI	0.221	-0.043	0.182	0.676	-0.679	0.356
		TP & CPI	2.052	2.102	2.038	1.769	1.119	9.080
		Multivariate	0.112	0.077	0.213	0.299	0.405	1.107
	6 Months	ER	-0.827	-0.734	-0.828	-0.913	-0.487	-3.790*
		ER & CPI	-0.380	-0.504	-0.318	-0.572	1.014	-0.761
		IR	-0.627	-0.527	-0.658	-0.654	-0.557	-3.022
		IR & CPI	-0.727	-0.618	-0.709	-0.700	-0.695	-3.449
		TPCPI	-0.033	-0.364	0.037	0.046	-0.212	-0.525
		TP & CPI	1.962	1.941	2.016	1.308	1.783	9.010
		Multivariate	0.631	0.806	0.461	1.486	-0.846	2.537
	12 Months	ER	-1.091	-1.009	-1.037	-1.369	-0.447	-4.953*
		ER & CPI	0.065	0.019	0.004	0.078	0.988	1.154
		IR	-0.498	-0.373	-0.494	-0.528	0.119	-1.774
		IR & CPI	0.669	0.427	0.173	0.844	-0.078	2.035
		TPCPI	-0.742	-0.860	-0.574	-0.780	-0.569	-3.524
		TP & CPI	1.867	1.972	2.074	1.578	1.490	8.981
		Multivariate	-0.270	-0.177	-0.145	0.177	-1.504	-1.919
In-Sample Forecasts	3 Months	ER	-1.053	-0.950	-0.964	-1.084	0.927	-3.123
		ER & CPI	0.547	0.442	0.559	0.629	-0.586	1.591
		IR	-0.944	-0.812	-0.900	-0.977	1.088	-2.544
		IR & CPI	1.194	1.316	1.258	1.099	0.297	5.164
		TPCPI	0.338	0.506	0.281	0.316	0.700	2.141
		TP & CPI	0.997	0.780	0.946	1.049	-0.999	2.774
		Multivariate	-1.080	-1.283	-1.180	-1.033	-1.427	-6.003*
	6 Months	ER	-0.692	-0.827	-0.681	-0.849	0.287	-2.762
		ER & CPI	-0.474	-0.438	-0.455	-0.296	-1.031	-2.693
		IR	-0.601	-0.686	-0.602	-0.734	0.288	-2.335
		IR & CPI	-0.025	0.052	0.013	0.275	-0.952	-0.636
		TPCPI	0.745	0.957	0.653	0.657	1.337	4.350
		TP & CPI	1.908	1.754	1.944	1.833	1.054	8.492
		Multivariate	-0.861	-0.812	-0.873	-0.886	-0.984	-4.416*
	12 Months	ER	-0.865	-0.685	-1.391	-0.873	-1.696	-5.511*
		ER & CPI	0.686	0.518	-0.813	2.684	1.092	4.166
		IR	-0.940	-0.643	-1.276	-1.090	-1.131	-5.080
		IR & CPI	-0.194	-0.062	-0.811	-0.345	-1.313	-2.726
		TPCPI	-0.276	-0.099	-0.935	-0.454	-1.241	-3.005
		TP & CPI	1.917	1.319	0.144	1.283	-1.480	3.183
		Multivariate	-0.328	-0.383	-1.234	-0.166	-1.742	-3.853

KENYA FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ER	-0.174	-0.608	-1.113	0.293	-0.699	-2.301
		ER & CPI	-0.330	-0.201	-0.028	-0.478	-0.339	-1.375
		IR	-1.888	-1.698	-1.102	-1.488	-0.105	-6.281*
		IR & CPI	0.536	0.899	1.688	-0.545	1.880	4.458
		TPCPI	-0.122	-0.284	-0.421	0.024	-0.837	-1.640
		TP & CPI	1.125	0.825	0.340	0.478	-0.707	2.061
		Multivariate	0.853	1.066	0.637	1.716	0.807	5.079
	6 Months	ER	-0.469	-0.731	-0.950	1.017	-0.798	-1.932
		ER & CPI	-0.512	-0.375	-0.358	-0.563	0.327	-1.479
		IR	-1.472	-1.445	-1.075	-1.814	0.748	-5.058*
		IR & CPI	0.642	0.942	0.210	-0.448	1.518	2.863
		TPCPI	-0.338	-0.312	-0.452	0.399	-0.370	-1.073
		TP & CPI	1.583	1.411	1.558	0.646	0.076	5.274
		Multivariate	0.565	0.510	1.067	0.763	-1.500	1.406
	12 Months	ER	-0.313	-0.062	-0.767	1.104	-0.597	-0.635
		ER & CPI	-0.588	-0.411	-0.375	-0.427	-0.572	-2.373
		IR	-1.401	-1.545	-1.160	-1.637	0.063	-5.680*
		IR & CPI	-0.149	-0.401	-0.126	-0.678	2.144	0.791
		TPCPI	-0.177	-0.051	-0.328	0.096	-0.795	-1.254
		TP & CPI	1.103	0.896	1.405	0.410	-0.287	3.527
		Multivariate	1.524	1.573	1.352	1.132	0.042	5.624
In-Sample Forecasts	**3 Months**	ER	0.955	1.233	0.359	1.096	0.997	4.640
		ER & CPI	0.862	1.220	0.265	0.944	1.067	4.358
		IR	0.412	-0.114	-1.242	0.245	0.041	-0.658
		IR & CPI	0.825	0.421	-1.278	0.799	0.615	1.383
		TPCPI	-0.516	-0.518	1.559	-0.895	-1.590	-1.960
		TP & CPI	-1.320	-1.220	0.433	-1.172	-0.965	-4.244*
		Multivariate	-1.219	-1.022	-0.096	-1.017	-0.166	-3.520
	6 Months	ER	0.903	0.904	0.110	1.122	0.689	3.727
		ER & CPI	0.910	0.702	-0.265	1.181	1.523	4.050
		IR	0.600	1.036	2.007	0.196	-0.809	3.030
		IR & CPI	0.676	0.235	0.087	0.503	-0.265	1.235
		TPCPI	-0.539	-0.366	-0.171	-0.862	-1.264	-3.202
		TP & CPI	-1.286	-0.881	-0.503	-1.177	-0.599	-4.445*
		Multivariate	-1.264	-1.628	-1.265	-0.964	0.726	-4.395
	12 Months	ER	0.793	-0.493	-0.855	1.397	1.533	2.375
		ER & CPI	0.687	-0.679	-0.882	1.132	1.367	1.624
		IR	0.819	1.465	1.436	0.105	-0.650	3.175
		IR & CPI	0.604	0.936	1.145	0.101	-0.680	2.106
		TPCPI	-0.132	0.665	0.236	-0.548	-0.639	-0.419
		TP & CPI	-1.450	-0.810	-0.051	-1.261	-0.632	-4.204
		Multivariate	-1.321	-1.084	-1.029	-0.926	-0.298	-4.658*

MAURITIUS OUT OF SAMPLE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	**3 Months**	ER	1.337	1.321	1.355	1.214	-0.601	4.625
		ER & CPI	0.657	0.644	0.760	0.183	1.187	3.432
		IR	-0.180	-0.053	-0.169	0.089	-0.874	-1.187
		IR & CPI	-0.957	-0.832	-1.023	-1.040	1.395	-2.457
		MS	0.893	1.039	0.607	1.078	-0.952	2.665
		MS & CPI	0.436	0.118	0.678	0.165	0.668	2.065
		TPCPI	0.303	0.374	0.059	0.777	-1.250	0.263
		TP & CPI	-0.671	-0.805	-0.389	-0.698	0.721	-1.841
		Multivariate	-1.818	-1.806	-1.879	-1.768	-0.295	-7.565*
	6 Months	ER	-0.752	0.492	1.231	-0.686	-0.358	-0.073
		ER & CPI	-0.834	0.520	0.891	-1.710	-1.490	-2.623
		IR	-0.479	-0.304	-0.262	0.263	0.741	-0.041
		IR & CPI	-0.139	-0.582	-0.883	-0.792	-0.687	-3.082*
		MS	1.318	1.407	0.623	1.503	-0.010	4.841
		MS & CPI	1.830	1.417	0.963	1.104	-0.960	4.355
		TPCPI	-0.885	-0.661	-0.283	0.342	1.774	0.288
		TP & CPI	-0.586	-1.066	-0.490	-0.408	0.306	-2.244
		Multivariate	0.526	-1.224	-1.791	0.384	0.684	-1.421
	12 Months	ER	-0.099	0.941	0.915	-0.069	-0.693	0.996
		ER & CPI	-1.056	-0.530	1.520	-1.543	-0.980	-2.588
		IR	0.477	0.787	-0.441	0.504	-0.279	1.049
		IR & CPI	-0.038	-0.390	0.788	-0.850	-1.057	-1.547
		MS	1.629	1.300	-0.530	1.762	0.773	4.934
		MS & CPI	1.198	0.378	0.799	0.412	-0.734	2.053
		TPCPI	-0.345	0.366	-1.091	0.818	1.905	1.652
		TP & CPI	-1.546	-1.541	-1.033	-0.800	0.660	-4.261*
		Multivariate	-0.219	-1.312	-0.928	-0.234	0.405	-2.287

MAURITIUS IN-SAMPLE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
In-Sample Forecasts	**3 Months**	ER	0.284	0.129	-0.202	0.168	-0.630	-0.251
		ER & CPI	0.328	0.408	0.263	0.338	0.292	1.628
		IR	-1.401	-1.476	-1.004	-1.383	-0.979	-6.242*
		IR & CPI	-1.515	-1.306	-0.354	-1.449	-0.295	-4.920
		MS	0.387	-0.098	-1.012	0.141	-1.349	-1.931
		MS & CPI	0.248	-0.265	-1.139	0.159	-0.247	-1.244
		TPCPI	1.174	1.196	0.617	1.248	0.422	4.657
		TP & CPI	1.207	1.550	1.570	1.375	0.875	6.577
		Multivariate	-0.711	-0.137	1.261	-0.595	1.910	1.727
	6 Months	ER	0.590	1.452	2.086	0.330	-0.908	3.549
		ER & CPI	0.182	0.114	-0.025	0.145	-0.178	0.238
		IR	-1.287	-0.773	-0.161	-1.337	-1.063	-4.620
		IR & CPI	-1.503	-1.242	-0.219	-1.469	-0.987	-5.420*
		MS	0.596	0.190	0.456	0.391	-0.536	1.097
		MS & CPI	0.199	-0.118	-0.272	0.142	0.123	0.073
		TPCPI	1.211	1.359	0.566	1.307	0.582	5.026
		TP & CPI	0.966	0.334	-1.125	1.226	1.468	2.869
		Multivariate	-0.954	-1.315	-1.307	-0.734	1.498	-2.812
	12 Months	ER	0.655	1.114	1.068	0.276	-0.291	2.822
		ER & CPI	0.630	1.319	1.384	0.156	-0.078	3.412
		IR	-1.039	0.182	0.250	-1.176	0.831	-0.953
		IR & CPI	-1.078	0.492	0.879	-1.324	2.347	1.315
		MS	0.230	-1.007	-0.792	0.356	-0.690	-1.903
		MS & CPI	0.085	-0.239	0.004	0.126	-0.691	-0.716
		TPCPI	1.080	0.049	-0.504	1.313	-0.421	1.517
		TP & CPI	1.051	0.006	-0.593	1.332	-0.309	1.486
		Multivariate	-1.613	-1.916	-1.696	-1.058	-0.697	-6.980*

NIGERIA FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	3 Months	ER	-0.892	-0.920	-0.739	-0.546	-1.114	-4.211*
		ER & CPI	-0.283	-0.438	-1.037	2.193	0.489	0.924
		IR	1.027	1.174	1.075	-0.153	1.005	4.127
		IR & CPI	1.541	1.404	1.451	0.062	0.709	5.167
		TPCPI	-0.721	-0.830	-0.597	-0.413	-1.120	-3.681
		TP & CPI	-1.025	-0.847	-0.688	-0.718	-0.920	-4.197
		Multivariate	0.353	0.455	0.536	-0.424	0.951	1.871
	6 Months	ER	-0.868	-0.852	-0.776	-0.520	-0.653	-3.669
		ER & CPI	-0.632	-0.875	-1.064	2.073	-0.876	-1.374
		IR	0.574	0.402	-0.468	-0.484	0.640	0.664
		IR & CPI	1.678	1.633	1.479	0.233	1.600	6.623
		TPCPI	-0.193	-0.165	0.156	0.088	-0.100	-0.215
		TP & CPI	-1.148	-0.978	-0.561	-0.985	-1.210	-4.882*
		Multivariate	0.589	0.836	1.234	-0.405	0.599	2.853
	12 Months	ER	-0.804	-0.770	-0.756	-0.962	0.570	-2.723
		ER & CPI	-0.775	-0.875	-0.951	1.007	-0.984	-2.578
		IR	0.780	0.505	-0.267	0.445	-0.384	1.080
		IR & CPI	1.210	1.289	1.214	0.678	1.436	5.827
		TPCPI	-0.511	-0.429	-0.175	-0.433	1.030	-0.519
		TP & CPI	-1.048	-0.978	-0.654	-1.581	-0.979	-5.240*
		Multivariate	1.149	1.259	1.588	0.847	-0.690	4.152
In-Sample Forecasts	3 Months	ER	-0.333	-0.427	-0.617	0.168	0.299	-0.910
		ER & CPI	1.043	1.022	0.975	0.278	0.644	3.963
		IR	-0.869	-0.962	-1.083	0.176	-0.810	-3.548
		IR & CPI	1.496	1.592	1.642	0.297	0.865	5.892
		TPCPI	0.263	-0.014	-0.299	0.410	0.001	0.361
		TP & CPI	-0.322	-0.067	0.200	0.873	-1.840	-1.157
		Multivariate	-1.278	-1.144	-0.819	-2.201	0.840	-4.602*
	6 Months	ER	-0.722	-0.807	-0.880	-0.350	0.119	-2.639
		ER & CPI	0.564	0.497	0.469	1.334	0.390	3.255
		IR	-0.964	-0.942	-0.995	-1.060	-0.006	-3.966*
		IR & CPI	1.469	1.563	1.404	1.315	0.708	6.457
		TPCPI	-0.518	-0.663	-0.818	-0.242	0.029	-2.212
		TP & CPI	1.032	0.973	1.132	0.089	-2.131	1.095
		Multivariate	-0.861	-0.621	-0.311	-1.086	0.890	-1.988
	12 Months	ER	-0.389	-0.402	-0.358	-0.364	-0.033	-1.546
		ER & CPI	-0.355	-0.383	-0.328	-0.192	1.573	0.314
		IR	-0.386	-0.364	-0.387	-0.376	-0.808	-2.322*
		IR & CPI	-0.318	-0.321	-0.429	0.035	0.450	-0.584
		TPCPI	-0.367	-0.375	-0.349	-0.308	0.050	-1.349
		TP & CPI	2.266	2.267	2.266	2.162	-1.592	7.369
		Multivariate	-0.450	-0.421	-0.414	-0.958	0.361	-1.883

SOUTH AFRICA OUT OF SAMPLE FORECASTING RESULTS RANKING								
Type of forecast	**Forecast Period**	**Model**	**RMSE**	**MAE**	**MAPE**	**TIC**	**BP**	**Total**
Out of Sample Forecasts	3 Months	ER	-0.581	-0.538	-0.507	-0.547	0.948	-1.226
		ER & CPI	-1.177	-1.103	-1.169	-1.588	-0.666	-5.703*
		IR	0.001	-0.028	0.176	0.318	-0.082	0.386
		IR & CPI	-0.716	-0.722	-0.498	-0.635	-1.394	-3.965
		MS	0.280	0.148	0.372	0.525	0.549	1.874
		MS & CPI	-0.638	-0.588	-0.646	-0.586	-0.354	-2.813
		TPCPI	1.447	1.463	1.205	1.503	-0.972	4.647
		TP & CPI	1.747	1.808	1.860	1.307	1.821	8.543
		Multivariate	-0.364	-0.440	-0.793	-0.297	0.149	-1.744
	6 Months	ER	-0.904	-0.709	-0.533	-1.077	-1.363	-4.587*
		ER & CPI	-0.239	-0.405	-1.114	0.358	1.686	0.287
		IR	-0.368	-0.301	0.151	-0.516	-0.650	-1.684
		IR & CPI	-0.220	-0.125	-0.444	0.275	0.018	-0.495
		MS	-0.214	-0.460	0.312	-0.375	0.069	-0.668
		MS & CPI	-0.441	-0.260	-0.622	-0.219	-0.662	-2.202
		TPCPI	1.803	2.000	1.280	1.645	-0.512	6.215
		TP & CPI	1.572	1.337	1.839	1.271	1.472	7.491
		Multivariate	-0.990	-1.078	-0.868	-1.363	-0.057	-4.357
	12 Months	ER	-1.316	-1.241	-0.663	-1.598	-0.397	-5.215*
		ER & CPI	-0.554	-0.629	-1.176	0.041	-0.897	-3.215
		IR	0.051	-0.063	0.231	-0.003	0.294	0.510
		IR & CPI	0.107	0.333	-0.315	0.546	-1.044	-0.372
		MS	-0.385	-0.421	0.285	-0.616	1.090	-0.047
		MS & CPI	-1.051	-0.881	-0.745	-1.085	-1.017	-4.779
		TPCPI	0.860	0.711	1.011	1.001	-0.504	3.078
		TP & CPI	1.962	2.118	1.995	1.605	1.640	9.320
		Multivariate	0.325	0.073	-0.622	0.110	0.835	0.720

SOUTH AFRICA IN-SAMPLE FORECASTING RESULTS RANKING								
Type of forecast	Forecast Period	Model	RMSE	MAE	MAPE	TIC	BP	Total
In-Sample Forecasts	3 Months	ER	0.041	0.246	0.221	-0.045	0.878	1.341
		ER & CPI	0.960	1.008	0.826	0.960	0.290	4.044
		IR	0.314	0.296	0.427	0.350	0.536	1.923
		IR & CPI	1.350	1.237	1.228	1.267	0.564	5.647
		MS	-0.038	0.122	0.130	-0.108	0.784	0.889
		MS & CPI	0.598	0.651	0.534	0.533	0.691	3.007
		TPCPI	-1.075	-1.368	-1.114	-1.037	-1.043	-5.638
		TP & CPI	-1.890	-1.641	-1.991	-1.993	-1.948	-9.463*
		Multivariate	-0.260	-0.551	-0.261	0.074	-0.752	-1.750
	6 Months	ER	-1.111	-0.705	-0.739	-1.284	0.548	-3.290
		ER & CPI	-0.171	-0.576	-0.558	0.071	-1.399	-2.634
		IR	-0.336	-0.267	-0.106	-0.284	0.153	-0.841
		IR & CPI	0.664	0.223	0.688	1.011	-0.814	1.772
		MS	-1.075	-0.780	-0.758	-1.190	0.223	-3.579*
		MS & CPI	-0.110	-0.371	-0.024	0.109	-0.533	-0.930
		TPCPI	-0.527	-0.404	-1.160	-0.735	-0.448	-3.273
		TP & CPI	2.103	2.439	2.105	1.711	2.121	10.479
		Multivariate	0.562	0.440	0.553	0.589	0.152	2.296
	12 Months	ER	-0.136	0.170	0.871	0.078	0.205	1.189
		ER & CPI	0.124	-0.289	0.361	0.086	-0.049	0.234
		IR	-0.046	0.045	0.402	-0.136	0.675	0.939
		IR & CPI	-1.220	-1.019	-1.366	-0.383	-2.225	-6.213*
		MS	-0.151	-0.075	1.169	-0.228	0.986	1.701
		MS & CPI	-0.337	-0.431	0.043	-0.490	0.349	-0.866
		TPCPI	0.277	0.138	-0.977	-0.164	0.486	-0.239
		TP & CPI	2.350	2.399	0.896	2.454	0.537	8.636
		Multivariate	-0.861	-0.939	-1.399	-1.217	-0.964	-5.380